as the final wrapup on the meeting. All in all, it looks excellent on paper and I am sure with the cooperation of everyone in the room we will have an outstanding meeting. I thank you for your indulgence during this discourse and promise not to bore you with too many announcements during the meeting.

It is my distinct honor to introduce to you the gentleman who will present the first paper of this meeting. His paper is entitled "The International Plant Propagators' Society Philosophy" and the speaker is James Wells of the James S. Wells Nursery in Redbank, New Jersey. It is hard to use enough adjectives to praise Jim Wells adequately but he is the man who was the first president of the Eastern Region, and who presented the first paper to the Society on November 8, 1951 at 10:00 A.M. He served two years: the 1951-1952 term and the 1952-1953 term. He is also a recipient of the Award of Merit in 1959. He is a well renowned author and an excellent nurseryman. One of Jim's loves is the International Plant Propagators' Society, and he has seen many of his dreams come true including the recent founding of our Great Britain and Ireland Region several years ago. I now present to you James Wells and "The International Plant Propagators' Society Philosophy".

THE INTERNATIONAL PLANT PROPAGATORS' SOCIETY PHILOSOPHY

JAMES WELLS
James S. Wells Nursery, Inc.
Red Bank, New Jersey

On November 8, 1951, as a result of the initiative of Edward H. Scanlon, the first organizational meeting of our Society was convened.

I wonder how many of us who met 20 years ago in Cleveland had any idea that the Plant Propagators' Society would reach — in this short time — the stature and the size that it now has.

I know that I speak for all of us who were at that first meeting when I say that this is indeed a most splendid day — a day to remember — for we see here, in this assembled company, the living and working essence of the Society's philosophy. Twenty years ago it was but a dim outline of the clear and simple pattern by which we all now work together.

Certainly our Society is much larger than we then thought possible or even desirable, and I think it says a great deal for both the philosophy itself and the officers of the Society through these formative years, that the inevitable increase in size has in no way diminished or diluted the individual and collective will to maintain our Society at the highest possible level.

We are indebted to one of our Past-presidents, Peter Vermeulen, for giving us our motto "TO SEEK AND TO SHARE" and this motto sums up neatly and clearly the essence of our philosophy. There is nothing unique about these sentiments — they are as old as mankind, and indeed form the essential basis of most religions, but there is often a wide gap between the idea and its everyday application and practice by individuals.

We who were at that first meeting, cannot therefore take kudos for thinking of the theme — our main task was to try to establish a fair and reasonable method to apply the theme and make it work. I would assure you that this problem was most carefully thought through and with the procedures established, has been most carefully nurtured over the past 20 years. It is because of the inherent soundness of the plan, and the careful guarding of the basic principles of sharing with each other, that we now see the strong and thriving Society to which we are all proud to belong.

You might be interested to know how all this came about. Unfortunately I no longer have my files for the year 1950, but I recall that a letter came from Ed Scanlon saying that he was contacting a number of people about the possible formation of a plant propagators' society, and would I be interested. Of course I was, and with similar support from everyone, Ed called the first meeting. For no good reason that I recall, it fell to my lot to suggest the manner in which we might organize, and I can assure you that a great deal of thought was given to the remarks I made at the first meeting in which it was stressed that there should be three essentials for a person to become a member in good standing.

1. Knowledge and experience.
2. A high standard of integrity.
3. A ready willingness — nay more — a compelling desire to share knowledge and skills with other members.

These three criteria were accepted as the cornerstone of our society, and it has been a steady source of wonder to us "oldsters" how readily these criteria have been accepted and maintained by each group as our Society widened. I recall that in the initial discussions for the formation of the Western and the English regions, both were all for establishing even more stringent requirements for membership, and in the interests of equality and uniformity, we had to urge them both to modify their requirements a little.

I am sure that very few of us really bother to read the By-laws, but they are important, and especially is this true of Article 2, which is deceptively short and simple. It reads:

"The purpose of this organization is to secure recognition of the plant propagator as a craftsman, to provide for the dissemination of knowledge through proper channels, and to provide helpful guidance and assistance to plant propagators."

It is impossible to say now how many hours of thoughtful consideration and study went into the phrasing of this simple sentence, but if you read it carefully and think about it, surely here is the simple essence of our philosophy.

First — recognition of the plant propagator as a craftsman. To achieve such recognition it is obvious that the person must indeed be a craftsman — a person of experience, knowledge and skill. We wished to seek out such people, recognize them, help them where possible, but especially ask them to make available to similar people, their wisdom in dealing with plants.

Second — In order to gather this knowledge, we needed to provide a method of collection and dissemination — our meetings and our publications — and thus ensure that this knowledge would be recorded; and finally, we realized that we have a prime responsibility to help the young student, to encourage the new generation to learn what we knew and to carry on the good work, extending the frontiers of knowledge, refining and, more especially, adapting our work to the rapidly changing techniques and vastly increased knowledge of this modern age.

These then were our objectives, and I think I can state, without fear of contradiction that they have been amply fulfilled.

The 20 years that we have been in existence have seen enormous changes — just think that there were no plastic houses in 1951 — and container growing then was largely confined to Florida and California. Many techniques now in daily use were then unheard of, but then so also was pollution.

The world is changing at an alarming pace, and it is idle to suppose that we can remain as we were — we must change and adapt to meet the new conditions. Yet, realizing this, I believe that the vital role of the plant propagator in our scheme of things is still to be recognized.

The remarks which I made 20 years ago, at our first meeting, were entitled, "The Plant Propagator — The Basis Of Our Industry", and while I believe this still to be true, I also believe that the time will come soon, when the plant propagator will not only be the basis of the horticultural industry, but the mainstay of a balanced ecology upon which all forms of life ultimately depend.

I heard two rather frightening statistics recently. First, that it required about 60 fair sized trees to provide the necessary oxygen for each person, and second, that about 1,000,000 acres of land are being denuded of vegetation and covered with asphalt or concrete annually in the U.S.A. The inference is obvious.

Scientists also report a significant world-wide increase in the concentration of carbon dioxide in the atmosphere due to the vast amount of combustion taking place, combined with the reduction on land covered with plants.

It may seem ridiculous now, but I believe that the time will come when the planned production of plants and the re-establishment of areas of land covered with plants may well be essential for the maintenance of a normal life balance. This is the work of the plant propagator.

If such a condition comes about, then the principles upon which we have organized and developed will be of vital — truly vital — importance, for "commercialism" and "profit" may well have to be put on one side at least for a time, and the skills and unselfish interest of the plant propagator used to the fullest if we are to survive. The yeast which is the philosophy of our society has risen well during these last 20 years. The spirit of helpful cooperation has spread first through the horticultural industry of this country and of Canada, resulting in the formation of the Western group. Now the ferment has moved beyond these shores and we have the British group — young, strong, and clearly well on the way to much bigger and better things. But this is by no means the end — it is really the end of the beginning, for there are many, many more fine propagators throughout the world to whom this Society would be of enormous value. And I am glad to be able to tell you that your Society is not lagging in missionary work, for I have received a couple of letters recently, one from a very good friend of mine in Denmark, Tony Thompson, who is a member of the G.B. & I. Region and he said, "I have talked with a few people here in Denmark about the Society and there seems to be some interest. We are having another meeting in September and I'm going to tell them about the meaning of the Society. In the latter part of September we have a meeting for nurserymen at which time I'll follow the case up. I believe there should be a fair chance to get the ball rolling." I also have a letter from one of our members, Mr. M. Richards, who is Reader in Horticulture at Massey University, Palmerston North, New Zealand and he said, "I think at the Minneapolis meeting you might report that there is some possibility of starting a chapter in New Zealand. As soon as it becomes a practical possibility to have a preliminary meeting I will keep you advised — this may not be until February 1971." So you see things are moving elsewhere.

The success which we all enjoy is due, I believe, to each and every one of us. It is due to the spirit of helpfulness, cooperation and friendly brotherhood which has been the hallmark of our Society from the beginning, and which now is beginning to be seen throughout the horticultural industry.

This attitude was, and still is new, yet because of it we have established a Society of people of the highest quality, dedicated to the advancement of knowledge and the improvement of our industry, as a whole. Ladies and gentlemen, I salute you.

RALPH SHUGERT: Thank you very much, Jim. On behalf of the chair, I congratulate you on your tribute (a standing ovation) to Jim Wells.

An author once said that there is a tremendous amount of correlation between philosophy and history, and with these sage works in mind, your program committee felt it would be apropos to use this philosophy at this meeting. The next gentleman on the program is unquestionably one of the most dedicated Society members. He served as Eastern Region President in 1961, and as International President in 1963; he was recipient of the Award of Merit in 1964 and has served faithfully and capably as the International Secretary-Treasurer. A close personal friend of mine and a friend of all Society members — Dr. William Snyder. Bill, it's a pleasure to have you speak on the history of the International Plant Propagators' Society.

THE INTERNATIONAL PLANT PROPAGATORS' SOCIETY: 1951 to 1970

WILLIAM E. SNYDER
Department of Horticulture and Forestry
Rutgers University
New Brunswick, New Jersey

At the invitation of Edward H. Scanlon, 68 persons interested in plant propagation met at the Statler Hotel, Cleveland, Ohio, on November 8-9, 1951. The purpose of this meeting was two-fold: first, to hear talks by six well-known plant propagators and second, to consider whether or not an organization of plant propagators should be formed. The result: 20 years later these six speakers at the First Annual Meeting have been followed by more than 450 persons who have presented talks on plant propagation and related subjects and the membership has increased from 68 to 886 persons affiliated with the three regional organizations.

An organization known as the National Association of Propagating Nurserymen was formed in 1919 and survived until 1931, when, due to internal problems and the severe economic conditions of that period, it foundered. In 1926 the first of six annual reports was published. At the 1958 meeting of the Plant Propagators' Society, Roy M. Nordine made an appeal for a set of these reports for the archives of this Society. Dr. Richard P. White, Executive Secretary of the American Association of Nurserymen, donated a complete set to Mr. Nordine and at the 1959 meeting in Philadelphia Mr. Nordine presented the reports to the Plant Propagators' Society. Based on these reports, Alfred J. Fordham has advancement of knowledge and the improvement of our industry, as a whole. Ladies and gentlemen, I salute you.

RALPH SHUGERT: Thank you very much, Jim. On behalf of the chair, I congratulate you on your tribute (a standing ovation) to Jim Wells.

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The objective of my presentation is to record the happenings of the International Plant Propagators' Society during the years 1951 to 1970.

In November, 1951, there was an enthusiastic response to the idea of a society devoted to the propagation of plants. On the night of November 8 a committee prepared a draft of a constitution which incorporated many of the ideas and concepts which had developed during the day's discussions. An organizational committee completed the writing of a constitution in July, 1952 in Detroit, during the meeting of the American Association of Nurserymen. Members of this organizational committee included:

L. C. Chadwick	Edward H. Scanlon
Richard H. Fillmore	John Siebenthaler
James IE Ilgenfritz	William E. Snyder
Roy M. Nordine	James S. Wells
Roger Pease	Pieter Zorg

Fillmore and Pease were unable to attend the Detroit meetings. Also in attendance at the 1952 Summer Organizational Meeting were: Ray D. Hartman, Case Hoogendoorn, Carl E. Kearn, Irwin J. Mathews, Frank Turner, Louis Vanderbrook and V. J. Vanicek.

The accomplishments of this meeting included:

(1) establishment of the Plant Propagators' Society on the basis of the 15 individuals present,

(2) election of the first officers: James S. Wells, President; L. C. Chadwick, Vice-president; and Edward H. Scanlon, Secretary-treasurer,

(3) establishment of a Board of Directors consisting of James S. Wells, L. C. Chadwick, Roy M. Nordine, John Seibenthaler, Carl Kern and Pieter Zorg.

(4) establishment of eligibility for charter membership: the 15 present plus any individual attending the November 8-9, 1951 meeting in Cleveland who paid dues ($10.00) for 1952, and

(5) establishment of a constitution to be voted upon during the 1952 meeting in Cleveland.

Based on the action taken at the Organizational Meeting and on the membership list published in the 1952 PROCEEDINGS, the 42 charter members of the Society are:

Anderson, Frank O. (deceased)
Arnold, W. D.
Beaudry, William A.
Carosello, Peter
* Chadwick, Dr. L. C.
Cron, Wilbur C.
* Dugan, David R.
* Fenicchia, Richard
* Fillmore, Richard H.
Gens, George F.
Guarino, Frank
Hartman, Ray D. (deceased)
Hetz, LeRoy,
* Hoogendoorn, Case
* Ilgenfritz, James IE
Kalley, Paul G.
Kenealy, John C. (deceased)
Kern, Carl E. (deceased)
Koskohryz, George
Loesch, Peter (deceased)
* Mahlstede, Case
* Michalko, John
* Mitiska, Laddie
* Monroe, Logan
* Nordine, Roy M.
O'Rourke, F. L. S.
Pease, Robert
Salow, Elmer
Scanlon, Edward H.
Siebenthaler, John
Simon, Gabe
* Snyder, Dr. W. E..
Sweeney, J. A.
Swingle, Roger
* Turner, Frank
Tyrell, John E.
Vanderbrook, Louis (deceased)
Wachs, Mrs. Theodore
* Warner, Zophar
Weber, Carl D. (deceased)
* Wells, James S.
Zorg, Pieter (deceased)

* Active members in 1970.

Sixteen of these charter members are still active in the Society; eight are deceased.

Attendance more than doubled at the 1952 Annual Meeting and the number of paid members was 119.: 81 commercial; 23 non-commercial; and 15 junior. The two Canadians included in the 1952 membership list were Constant DeGroot and Leslie Hancock.

The development of the Society can be divided into three periods:

(1) 1951 through 1959. Membership in the Plant Propagators' Society was largely in the northeastern part of the United States and the southeastern part of Canada. Meetings were held in Cleveland (1951 through 1958) and in Philadelphia (1959).

(2) 1960 through 1968. In 1960, a Western Plant Propagators' Conference was held at Asilomar, California and steps were taken to establish the International Plant Propagators' Society with two regions: Eastern (North America) and Western (North America).

(3) 1969 to 1970. Addition of the Region of Great Britain and Ireland in 1969 and the 1970 joint meeting of the Eastern and Western Regions here in St. Paul.

As the Society has grown in regional organizations and in number of individual members, there has been no fundamental departure from the principles, objectives and philosophy which were expressed at the 1951 and 1952 meetings and which have been so ably discussed by James S. Wells this morning.

By 1959 there were 21 members of the Plant Propagators' Society who lived west of the Rocky Mountains. The possibility of a western propagators' group was being discussed. In October, 1960 a Western Plant Propagators' Conference was held at Asilomar, California. The Organizational Committee included:

Alley, Curtis J.
Armstrong, David
Barker, Philip
Brown, Howard C.
Byerly, Russell
Everett, Percy
Harris, Richard
Hartman, Don
Kester, Dale
Morey, Dennison
Roberts, A. N.
Sandkuhle, Herman Jr.
Spring, John J.
Stuke, William
Stump, David
Van Rensselaer, Maunsell
Wick, Jack

Don Hartman served as chairman of this committee. A committee from the Plant Propagators' Society attended this conference. Chairman of this committee was Richard H. Fillmore and the other committee members included Harvey Templeton, Hugh Steavenson, John P. Mahlstede and Kenneth Reisch. It was during this conference that discussions were held which would lead, in 1961, to the formation of The International Plant Propagators' Society with the two regions.

The Society's first President, James S. Wells, was primarily responsible for the development of the Region of Great Britain and Ireland. After obtaining assurances from the Board of Directors that there were no serious objections *per se* to an "overseas" region, he worked through Brian Humphrey and R. J. Gardner, both IPPS members, and R. F. Martyr, A. D. Weguelin and J. O'Connor. The first meeting was held at Syon Park, England on September 18, 1968 and two meetings in 1969, January 2 at the Pershore College of Horticulture and September 11-12 at Hadlow College in Tonbridge, were well attended and showed that there was definite interest in an organization of plant propagators. Meanwhile the slow wheels of constitutional change were moving within IPPS and the Region of Great Britain and Ireland formally became the third region in December, 1969. Their membership of over 130 far surpassed expectations.

The International Plant Propagators' Society was incorporated in 1965 as a non-profit organization under the laws of the State of New Jersey. Two years later the Western Region was incorporated in Oregon and the Eastern Region in Indiana.

The major functions of the three regional organizations are to hold the annual meetings and to elect members to the Society. The major functions of the international organization are to publish, in a single volume, the proceedings of the three annual meetings; to publish the quarterly journal, THE PLANT PROPAGATOR; and to coordinate the activities of the regions.

CONSTITUTION: The Constitution adopted at the 1952 meeting was modified only slightly until 1961 when the International Plant Propagators' Society was organized and a new constitution was adopted. The major changes included:

1. changing the name from Plant Propagators' Society to International Plant Propagators' Society,

2. establishing an international board charged with the responsibility of publishing the PROCEEDINGS and THE PLANT PROPAGATOR, and

3. establishing the policy of active participation. Article 3, Section II states " — — It shall be the duty of a member to attend a minimum of one regional meeting each three years, or, in lieu of attendance, to contribute a written article for publication in the newsletter." The objective of this requirement is to maintain a society of actively participating members.

It is of interest that only the change in the name of the society precipitated any discussion when the 1961 constitution was voted upon.

The constitution was again modified in 1969 to permit the addition of the Region of Great Britain and Ireland to membership.

MEMBERSHIP: The Society is an organization composed of individuals engaged in the commercial propagation of plants and / or in teaching and research related to plant propagation. Members are required to share freely their knowledge and experiences in plant propagation. All members are required to attend one of the three regional meetings each three years, or, in lieu of attendance to contribute material in writing for publication in THE PLANT PROPAGATOR or the PROCEEDINGS. Individuals may be elected to membership only at the annual meetings. Each of the regions has a membership committee whose responsibility is to screen each application to make certain that the applicant has the required qualifications. Over the years these committees have performed a "yeoman's task" and have been responsible for maintaining the high standards required for membership.

The five classes of individual membership are;

(1) Commercial — any person actively engaged in the propagation of plants for commercial purposes,

(2) Non-commercial — individuals who are engaged in the teaching or research in plant propagation not directly nor indirectly commercial,

(3) Junior — individuals who lack the required five years' experience in plant propagation,

(4) Privileged — individuals who have actively participated in the Society for ten years or more and who have retired, and

(5) Honorary — a special category of membership for individuals who have made outstanding contributions in the field of propagation or horticulture.

The number of members of the three major classes are recorded in Table 1. These numbers are based on the listing of active members on December 31st of each year and published in the PROCEEDINGS. From 1951 through 1964 there was a uniform increase in membership. During the years 1964 to 1968 the rate of increase of members in the Eastern and Western Regions decreased slightly. In 1969, the membership increased by 172, largely as a result of the 135 members of the Region of Great Britain and Ireland which became a part of the Society. At the present, the Eastern Region accounts for 54 per cent of the membership, the Western Region for 30 per cent and the Region of Great Britain and Ireland for 16 per cent.

Table 1. Number of Members in the Society — 1951 — 1969

Year	Commercial	Non-Commercial	Junior	Total
1951	50	18	—	68
1952	81	23	15	119
1953	104	40	23	167
1954	145	58	16	219
1955	177	60	25	262
1956	195	61	26	282
1957	215	70	43	328
1958	233	71	30	334
1959	262	86	24	372
1960	304	116	32	452
1961	343	127	26	496
1962	400	143	38	581
1963	391	148	44	583
1964	437	165	39	641
1965	452	175	46	673
1966	452	183	61	696
1967	439	186	68	693
1968	440	195	79	714
1969	528	258	100	886

The percentages of members by classification are: commercial, 59 per cent; non-commercial, 29 per cent; and junior, 12 per cent. This distribution of membership class holds for each of the three regions.

Members are affiliated with the region within which they reside unless the member specifically requests otherwise. Those who reside outside the geographical boundaries of the three regions may become affiliated with the region of their choice. Members are listed in each volume of the PROCEEDINGS.

In 1951, the 68 individuals attending the first meeting in Cleveland represented only eleven states. Ohio led with 44 members. The first Canadians became members in 1952 and in 1954 there were three members residing outside of North America (2 from Holland and 1 from New Zealand). By 1959 (the year before the Western Region was organized) the membership was from 37 of the United States, 4 provinces of Canada and 8 countries outside North America.

When the International was organized in 1960, members represented 36 states, 5 provinces and 9 countries. California had 80 members, Ohio had 72 members and Ontario had 22 members.

In 1969, there were 644 members from 45 states, 78 from seven provinces, 131 from Great Britain and Ireland, and 31 from other countries.

There are two privileged members: Martin Van Hof of the Eastern Region and Percy C. Everett of the Western Region.

The Society has elected four honorary members. Those so honored include:

Dr. L. C. Chadwick
Dr. S. L. Emsweller (deceased, 1966)
Mr. Ray D. Hartman (deceased, 1964)
Dr. F. L. Skinner (deceased, 1967).

A total of 460 names have been removed from the membership roles:

Deceased	41
Resigned	137
Non-payment of dues	165
Failure to actively participate	112
Other reasons	5

A vast majority (80 per cent) of the membership loss has occurred since 1963.

OFFICERS: The officers of the Plant Propagators' Society for the years 1951-1960 and of The International Plant Propagators' Society for the years 1961-1970 are recorded in Tables 2 and 3. Tables 4, 5, and 6 list the names of the officers of the three regional organizations. A total of 36 members have served as officers in the Society. Only one past president, James S. Wells, has the distinction of serving more than one term (1951 and 1952). Louis Vanderbrook, president in 1956, is deceased.

Table 2. **Officers — Plant Propagators' Society, 1951 — 1960**

Year	President	Vice-President	Secretary-Treasurer	Editor
1951	James S. Wells	L. C. Chadwick	Edward H. Scanlon	Edward H. Scanlon
1952	James S. Wells	L. C. Chadwick	Edward H. Scanlon	Edward H. Scanlon
1953	L. C. Chadwick	Richard H. Fillmore	Edward H. Scanlon	William E. Snyder
1954	Richard H. Fillmore	Edward H. Scanlon	William E. Snyder	William E. Snyder
1955	Edward H. Scanlon	Louis Vanderbrook	William E. Snyder	William E. Snyder
1956	Louis Vanderbrook	Hugh Steavenson	William E. Snyder	William E. Snyder
1957	Hugh Steavenson	Roy M. Nordine	Kenneth W. Reisch	John P. Mahlstede
1958	Roy M. Nordine	Harvey M. Templeton Jr.	Kenneth W. Reisch	John P. Mahlstede
1959	Harvey M. Templeton Jr.	Martin Van Hof	Kenneth W. Reisch	John P. Mahlstede
1960	Martin Van Hof	William E. Snyder	Louis Vanderbrook	John P. Mahlstede

Table 3. Officers — International Plant Propagators' Society, 1961 — 1970

Year	President	Vice-President	Secretary-Treasurer	Editor
1961	Harvey M. Templeton, Jr.	Don J. Hartman		
1962	Don J. Hartman	Martin Van Hof	Louis Vanderbrook	Charles E. Hess
1963	William E. Snyder	Herman Sandkuhle, Jr.	Sidney Waxman	Charles E. Hess
1964	Percy C. Everett	John P. Mahlstede	William E. Snyder	Charles E. Hess
1965	John P. Mahlstede	William J. Curtis	William E. Snyder	Charles E. Hess
1966	William J. Curtis	John B. Roller	William E. Snyder	Charles E. Hess
1967	John B. Roller	Howard C. Brown	William E. Snyder	Charles E. Hess
1968	Howard C. Brown	J. Peter Vermeulen	William E. Snyder	Charles E. Hess
1969	J. Peter Vermeulen	Henery J. Ishida	William E. Snyder	Charles E. Hess
1970	Henry J. Ishida	Ralph Shugert	William E. Snyder	Hudson T. Hartmann

Table 4. **Officers — Eastern Region, International Plant Propagators' Society, 1960 - 1970**

Year	President	Vice-President	Secretary-Treasurer	Editor
1961-62	William E. Snyder	John P. Mahlstede	Louis Vanderbrook	Charles E. Hess
1962-63	John P. Mahlstede	John B. Roller	Sidney Waxman	Charles E. Hess
1963-64	John B. Roller	Vincent K. Bailey	Sidney Waxman	Charles E. Hess
1964-65	Vincent K. Bailey	J. Peter Vermeulen	Sidney Waxman	Charles E. Hess
1965-66	J. Peter Vermeulen	Stuart H. Nelson	Sidney Waxman	Charles E. Hess
			Frederick O. Lanphear	
1966-67	Stuart H. Nelson	Ralph Shugert	Frederick O. Lanphear	Charles E. Hess
1967-68	Ralph Shugert	David R. Dugan	Frederick O. Lanphear	Charles E. Hess
1968-69	David R. Dugan	Charles E. Hess	Frederick O. Lanphear	Leonard P. Stoltz
1969-70	Charles E. Hess	Thomas S. Pinney, Jr.	Frederick O. Lanphear	Leonard P. Stoltz

Table 5. Officers — Western Region, International Plant Propagators' Society, 1960 — 1970

Year	President	Vice-President	Secretary-Treasurer	Editor
1960-61	Don J. Hartman	Herman J. Sandkuhle	Dale E. Kester	Richard W. Harris
1961-62	Herman J. Sandkuhle	Percy C. Everett	Dale E. Kester	Hudson T. Hartmann
1962-63	Percy C. Everett	William J. Curtis	Curtis J. Alley	Hudson T. Hartmann
1963-64	William J. Curtis	Robert M. Boddy	Curtis J. Alley	Hudson T. Hartmann
1964-65	Robert M. Boddy	Harold C. Brown	Curtis J. Alley	Dale E. Kester
1965-66	Harold C. Brown	Henry J. Ishida	Curtis J. Alley	Hudson T. Hartmann
1966-67	Henry J. Ishida	Robert Ticknor	Curtis J. Alley	Hudson T. Hartmann
1967-68	Robert Ticknor	Walter D. Krause	Curtis J. Alley	Hudson T. Hartmann
1968-69	Walter D. Krause	Bruce A. Briggs	Curtis J. Alley	Wesley P. Hackett
1969-70	Bruce A. Briggs	Andrew T. Leiser	Curtis J. Alley	Hudson T. Hartmann

Table 6. Officers — Region of Great Britain & Ireland, International Plant Propagators' Society 1968 — 1970

Year	President	Vice President	Secretary-Treasurer	Editor
1968-69	Brian E. Humphrey	Robert J. Garner	A. Bruce McDonald, Secy. John O'Connor, Treas.	Richard F. Martyr
1969-70	Robert J. Garner	A. D. Weguelin	A. Bruce McDonald, Secy. P. D. A. McMillan-Browse, Treas.	Richard F. Martyr
1970-71	A. D. Weguelin	A.R. Carter	A. B. McDonald, Secy. P. D. A. Mc Millan-Browse, Treas.	Richard F. Martyr

GOVERNING BOARDS: The International Plant Propagators' Society is governed by a Board of Directors consisting of the following:

Past President
President
Vice-President
Past Presidents of the three regions
Presidents of the three regions

The vice-presidents of the three regions may serve as alternate members of the Board. The Board appoints a secretary-treasurer and an editor annually. The International Board meets each year in conjunction with one of the annual regional meetings. The term of office for the officers and Board of Directors is from January 1st to December 31st.

The regions have executive committees which consist of the following:

Past President of the Region
President
Vice-President
Two to four elected members.

The regions also appoint the secretary, treasurer and editor annually.

The elected members of the executive committee of the Plant Propagators' Society were:

Name	Term of Office	Name	Term of Office
Skinner, Henry T.	1953	Van Hof, Martin	1956-57
Kern, Carl	1953	Nelson, Stuart H.	1957-58
McGill, Wayne	1953-54	Templeton, Harvey M., Jr.	1957-58
Vanderbrook, Louis	1953-54	Fenicchia, Richard A.	1958-59
Pease, Roger	1954-55	Ravestein, John	1958-59
Turner, Frank	1954-55	Buckley, A. R.	1959-60
Hancock Leslie	1955-56	Lancaster, Arthur J., Jr.	1959-60
Siebenthaler, Jack	1955-56	Galle, Fred C.	1960
Meahl, Robert	1956-57	Waxman, Sidney	1960

Elected members of the regional organizations include:

EASTERN REGION:

Name	Term of Office	Name	Term of Office
Galle, Fred C.	1961	Pinney, Thomas S., Jr.	1964-65
Waxman, Sidney	1961	Forster, R. Ray	1965-66
Hill, John B.	1961-62	Shugert, Ralph	1965-66
Flemer, William, III	1961-62	Cannon, Thomas F.	1966-67
Roller, John (Served only 1 yr. elected Vice-Pres.)	1962	Hess, Hans	1966-67
Reisch, Kenneth W.	1962-63	Cunningham, William E.	1967-68
Dugan, David W. (Completed term of John Roller)	1963	Vanderbilt, Richard	1967-68
Halward, Ray E.	1963-64	Tukey, Harold B., Jr.	1968-69
Vermeulen, J. Peter	1963-64	Law, James B.	1968-69
Leach, David G.	1964-65	Flemer, William, III	1969-70
		Nielsen, Peter	1969-70

WESTERN REGION:

Name	Term of Office	Name	Term of Office
Schneider, Gerd	1960	Roberts, A. N.	1964-65
Stuke, William E.	1960	Ticknor, Robert	1965-66
Lindquist, Robert V.	1960	Leiser, Andrew T.	1965-66
Usrey, Martin W.	1960-61	Armstrong, David	1965-66
Melott, Wayne	1961	Hartman, Hudson T.	1966-67
Frolich, Edward F.	1961-62	Wood, Edsal A.	1966-67
Kershaw, Gordon	1961	Christie, W. D.	1967-68
Batchellor, Oliver A.	1962-63	Fazio, Steve	1967-68
Morey, Dennison	1962-63	Real, Fred	1968-69
Briggs, Bruce A.	1963-64	Wagner, Gottlob	1968-69
Barker, Philip A.	1963-64	Van Vloten, Walter	1969-70
Ishida, Henry J.	1964-65	Pinkus, Ralph	1969-70

REGION OF GREAT BRITAIN AND IRELAND:

Name	Term of Office
Chandler, G. P.	1969-70
Clark, David N.	1969-70
Weguelin, A. D. (Served 1 yr. elected Vice-Pres.)	1969
Gaggini, J. B.	1970

FINANCES: The Society is financed primarily by annual membership dues. Secondary sources of income are from the sale of publications to institutional libraries and from interest on surplus funds. The fiscal year is from July 1 to June 30. From 1951 through 1960 annual dues were:

Commercial Member	$ 10.00
Non-commercial Member	5.00
Junior Member	required to purchase copy of Proceedings

In 1961, the dues were increased to:

Commercial Member	$ 12.50
Non-commercial Member	7.50
Junior Member	5.00

A second increase in dues was effected in 1967:

Commercial Member	$ 15.00
Non-commercial Member	10.00
Privileged Member	10.00
Junior Member	7.50

Honorary Members do not pay annual dues.

The regions have accrued funds by an initiation fee charged new members, interest on surplus funds, a surplus from the annual meetings and, on two occasions, a partial rebate of the annual dues.

ANNUAL MEETINGS: The regional vice-president is charged with the responsibility of arranging the program for the annual meeting. Many of the speakers are selected from the membership, however, guest speakers have made valuable contributions to the programs. As listed in the first 18 volumes of the PROCEEDINGS, there have been 454 different speakers. One hundred-forty-six of the speakers have been on the program two or more times. At the 1953 annual meeting a speaker-exhibitor session was inaugurated. At these sessions a speaker is limited to 5 or 10 minutes to tell of some aspect of plant propagation which he feels would be of interest to the group. Also, at the 1953 meeting a "Plant Propagator's Question Box" was started. Members write questions on a card, drop the card in the "Question Box" and a moderator asks for volunteers to answer the question. Both of these features have become traditional parts of the meetings. Tours of local nurseries, botanical gardens, arboreta, etc. are arranged as an optional part of the program.

Members may attend any of the regional meetings. Members may also invite prospective members as guests, however, a guest may attend only one meeting.

The time and place of the regional meetings are determined by the regional executive committees. Meetings are usually held at a time which fits best into the nursery production schedule of the region. The dates and locations of the annual meetings are listed in Tables 7 and 8. Both the Eastern and Western Regions have held one annual meeting in Canada.

Table 7. Dates and places of the annual meetings of the Plant Propagators' Society

Year	Place and Dates	Year	Place and Dates
1951	Cleveland, Ohio November 8—9	1956	Cleveland, Ohio November 29 — December 1
1952	Cleveland, Ohio December 12—13	1957	Cleveland, Ohio November 21—23
1953	Cleveland, Ohio December 10—12	1958	Cleveland, Ohio December 4—6
1954	Cleveland, Ohio December 2—4	1959	Philadelphia, Pa. December 10—12
1955	Cleveland, Ohio December 15—17		

Table 8. **Dates and places of the annual regional meetings — International Plant Propagators' Society**

	EASTERN REGION Place and Dates	WESTERN REGION Place and Dates	REG. OF GR. BRIT. & IRE. Place and Dates
1960	Cleveland, Ohio December 1—3	Asilomar, Calif. October 14—16	
1961	* Washington, D. C. December 6—9	Asilomar, Calif. October 25—27	
1962	Cincinnati, Ohio December 6—8	* San Dimas, Calif. October 18—20	
1963	* St. Louis, Mo. December 5—7	West Lynn, Oregon October 3—6	
1964	Rochester, N. Y. December 3—5	* West Sacramento, Calif. October 15—17	
1965	* Cleveland, Ohio December 8—11	Los Gatos, Calif. October 21—23	
1966	Newport, R. I. December 7—10	* Anaheim, Calif. October 13—15	
1967	* Mobile, Ala. November 29 — December 2	Vancouver, B. C. September 7—8	
1968	Toronto, Ontario December 3—7	* Fresno, Calif. October 16—18	Syon Park, Middlesex September 18
1969	* New York, N. Y. December 3—6	Olympia, Wash. September 2—5	Pershore, Worcs., January 2 and Tonbridge, Herts. Sept 11—12
1970	**JOINT MEETING** * St. Paul, Minn. September 9—12		Sutton Bonnington, July 22—25 Nr. Loughborough, Leics.

* International Board of Directors met concurrently.

PROCEEDINGS: Each year the talks, papers, discussions and reports of the regional meetings are published in a single volume, called the PROCEEDINGS. A copy of the PROCEEDINGS is distributed to each member and purchased by more than 100 libraries of colleges, universities, experiment stations, botanical gardens and arboreta for use as reference material. Back issues of the PROCEEDINGS may be purchased by members and libraries. The 1951 PROCEEDINGS has recently been reprinted in a limited quantity. Volume 12 (1962) is out-of-print and the supplies of Volume 4 (1954) and 15 (1965) are almost exhausted.

The 1951 PROCEEDINGS contains seven articles and since 1964 there have been more than 60 articles in each volume. The 1951 PROCEEDINGS contained only 50 pages but Volume 18 contained 453. Since Volume 15, the PROCEEDINGS have been bound in a hard cover. The 18 volumes represent a total of 4,637 pages and 800 articles. Cumulative indices were prepared for Volumes 1-5 and 6-10, and since 1962 each volume has contained an index.

The Editor of each region is responsible for editing the Region's material in the PROCEEDINGS. The International Editor is then responsible for final editing and publishing. Distribution to members and sales to libraries are handled through the International Secretary-Treasurer. Nine members, listed in Tables 2-6 have served the Society as editor during its 20 years of existence.

Of special note in Volume 18 is the report prepared by Dr. S. H. Nelson on "Incompatibility Survey Among Horticultural Plants." This is the most complete stock-scion compatibility compilation available and the Society has reprints of the report.

THE PLANT PROPAGATOR: The International Editor is also responsible for the preparation and printing of the quarterly journal, THE PLANT PROPAGATOR. Volume I was published in 1955. Volumes 1 through 10 were mimeographed and several styles were used. Starting with Volume 11 in 1965, THE PLANT PROPAGATOR has been printed by photo-offset on 8½ x 11
THE PLANT PROPAGATOR contains notes and articles on plant propagation submitted by the members as well as announcements and news of the Society. It is distributed to each member and to institutional libraries which purchase the PROCEEDINGS.

INSIGNIA: The original insignia was selected by Edward H. Scanlon for the first issue of the PROCEEDINGS. It showed the hands of a propagator holding a piece of grafting wood and a grafting knife. In Volume 8 (1958) of the PROCEEDINGS the name and date of founding of the Society — Plant Propagators' Society, 1951 — surrounded the insignia. In 1967 the insignia was revised by changing the name to "The International Plant Propagators' Society and the motto of the Society, " *quaere et imperitire* " was added. The motto, which means "to seek and to share" was adopted at the suggestion of J. Peter Vermeulen and exemplifies the basic philosophy of learning and sharing knowledge with one another — a philosophy on which the Society was founded.

MEMBERSHIP PLAQUES: The basic concepts of the insignia were kept in the membership plaques which, in 1968, were purchased and distributed to all members. The plaque consists of a 6 x 6 inch white tile set in a background of 10 x 10 birch wood. Gold lettering on a black background was used for the name, motto and founding date. The background of the insignia was green; the piece of grafting wood was gold and the propagator's hands were white. A thin gold line within a black line on the outer edge of the tile framed the insignia. A place for an annual membership date tag lies below the insignia. An embossed name tag was affixed to the birchwood immediately below the title.

PLANT PROPAGATORS' AWARD OF MERIT: The Plant Propagators' Award of Merit is made by the Eastern Region to the individual who, in the opinion of the membership and the Awards Committee, has made a significant contribution to the field of plant propagation. The criteria for selection includes scientific discovery and application of facts related to propagation practices and techniques and/or for service rendered to the science and practice of plant propagation. Recipients of this award are:

1957 Dr. L. C. Chadwick, Ohio State University
1958 Dr. F. L. Skinner, Morden, Manitoba, Canada
1959 Mr. James S. Wells, Red Bank, New Jersey
1960 Mr. Harvey M. Templeton, Jr., Winchester, Tennessee
1962 Mr. Carl Kern, Cincinnati, Ohio
1963 Dr. Charles E. Hess, Purdue University
1964 Dr. William E. Snyder, Rutgers University
1966 Mr. Martin Van Hof, Newport, Rhode Island
1967 Mr. John P. Mahlstede, Iowa State University
1968 Mr. Leslie Hancock, Cooksville, Ontario, Canada
1969 Professor F. L. S. O'Rourke, Colorado State University

STUDENT AWARDS: To stimulate interest and research in plant propagation the Eastern Region has established student awards for the best paper on a subject dealing with some phase of plant propagation. Two awards may be given: one for the best paper submitted by an undergraduate student and another for the best paper submitted by a graduate student. Winners of the undergraduate award are:

1967 Donald C. Ferguson, Cornell University
1968 George R. McKinnis, Purdue University

Winners of the graduate student award are:

1967 John A. Wott, Cornell University
1968 Wayne O. Doede, Purdue University
1969 Chong Il Lee, University of Rhode Island

"IDIOT'S STICK": A symbol of office of the president of the Plant Propagators' Society was presented to L. C. Chadwick, the second president, by Jack Siebenthaler. It is a huge mallet suitably inscribed on the handle in red paint "IDIOT'S STICK". This "idiot's stick" was passed to each succeeding president of the Plant Propagators' Society and is now the badge of office of the president of the Eastern Region.

The members of The International Plant Propagators' Society have every reason to be proud of their Society — its philosophy, objectives, standards and accomplishments during the past 20 years. But pride of the past must be accompanied by the dedication of each member to make the future excel the past.

THE NATIONAL ASSOCIATION OF PROPAGATING NURSERYMEN[1]

ALFRED J. FORDHAM
The Arnold Arboretum
Jamaica Plain, Massachusetts

Much of the great technological advance made in plant propagation during recent years can be credited directly to the organization known as The International Plant Propagators' Society. This unique body has successfully brought together those concerned with the scientific investigation of propagation and those involved in the more practical aspects of commercial plant production. Most people, however, are unaware that its origin is traceable to the existence of a previous and somewhat similar group.

This organization, first known as the National Association of Propagating Nurserymen, was formed in 1919 and survived until 1931, when, due to internal problems and the severe economic depression of that period, it foundered. The group met in conjunction with the annual convention of the American Association of Nurserymen and hence moved about the country to different major cities each year. Meetings consisted of one night sessions which were supposed to convene at 8 o'clock but rarely did.

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[1]Reprinted from THE PLANT PROPAGATOR, Vol. 15, No. 4, 1969.

submitted by a graduate student. Winners of the undergraduate award are:

1967 Donald C. Ferguson, Cornell University
1968 George R. McKinnis, Purdue University

Winners of the graduate student award are:

1967 John A. Wott, Cornell University
1968 Wayne O. Doede, Purdue University
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At the 7th Annual Meeting held at Louisville, Kentucky, on June 23, 1926 it was agreed "that a report of this meeting and future meetings be printed and distributed to the members and that the report contain a list of the membership of the association." The first issue consisting of fourteen pages covered that meeting. Five subsequent publications followed annually until the organization failed in 1931 Were it not for these issues it is quite probable that all knowledge pertaining to the society and its activities would be lost forever.

It is of interest to note that those wishing to bind this material were confronted with a problem for the six issues appeared in three widely differing sizes. At the 1958 meeting of the International Plant Propagators' Society, Mr. Roy Nordine of the Morton Arboretum made an appeal for the location and gift of these volumes. His purpose was to obtain copies for the archives of the present society and thus provide information which would throw light on the history of the early organization. Dr. Richard P. White of the American Association of Nurserymen donated a complete set of six copies and Mr. Nordine presented them to the International Plant Propagators' Society at the 9th annual meeting held in Philadelphia, Pennsylvania, on December 9, 1959. These I now have on loan from that society and from them have extracted the information which forms the basis of this history.

Mr. Nordine also made a fruitless attempt to locate the last secretary-treasurer. His intentions were two-fold, first to obtain the secretarial records for the archives of the more recent organization, and secondly, to learn what became of the final cash balance comprising $584.97! If per chance these records still exist, and a reader has knowledge of their whereabouts they would provide the information necessary to complete this history.

A perusal of these proceedings reveals much of horticultural interest, for example, the discussions involve the approach to propagational problems by scientific investigators when this activity was in its infancy, and the old controversy of apprenticeship versus academic education in the production of capable horticultural personnel. The shaky foundation on which the association rested is apparent from comments that appeared every now and then.

An interesting sidelight on the association is provided by the comments of President Thomas A. McBeth of Springfield, Ohio, when at the 7th Annual Meeting (1926), he pointed out that a motion had been passed the previous year to appoint a committee to revise the bylaws of this association. As far as he knew nothing had been done, or that a committee had even been appointed but he recommended that some action should be taken. He also suggested that "the constitution be rewritten as it was very poor, and that the constitution for some reason or other had been lost, I guess"

Table 1—Meetings Held, Together with Officers who Presided:

Date	Location	Presiding Officers
June 23, 1926	Louisville, Kentucky	Thomas A. McBeth Springfield, Ohio
June 21, 1927	Cleveland, Ohio	W. B. Cole Painesville, Ohio
June 20, 1928	Denver, Colorado	Henry Klehm Arlington Heights, Illinois
July 16, 1929	Boston, Massachusetts	Henry Klehm Arlington Heights, Illinois
July 15, 1930	Minneapolis, Minnesota	E. H. Costich Westbury, New York (in lieu of President John M. Nordine, Lake City, Minnesota, who was absent)
July 22, 1931	Detroit, Michigan	John Siebenthaler Dayton, Ohio
1932	No meeting held — E. H. Costich would have presided, having been elected president at the 12th Annual Meeting in 1931.	

This recommendation led to action and the Executive Committee met in Chicago during the winter to draft a constitution which was put before the members and accepted during the 8th Annual Meeting in 1927. At this time, and without explanation in the records at least, the name was changed from the National Association of Propagating Nurserymen to the American Plant Propagators Association. The constitution reads as follows:

Constitution and By-Laws
The American Plant Propagators Association

(1.) This organization shall be known as the American Plant Propagators Association.

(2.) The purpose of this organization shall be the upbuilding of the science and art of the propagation of nursery stock and plant material for distribution throughout the United States, and for the establishing of standards of quality and grades. Further: — to assist in developing a Nursery business for the benefit and protection of all those engaged in the business.

(3.) All nurserymen or nursery firms of good standing who are engaged in the propagation of nursery stock for lining out in nursery rows, shall be eligible for membership.

By-Laws

(1.) The officers shall consist of President, Vice President and Secretary- Treasurer, who shall be elected at the Annual Meeting by majority vote of those members present.

(2.) An Executive Committee shall consist of seven members. The President to be a member of the Committee, and two members elected each year to serve three years.

(3.) The Executive Committee shall pass on all applications for membership, shall approve all bills before payment, provide program for the annual meeting, and perform such other duties as the name signifies, or that the President may call upon them for. All action of the Committee shall be governed by majority vote.

(4.) The Secretary-Treasurer shall receive all moneys, giving his receipt therefore, and pay all bills ordered by the Executive Committee. He shall keep a record of all proceedings and publish a report after each annual meeting.

(5.) The yearly membership dues shall be $5.00.

The university and research people whose papers appear in the proceedings must have been honorary members or guest speakers, for according to article 3 of the constitution they would not qualify for membership. Article 3 was also designed to exclude florists and others involved in the propagation of plants not considered nursery stock. Article 2 limited membership to those propagating nursery stock for distribution throughout the United States. One wonders if this stipulation could lead to expulsion of a member doing foreign business!

Statistical Information

Throughout these publications statistical information is sketchy. Although it was voted that the proceedings contain a membership list, only once did it appear. (Proceedings of the 7th Annual Meeting). Apparently membership was held by organizations or nursery firms rather than by individuals, at least at first, and the published list showed sixty such members. (Table 2.) However twenty-four new members were accepted in 1926, which represented a membership boost of 40 per cent. The report presented at the 10th Annual Meeting in 1929 gives an idea of the Association's size for that year. It mentions five honorary members, seventy-seven members paid in full, and twenty-one up to three years behind in dues.

Table 2 — List of Members, 7th Annual Meeting, 1926.

J W Adams Nursery Co , Springfield, Mass
Ashford Park Nurseries, Atlanta, Georgia
Augustine and Company, Normal, Illinois
Mark Aukeman, Springfield, Ohio
J V Bailey, St Paul, Minn
Baker Bros Inc , Fort Worth, Texas
Berryhill Nursery Co , Springfield, Ohio
Bunting's Nurseries, Selbyville, Del
J S Burton, Casstown, Ohio
M L Carr's Sons, Yellow Springs, Ohio
Charlevoix County Nurseries, Charlevoix, Mich
Chase Nursery Company, Chase, Alabama
Cole Nursery Company, Painesville, Ohio
Conard-Pyle Company, West Grove, Penna.
J F Donaldson, Sparta, Kentucky
Wilbur Dubois and Son, Madisonville, Ohio
F and F Nurseries, Springfield, N J
Forest Nurseries Co , McMinnville, Tenn
Fraser Nursery Co , Birmingham, Ala
Greening Nursery Co , Monroe, Mich
Griffings Interstate Nurseries, Jacksonville, Fla
Hess Nurseries, Paterson, New Jersey
I Hicks and Son, Westbury, Long Island, N Y.
D Hill Nursery, Inc , Dundee, Illinois
Hogansville Nurseries, Hogansville, Georgia
Howard-Hickory Company, Hickory, N C
Howell Nurseries, Knoxville, Tenn
T S Hubbard and Company, Fredonia, N Y
I E Ilgenfritz Sons Co , Monroe, Mich
Imlay Company, Zanesville, Ohio
Jackson and Perkins Co , Newark, N Y
J Jenkins and Son, Winona, Ohio
Jones Norfolk Nurseries, Norfolk, Virginia
Klehm's Nurseries, Arlington Heights, Ill
Littleford Nurseries Co , Downers Grove, Ill
Lovett's Nurseries, Little Silver, N J
Malmo and Company, Seattle, Washington
T A McBeth, Springfield, Ohio
Thomas B Meehan Co , Dresher, Penna
Mt Arbor Nurseries, Shenandoah, Iowa
Naperville Nurseries, Naperville, Illinois
Netts-McBeth Nursery, Springfield, Ohio
Northeastern Forestry Assoc , Cheshire, Conn
North Star Nurseries, Pardeeville, Wis
Northwest Nursery Co , Valley City, N D
Onarga Nursery Company, Onarga, Illinois
L Dwight Page, Staunton, Illinois
Princeton Nurseries, Princeton, New Jersey
Prudential Nursery Co , Kalamazoo, Mich
Rosebank Nursery Co , Huntsville, Ala
W N Scarff and Sons, New Carlisle, Ohio
Henry Schnitzspahn, Bound Brook, N J
Shady Lane Nurseries, Columbus, Ohio
Sherman Nursery Co , Charles City, Iowa
J Siebenthaler Nurseries, Dayton, Ohio
Templin-Bradley Co , Cleveland, Ohio
Texas Nursery Company, Sherman, Texas
Troy Nurseries, Troy, Kansas
The Villa Nurseries, Portland, Oregon
Thomas Windon, Whitesbog, N J

At the 1928 meeting George Verhalen, Secretary, read the report of Treasurer E. M. Jenkins, who had resigned. It is the only fully detailed report that appears in the six issues:

Report of Secretary — Treasurer, June 15, 1928

Balance on hand last report, June, 1927	$466.77	
Dues received	355.00	
	$821.77	
Interest received on Savings Account:		
July 1, 1927	$9.29	
January 1, 1928	9.52	18.81
TOTAL RECEIPTS		$840.58

EXPENDITURES

1927

Aug. 10,	H. B. Tukey, Railroad fare and so forth	$ 30.00
Aug. 10,	Harris and Company, Printing	15.20
Aug. 10,	E. M. Jenkins, Books	2.25
Aug. 10,	C. W. Zimmerman, Expense Account	$ 69.44
Aug. 10,	J. Jenkins & Son, Postage	$ 4.82
Sept. 1,	Benton & Brown Reporting Service Report of 1927 meeting	$ 34.32
Sept. 22,	Harris and Company, Printing	$ 5.10

continued

1928			
June 1,	Educational Supply Company, Printing Reports	$ 95.00	
June 1,	J. Jenkins & Son, Postage	$ 6.19	
TOTAL. EXPENDITURES			$ 262.32
Balance on hand June 15, 1928			$ 578.26

The precarious conditions of the society is apparent from comments that appear from time to time. President McBeth in his opening remarks at the 7th Annual Meeting spoke as follows:

> "I believe this organization has a place under the sun. It may be the means of doing a considerable amount of good providing it is properly conducted and enthusiastically supported — put the emphasis on enthusiastically. Some of us thought last year it was in such a condition that it was about time to call an undertaker. I am happy to report it is past that state of coma and that it has taken on new life — it has come to stay.
>
> "If we go out into the field and see a plant in good growing conditions we have hope that that plant will amount to something. We all understand that part of it. It seems to me that is somewhat the condition of this society at this time. It is growing and if you will help to cultivate it, it may become an institution of a great deal of benefit to the trade.
>
> "As I see it, one of the obstacles to be surmounted is the time of our meeting. We have to tack this on to the apron strings of someone else and it is not convenient. We have had a good deal of trouble to get arrangements made here tonight. It is now conflicting with several meetings, keeping some of our members away. We are rather small as yet to call an independent meeting."

Secretary-Treasurer H. Lloyd Haupt at the 10th Annual Meeting made the following comments:

> "It is just a year since I relieved George Verhalen of the books, at Denver, and I thought then I was going to do a lot of things which I am sorry to say I have not accomplished. However, we have kept the old ship afloat and have a little more money in the bank than then, and I think we can do a lot more in the future."

Throughout the reports, mention is made of efforts to collect back dues and of ideas to increase membership. At the 12th and final meeting Secretary Haupt reports as follows on a final, futile attempt:

> "Our program last year at Minneapolis was most complete and the enthusiasm ran high. Your secretary therefore planned and printed up a very good issue of the Proceedings anticipating that the membership would back him up.
>
> "Hoping to add a number to the list of members, he sent copies of the Proceedings to the various trade papers for review. Everyone of them gave us a good write-up, but of the inquiries resulting therefrom, only one new member was signed up."

Attendance records did not appear in any of the Proceedings. However, the membership present at the 12th and final meeting must have been small for when President John Siebenthaller made a proposal Mr. Jones moved that it be postponed until there was a better attendance. At the meeting's end, Mr. Jones' motion to adjourn terminated the session and also the society which never convened again.

RALPH SHUGERT: Thank you very much, Bill. On behalf of the entire Society and guests in this room we appreciate this very comprehensive report. It's apparent it took many hours to compile and it is an excellent history of our Society.

Ladies and gentlemen, we are now going to begin the first of four symposia for this meeting: there will be two today and two Friday. Each will be followed by a critique; today's critique will be handled by Dr. Hess and Dr. Leiser. This first symposium carries the title of the "Role of Environment in Plant Propagation." The moderator is the immediate Past-president of the American Association of Nurserymen and currently is serving on the Eastern Region Executive Committee. He is an author, has received numerous titles, awards, etc. It is with considerable amount of honor that I present to you Bill Flemer.

BILL FLEMER: Today, we are going to approach some traditional considerations in plant propagation from a more integrated point of view, that is considering the whole environment and its effect on propagation. Usually presentations consider the role of a single aspect of the environment such as water or light upon the rooting of plants or germination of seeds. However, this approach neglects the rather complex and subtle interaction of all phases of the environment on plant propagation. In this respect, you might consider the growth of a plant or the rooting of a cutting as a quadratic equation with four variables — water, light, temperature and mineral nutrition all interacting together on the same basis with each affecting the others. I recall a similie which Charley Hess presented to us several years ago in which he likened the growth of a plant or the rooting of a cutting to a column which could be filled with liquid; the column having four series of holes on its sides. One series representing temperature, another water, a third light intensity, and the fourth mineral nutrition. In order to achieve the maximum amount of growth or degree of rooting of cuttings in a bed you must begin at the bottom of each series and plug the holes so that the liquid will rise in the cylinder. This has been a useful concept to me in evaluating the success or failure of our propagation efforts at Princeton.

The kinds of things that can be accomplished are wonderful if you have a perfect environment. I remember Jim Wells telling of a nursery on the West Coast of Scotland where conditions were so ideal that rhododendron cuttings were stuck and rooted directly in raised, open beds much as we would root hardwood cuttings of privet. I also remember going to Normandy in the spring of 1944 and a nurseryman there was top-grafting apple trees on high stems with nothing more than a little mud and a twist of straw around the scion and having complete success. As these examples indicate, when the environment is perfect from the plants point of view the results you can get are simply astounding. For this first symposium we are going to have a group of experts with us who are going to discuss four aspects of the environment and their interrelationships in plant propagation. The first speaker is Dr. Ted Kozlowski from the University of Wisconsin who is going to discuss some of the interrelations of water.

ROLE OF ENVIRONMENT IN PLANT PROPAGATION: WATER RELATIONS[1]

T. T. KOZLOWSKI
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INTRODUCTION

All plantsmen know that plants need water for growth. Water is essential for plants as the major constituent of physiologically active tissues. It is a reagent in photosynthesis and in hydrolytic processes as well as a solvent in which salts, sugars, and other solutes move from cell to cell. Water is also essential for maintenance of plant turgidity.

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[1]Publication approved by Director of Research, College of Agricultural and Life Sciences, University of Wisconsin.

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soil we can only conclude that it allows most of it to evaporate from the shoots and uses only very small amounts in growth. It has been estimated, for example, that plants may use from 250 to 1,000 pounds of water to produce one pound of dry matter in growth of roots, stems, leaves, and reproductive tissues. Yet we know that if a plant cannot get water from the soil its growth is adversely affected and it may be killed. It should be obvious, therefore, that plants are extremely inefficient in their use of water and this is a matter of concern to all of us.

The plant propagator in particular must always be deeply concerned with plant-water relations. This is so not only because growth and survival of plants probably depend more on availability of water than on any other environmental factor, but also because the techniques of plant propagators unfortunately tend to create unusually severe internal water deficits in plants. For example, the preparation of cuttings and scions for rooting or grafting disrupts the path of normal water movement through the soil-plant-air continuum and thereby creates ideal conditions for desiccation of shoots.

This paper will allude briefly to some aspects of plant-water relations with which the plant propagator should be familiar. At the outset, I would like to emphasize the following major points:

(1) **All** plants growing in soil undergo internal water deficits. Such deficits develop periodically, even in plants growing in well-watered soils, when transpiration from shoots exceeds absorption of water through the roots.

(2) Growth and development of plants would proceed unimpaired and growth would be maximal only if a favorable internal water balance were maintained **continuously** during the life of a plant. Even temporary mild water deficits inhibit plant growth. The amounts of loss of plant growth as a result of unfavorable water balance are tremendous. In addition to restricting growth, water deficits modify various aspects of plant quality such as taste of fruits and density of wood (20, 24, 27).

(3) Growth limitations because of internal water deficits frequently are overlooked in situations where other deleterious agents operate, including plant competition, disease, or insect pests. Stunting and killing of desirable plants by "weed competition" commonly involves competition for water leading to a desiccation effect. Root diseases and insect injury to roots often interfere with absorption of water and thereby cause desiccation of shoots. In vascular wilt diseases, the desiccation of tops following vascular plugging often plays a major role in wilting of leaves and ultimate death of plants.

Leaf desiccation causes considerable winter injury to evergreens. During some warm winter or spring days transpiration is appreciable but water cannot be absorbed readily from cold or frozen soils and leaves consequently dry out.

Water deficits also play an important role in predisposing host plants to attacks by certain fungus pathogens and insects (26). Physiological changes which reflect decreasing vigor in trees often are a prerequisite to attack by certain insects. Copious exudation of oleoresins in gymnosperms and flow of sap or gum in angiosperms are correlated with resistance to bark beetle attacks. Vité (45) showed that success of bark beetle attack was closely correlated with low oleoresin exudation pressures. Whereas initial attack occurred at random, only beetles in trees with low oleoresin exudation pressure made successful invasions which led to mass attacks later. Differences in susceptibility due to site and stand conditions were related to rates of flow of oleoresin and these, in turn, to stem hydration. Oleoresin exudation pressures decreased as internal water deficits in trees increased, indicating that drought often predisposed trees to attack by bark beetles.

(4) It is very difficult to appraise clearly the mechanisms by which water deficits adversely affect plant growth. One reason for this is that the internal water status of a plant is a dynamic parameter, influenced by conditions in the soil and atmosphere and regulated to various degrees in different situations and with different species by physiological factors. Another difficulty is that internal water deficits affect plant growth in many ways, both directly and indirectly. Hence, cause and effect relationships are difficult to assign (43).

(5) Internal water balance of plants is rapidly altered. Even well-rooted plants may have a very favorable internal water balance and within a matter of minutes they can develop severe internal water deficits, causing them to wilt. Thus, water deficiency develops much more rapidly than deficiency of other internal requirements for growth such as carbohydrates, hormones or minerals. For these several reasons it behooves plant propagators to be familiar with causes, effects, and control of water deficits in plants.

MEASUREMENT OF WATER DEFICITS

As internal water deficits in plants control plant growth they need to be characterized and measured. This has been done in various ways, for example, by determining water content, relative water content (relative turgidity), saturation deficit, stomatal aperture, water potential, or shrinkage of plant tissues. The usefulness and limitations of these methods of determining water deficits in plants are discussed by Barrs (2).

Water that is subjected to molecular restraints is less free to enter into physiological reactions within plants than is pure free water. Restraints may result from differences in pressure, salt concentration, absorption at colloidal interfaces, confinement in capillaries, or inadequate water supply at a particular place. Many plant physiologists characterize water status of plants or soil in terms of water potential — the difference in chemical potential of the water in the system and pure free water at the same temperature. This thermodynamic term represents the sum of all contributing factors to the water potential under any given set of external conditions. Its major components include 1) a pressure potential resulting from net pressure difference such as occurs as a result of turgor pressure in plants or hydraulic pressure in saturated soils, 2) a matric potential attributable to the colloidal matrix of the soil or plant system, and 3) a solute potential. The use of water potential to characterize water status in plants and soil has many advantages over other measurements (44).

WATER RELATIONS DURING SEED GERMINATION

The effects of water deficits on seed germination have important implications in plant propagation and agriculture. Many plant propagators soak seeds to speed up germination. In regions of irrigation agriculture seed beds often are pre-irrigated and planted shortly thereafter. In areas of dry-land agriculture seeding usually follows a period of rain. When soil moisture supplies are low, catch crops such a milo (*Sorghum vulgare*) or safflower (*Carthamus tinctorius*) are often used (9).

Most seeds need to absorb water to trigger the metabolic processes associated with germination. Only small amounts of water are needed to initiate these biochemical activities. However, once such processes are underway, the seed and the germinant thereafter require increasingly larger amounts of water and in continuous supply. Desiccation after germination begins often is very harmful.

The degree of protoplasmic hydration necessary to stimulate seed germination varies greatly among species, and only a few examples will be given. Most seeds can absorb enough water for germination if soil is at field capacity. Some vegetable seeds, however, can germinate in soil which has dried to wilting percentage. Seeds of Hinoki cypress (*Chamaecyparis obtusa*), Japanese red pine (*Pinus densiflora*) and Japanese black pine (*Pinus thunbergiana*) germinated when soil moisture tension was 8 atm. or less. Above this value seed germination of each of these species declined as soil dried further. The greatest decrease in germination with increasing of soil moisture deficit occurred in *Chamaecyparis obtusa* (42). Kaufmann (15) studied the effects of water deficits on the rate of seed germination of sweet orange (*Citrus sinensis* 'Argentina'), sunflower (*Helianthus annuus* 'Mammoth Russian'), and lettuce (*Lactuca sativa* 'Phoenix'). Germination of lettuce or orange seeds occurred only when water deficits were low (at water potentials above —4.1 or —4.7 bars). Water availability was less critical for germination of sunflower seeds as they germinated well at —4.1 and slowly at —8.0 bars.

Some seeds can germinate in very dry soils. Owen (41) for example, showed that about 20 per cent of wheat seeds germinated when soil moisture content was below the permanent wilting percentage. The critical level of moisture stress at which germination was completely inhibited was not reached. It should be remembered that permeability of seed coats to water varies greatly among species. For example, the coats of many legume seeds inhibit water uptake. Some portions of seeds may also be more permeable than others. According to Koller and Roth (17), germination of *Panicum turgidum* seeds depended on whether the flat or convex side was in contact with the moist substrate.

Most seeds have an optimum period of moistening before germination. Species also vary in the capacity of their seeds to germinate following prolonged immersion in water. Soaking seeds of many species for a few hours often accelerates germination whereas prolonged immersion may injure seeds or decrease their viability. Soaking seeds of white pine *(Pinus strobus)* for 70 hours has harmful effects on germination. By comparison, seeds of tupelo gum *(Nyssa aquatica)* survive submersion of 7 months and of bald cypress *(Taxodium distichum)* for 30 months. However, these seeds do not germinate under water (38). It is well known that seeds of many weeds, especially those of aquatic habitats, can survive immersion for months.

Water also plays an important role in stimulating germination of seeds which are dormant because they contain water-soluble inhibitors. For example, seed germination in hot and dry regions often is geared to the short wet period of the year. When enough rain falls to wet the soil thoroughly the inhibitors are leached out of the seeds and the seeds are rehydrated, thereby creating internal conditions conducive to germination.

DEVELOPMENT OF WATER DEFICITS IN LEAFY PLANTS

Under ideal conditions with free access to unlimited water supplies leafy plants transpire vast amounts of water. However, the amount actually lost varies greatly with soil water availability and other factors. Most of the water lost escapes as vapor through the stomates which are the path of least resistance to diffusion of water vapor. Stomates generally are open in bright light and closed in the dark. They can also be closed by water deficits in the plant.

Internal water deficits in plants are controlled by relative rates of transpirational water loss from shoots and absorption of water through the roots. During the daytime more water is lost in transpiration than is replaced by absorption. Therefore, plants tend to be depleted of water during the day, especially on hot sunny days. During the night, however, both transpiration and absorption are low but the rate of absorption exceeds transpiration and plants tend to refill with water. The rate of absorption of water by roots during the day lags behind transpiration even if the soil is well-watered. Such an absorption lag is the result of resistance to water movement in various parts of its translocation pathway from the soil through the plant and into the air. For example, some resistance to translocation of water occurs in the soil and in roots, stems, and leaves.

It should be obvious that internal water deficits in plants will result from excessive transpiration or slow absorption of water from dry, cold, or poorly aerated soils or, more commonly, from a combination of both. Absorption of water and transpiration are partly controlled by different sets of factors. Transpiration is largely controlled by atmospheric factors (primarily light, humidity, temperature, wind) as well as by structure of leaves and opening and closing of stomates. Absorption is controlled by transpiration rate and also by the size and distribution of the root system and soil factors (primarily soil water availability, temperature, concentration of the soil solution, aeration, etc.). Temporary wilting of leaves in the afternoon often occurs because of excessive transpiration. This is not serious if the soil is well-watered because the leaves usually recover turgidity at night (when transpiration is low and absorption is somewhat higher). When soils begin to dry out, however, temporary wilting of leaves tends to become more permanent because leaves are less likely to recover turgidity at night (35, 36).

The recurrent daily development of internal water deficits in plants is shown by afternoon decreases in moisture content of plant tissues and by shrinkage of various plant parts including leaves, stems, roots, as well as fruits and cones (6, 7, 8, 20, 21, 25).

EXPANSION AND CONTRACTION OF STEMS

As a result of recurrent dehydration and rehydration tree stems usually shrink slightly during the day and expand at night (Fig. 1) (18, 19, 22). Kozlowski and Winget (32) found that amounts of daily shrinking of tree stems in Wisconsin varied greatly during the summer, with small amounts occurring early in the growing season, followed by increased shrinkage in midseason, and greatly decreased shrinkage in late summer after transpiration had depleted the soil and tree reserves of water.

In addition to reversible diurnal stem shrinkage, seasonal shrinkage of stems occurs commonly during droughts. The radial decrease of stems during droughts often exceeds the amount of radial increase as a result of cambial growth during the same period. For example, many large white pine (*Pinus strobus*) stems in New England showed net weekly radial decreases during the summer (4). Dimock (11) reported that Douglas fir (*Pseudotsuga menziesii*) stems

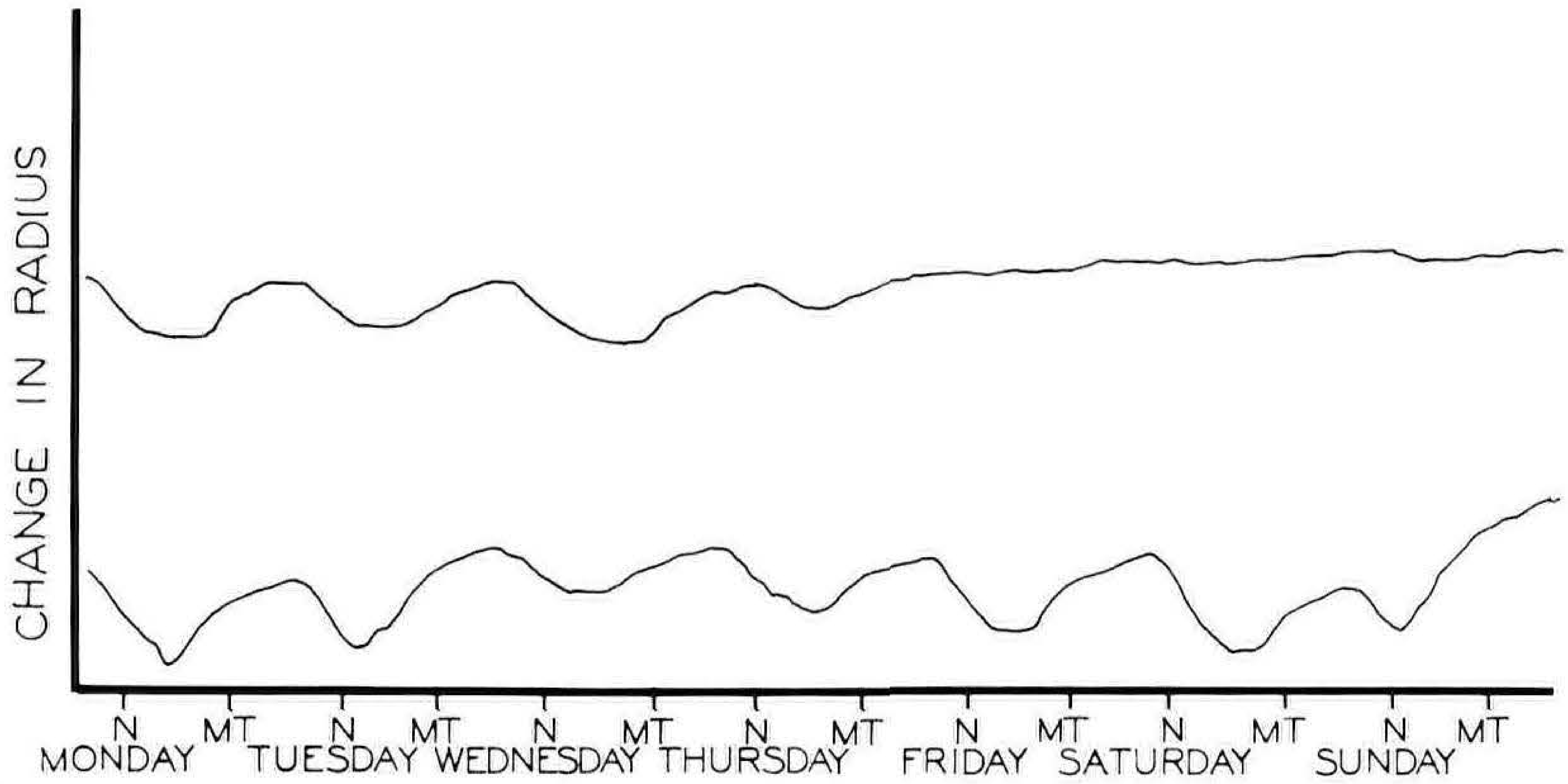

Fig. 1.

Dendrograph record showing shrinkage of red pine (*Pinus resinosa*) stems in the afternoon followed by expansion during the night. The upper curve is for July 10-17 and the lower curve for August 21-28. Note lack of stem shrinkage and expansion during the latter part of the week (upper curve) when cloudy and rainy weather occurred. From Kozlowski (25).

shrank consistently during a 6-week period in the summer. Buell, Small, and Monk (5) demonstrated that during a severe drought in New Jersey in August of 1957 tree stems shrank so much that their diameters were smaller than they were before the growing season started. When internal water balance was finally restored by rains in December the tree stems expanded rapidly. Kozlowski, Winget, and Torrie (33) recorded marked swelling of tree stems on each day following a rain during the summer.

EXPANSION AND CONTRACTION OF REPRODUCTIVE TISSUES

There is considerable evidence of shrinkage of reproductive tissues during the day and expansion at night because of hydration changes (20, 21).Excessive transpirational losses of water in the afternoon create high water deficits in the leaves and water is extracted from the fruits. At night when stomates close the fruits tend to refill with water. Diurnal expansion and shrinkage of fruits have been reported for a variety of fruits including cherries, oranges, apples, plums, walnuts, pears, avocados, and acorns, as well as cones or strobili of gymnosperms (21). Our experiments showed that Montmorency cherry *(Prunus cerasus)* fruits that were in a mid-stage of development often shrank during the morning and afternoon and they expanded beginning in late afternoon and continuing into the night (Fig. 2). The time of beginning as well as the amount and duration of dial shrinkage of cherry fruits varied with the stage of fruit development, soil moisture availability, weather, and degree of internal water stress in the tree (23).

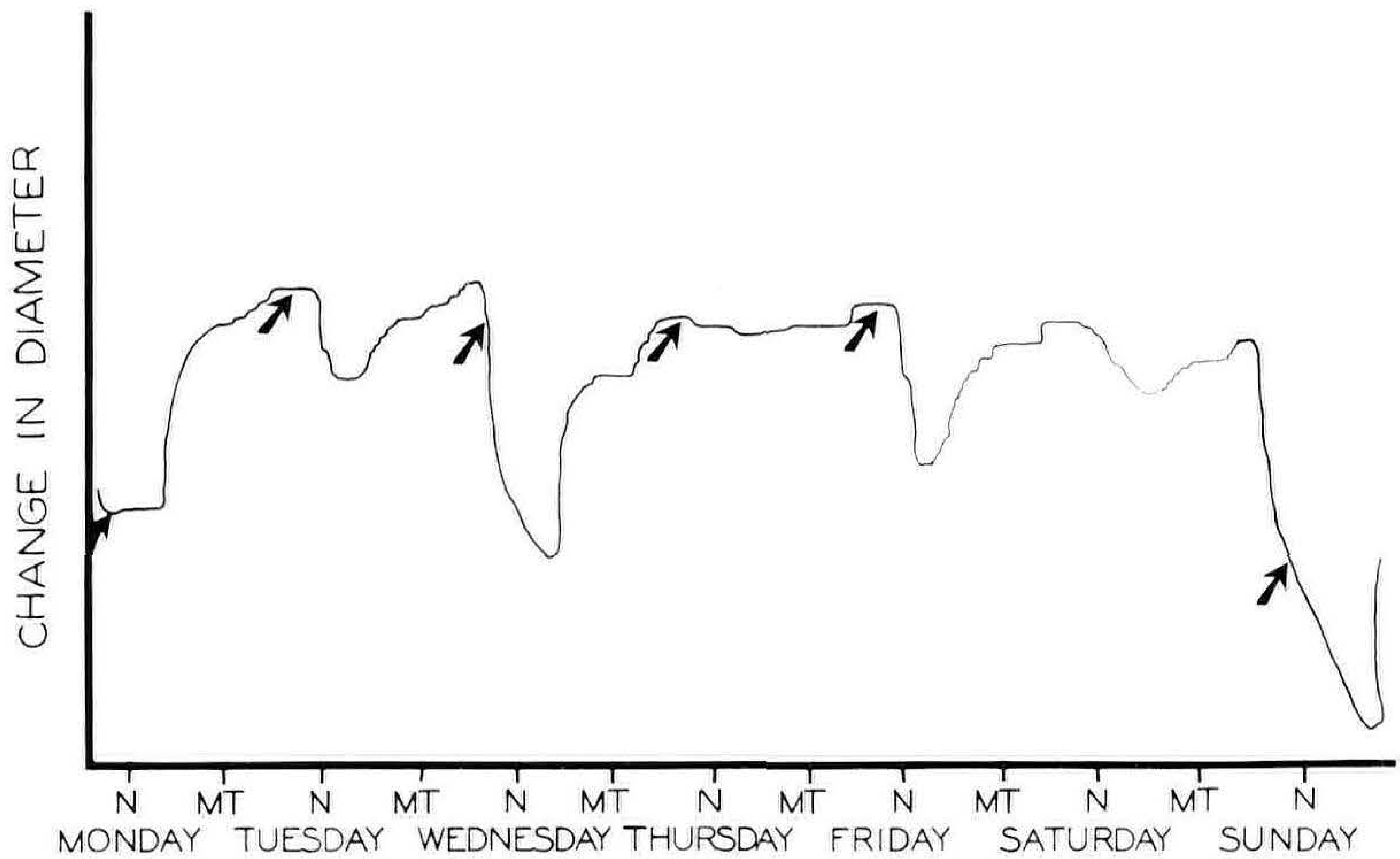

Fig. 2.

Recurrent daily shrinkage and expansion of fruits of Montmorency cherry *(Prunus cerasus)* as a result of changes in internal water balance. The arrows indicate time of irrigation. From Kozlowski (25).

Even when the soil was well-watered leaf thickness of Calamondin orange *(Citrus nitus)* began to decrease around sunrise when stomata opened and transpiration began. The fruit, however, did not begin to contract until about 1.5 hours after sunrise. Transpiration for about 1.5 hours apparently resulted in a water potential gradient from the fruit to leaves and water was translocated from the fruit along a free energy gradient (29). Klepper (16) found that such a gradient existed between fruits and leaves of pear trees. During droughts daily shrinkage of fruits and leaves continued until later in the day than when trees were well-irrigated.

Bartholomew (3) showed that during the afternoon of a hot, dry day lemons attached to trees shrank, but they expanded at night. Lemons attached to the tree lost a third more water than detached ones, emphasizing that attached lemons were a water-reservoir for other tissues. The drier the soil became the greater was the amount of water withdrawn from the fruits. Other evidence indicates tthat fruits act as water reservoirs in plants. For example, shoots pruned from plants bearing fruits do not wilt as rapidly as non-bearing shoots. Also fruits on pruned-off branches usually soften faster than fruits picked off the tree (23).

The cones of gymnosperms also undergo periodic water deficits, with the amount of diurnal shrinkage varying with the stage of cone development. Early in their development cones of white spruce *(Picea glauca)*, red pine *(Pinus resinosa), and jack pine (Pinus banksiana)* exhibited a predominantly stepwise increase in diameter with little or no midday shrinkage. After the major surge of early-season cone growth was completed, the cones showed recurrent shrinkage during the day and expansion at night. Maturing cones showed progressive overall shrinkage prior to opening. Percentage moisture of maturing cones decreased markedly in late summer (7, 10).

WATER RELATIONS OF TRANSPLANTS

Undoubtedly the most important cause of reduced growth or death of transplants is desiccation resulting from excessive transpiration and reduced absorption of water. Transplants undergo a massive physiological shock, because their uprooting and subsequent handling in a barerooted condition may cause critical drying. Even after plants are reset in the ground, excessive water loss occurs since roots grow often too slowly to absorb enough water to keep up with transpirational losses (34, 36). Trees which survive transplanting often exhibit reduced growth long afterward (24). For example, leader growth of white spruce was reduced by half in the first year after replanting. Furthermore, growth of some trees was reduced for as much as ten years following transplanting (39).

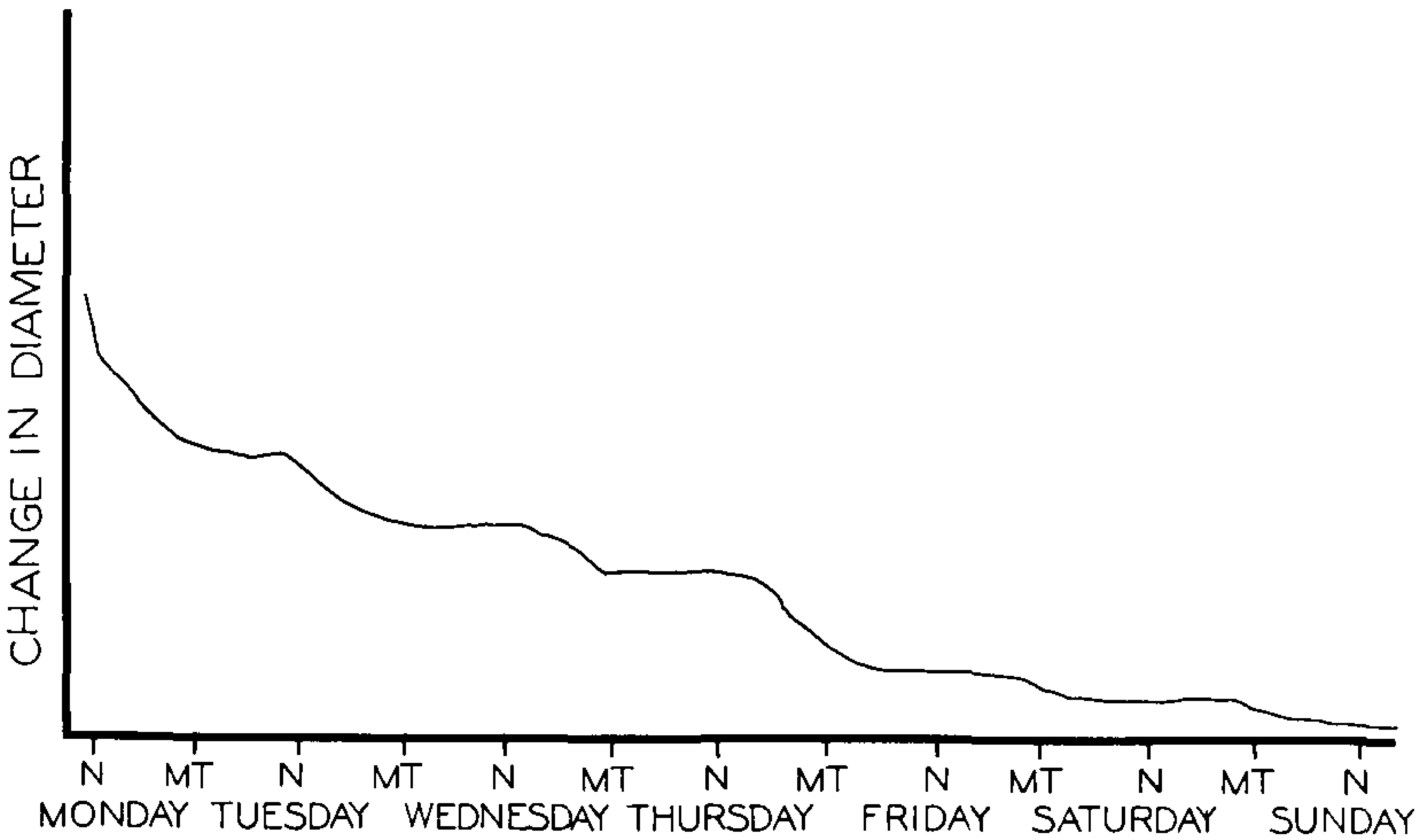

Fig. 3.
Progressive stem shrinkage resulting from excessive water loss from a young red pine (*Pinus resinosa*) tree during the first week after transplanting. From Kozlowski (25).

A very small percentage of trees removed from the nursery will rapidly restore a favorable internal water balance on outplanting. Actually, many transplants undergo very severe water deficits from the time they are lifted from the nursery until their roots become reestablished after planting. This takes a long time. Transpiration continues meanwhile and shoots may develop very severe water stresses. Research by Watanabe (47) in Japan showed that moisture content of leaves of many transplanted one-year-old camphor *(Cinnamomum camphora)* seedlings often dropped to 30 per cent of that of control seedlings.

Our experiments confirmed development of severe water deficits in trees following transplanting. Even though soil moisture was maintained in the readily available range, many transplanted trees lost large amounts of water and stem diameters decreased each day (Fig. 3) (22). This indicated that transpirational losses repeatedly exceeded absorption rates, emphasizing the harmful effects of disrupting the soil-plant-air continuum during transplanting. Extreme variability of stem shrinkage among transplants pointed up the uncertainty of early reestablishment of individual trees. Such variations in reestablishment usually are related to differences in internal water deficits which often are due to differences in root-shoot balance of seedlings, variations in root regenerating potential, and amount of damage to fine roots in transplanting.

The capacity of transplants to resume root growth rapidly often is critical to survival. Capillary movement of water from wet to dry regions in soils at or below field capacity is slow. When there is little or no capillary water movement toward roots, continuous root extension becomes essential for absorption of enough water to sustain growth (37). As Kramer (34) stated, the water in the mass of soil into which roots do not grow is essentially unavailable to plants. This means that plants with an inherent capacity to develop rapidly growing root systems are most likely to maintain a favorable water balance after transplanting.

If the root surface is not adequate to supply transpirational losses, internal water deficits are likely to develop. Reduction of the size of the root system relative to size of the shoot by fertilizers, eradicants, mechanical injury, diseases, or insects often causes severe water deficits in the top.

CONTROL OF WATER BALANCE

Plants have three basic means for controlling their internal water balance — absorption, transpiration, and internal redistribution. A favorable internal water balance is fostered by high absorption and low transpiration rates. Absorption of water can be promoted by keeping soil moisture supplies readily available. Although this seems to be widely understood it too often is neglected in practice, especially following transplanting. Much apparent drought resistance is traceable to deep and branched root systems of plants. Hence, some plant breeders are giving attention to development of seedlings with deeply penetrating and profusely branching root systems.

Allen (1) demonstrated that most outplanted longleaf pine *(Pinus palustris)* trees died simply because they lost water faster than their recently disturbed and damaged roots could supply it. Reducing the amount of needle surface by clipping affected the top-root balance and decreased transpiration. Average increases in survival of transplants following clipping of needles varied from 10 to 30 percent, and sometimes exceeded 50 percent.

Plant propagators can do much to insure that transplants do not desiccate to critical levels. Use of polythene packaging has been helpful in conserving moisture of planting stock (12). It should be remembered that exposure of nursery stock to drying for even short periods of time may have serious effects on their growth and survival, but this varies with species and condition of the plants at the time they are exposed (29). In one experiment, exposure of Douglas-fir nursery stock for as little as 4 minutes affected survival (13). In another experiment Hermann (14) exposed two-year-old Douglas-fir plants at 90 degrees F and 30 percent relative humidity for periods up to 120 minutes. Survival by November of the year of field planting decreased with each added length of exposure. Critical limits of exposure varied with the physiological condition of the nursery stock. Whereas seedlings lifted in the autumn could not survive more than a few minutes of exposure, those lifted in the winter could survive exposure up to 30 minutes. These differences appeared to be related to capacity for root regeneration. Prolonged storage of nursery stock also increased susceptibility to exposure. Even if long exposures did not reduce survival, they caused slow growth of transplants. Thus the importance of keeping exposure of nursery stock to a minimum during transplanting was demonstrated.

Much attention is being given to influencing internal water balance of plants by controlling transpirational water loss. The benefits of preventing or reducing transpirational losses of cuttings by water mists are well known to plant propagators and will not be discussed further. Attention has also been given by plant breeders to producing plants with thick cutin and very responsive stomata which will conserve water during droughts. Reducing energy absorption by modifying leaf color or leaf arrangement may also be helpful.

There is a great deal of interest in maintaining a favorable water balance in plants by use of antitranspirants. Over the years scores of compounds have been applied, including oils, plastic films, wax emulsions, and metabolic inhibitors. The results have been variable. Film type antitranspirants reduced transpiration effectively in some cases but not others. Many leaf coatings which physically blocked stomata, have been disappointing. Whereas they reduced transpiration, they also checked photosynthesis and eventually the treated plants died or their growth was greatly reduced.

The fairly recent discovery that antitranspirants which operate as metabolic inhibitors can prevent opening of stomata in the light and induce closure of already open stomates was a very important contribution (48, 49). Zelitch (48) observed that hydroxysulfonates effectively inhibited the enzyme glycolic oxidase and caused rapid changes in products formed during photosynthesis. When somewhat wilted plants were supplied with such an inhibitor of glycolic oxidase, the rate of transpiration decreased and the leaves became turgid faster than did leaves of control plants. The metabolic antitranspirant appeared to influence the osmotic pressure of guard cells and thus controlled stomatal aperture. Zelitch and Waggoner (50, 51) reported that phenylmercuric acetate sprayed on leaves at concentrations of 10^{-4} M caused stomates to close for about 2 weeks. In our laboratory

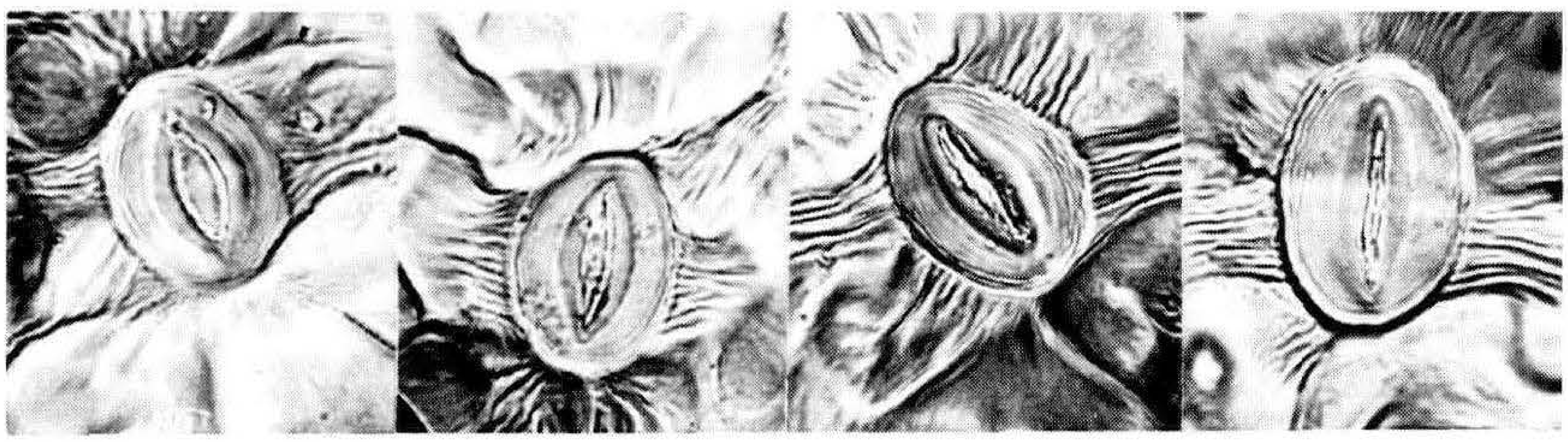

Fig. 4.
Stages *(left to right)* in stomatal closure of white birch *(Betula papyrifera)* leaves following treatment with phenylmercuric acetate. From Waisel, Borger, and Kozlowski (46).

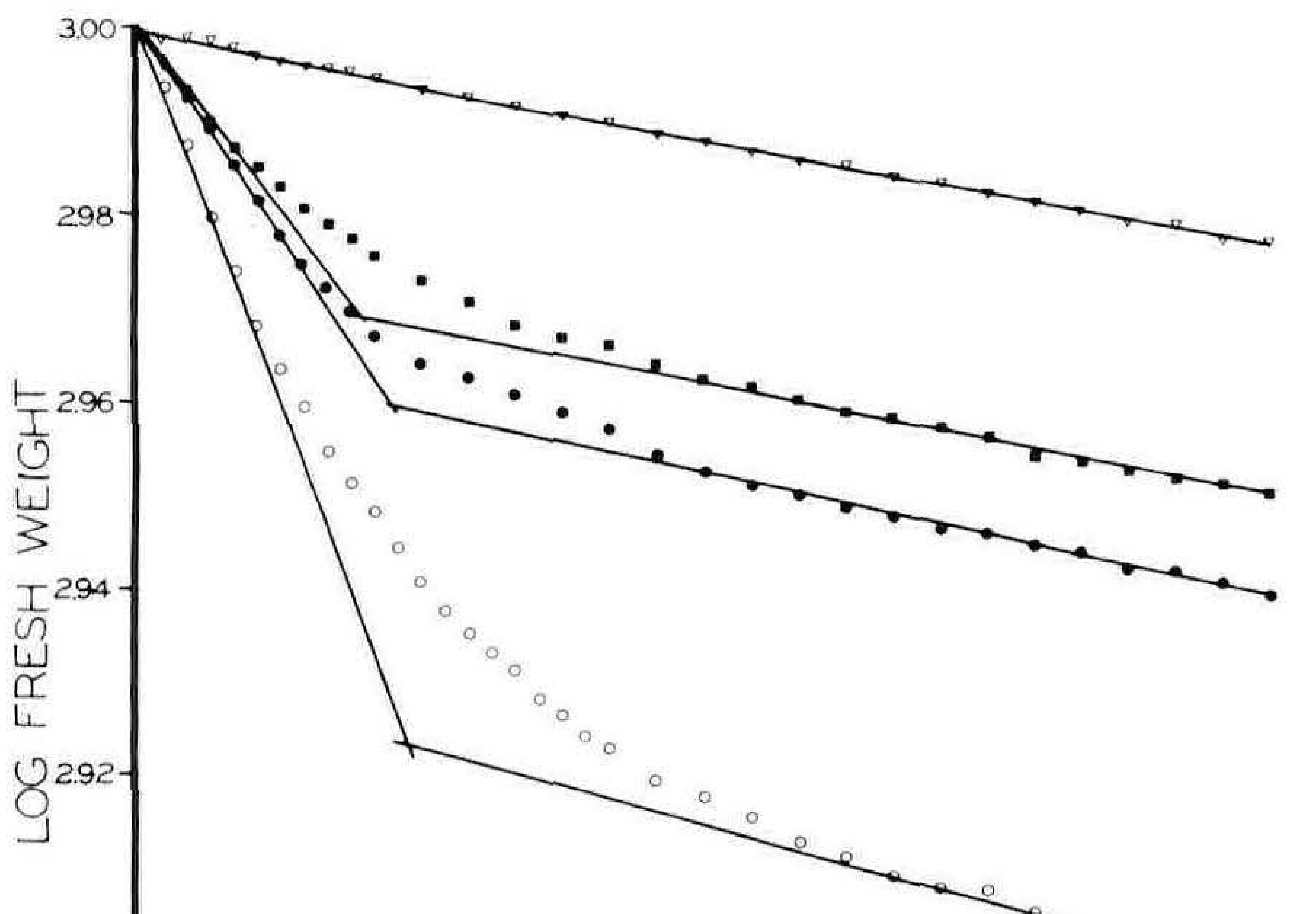

Fig. 5.
Effect of phenylmercuric acetate (PMA) on stomatal closure as shown by transpiration-decline curves of treated and untreated leaves of white birch *(Betula papyrifera)*. (Δ — 10^{-3} M PMA; ■ — 10^{-4} M PMA; ● — 10^{-5} M PMA; 0 — control. From Waisel, Borger, and Kozlowski (46).

we have also been able to induce stomatal closure of white birch *(Betula papyrifera)* leaves with phenylmercuric acetate sprays (4, 5). Although these results are exciting I cannot reemphasize too strongly that, because of toxic side effects, we need to do much more research with these metabolic antitranspirants. We observed for example that after leaves of white ash *(Fraxinus americana)* were dipped into alkenyl or decenylsuccinic acid (DSA) the efficiency of the cutinized layer of leaves in preventing water loss was decreased (30). We also found that sprays of DSA at concentrations of 1×10^{-1} M or greater applied to red pine trees in the summer, injured the leaves and adversely affected late summer development of buds. Shoot growth in the year after application of DSA was adversely affected (31). Thus the problems of dosages and kinds of chemicals to use are many. Extreme caution in the use of metabolic antitranspirants, in our present stage of knowledge, seems to be in order. Nevertheless, because the stakes are so high and some progress has been made in bringing about stomatal closure by metabolic inhibitors, we should continue research along these lines.

DROUGHT RESISTANCE

Drought resistance of plants depends on their capacity to endure dehydration or to prevent it. Very great desiccation resistance is found in nearly all the main groups of lower plants. In contrast, very few species of higher plants can withstand water loss at least below 50 percent of the saturation water content without injury or death.

Plants have many different structural features which contribute to drought tolerance and it seems futile to seek a single cause in any one species (20). Contributing adaptations may be found in roots, stems, or leaves. Plant survival in xeric habitats often bears a close relation to depth and spread of root systems. Whereas shallow-rooted plants often show marked damage during dry periods those with unusually deep roots are drought-tolerant. Reduction of the transpiring surface by leaf abscission during the dry season is another effective adaptation to drought. This is more important in angiosperms than gymnosperms, and is considered the most important factor in water economy and survival of desert plants of the Near East. In that region larger winter leaves abscise in summer and are replaced by smaller ones. The total reduction in leaf dry weight may be as high as 85 percent. Even in trees in a leafless state, some transpiration occurs through twigs, branches, and buds. Therefore, slow water absorption is necessary in leafless plants (28).

Another factor in drought tolerance is capacity for rapid stomatal closure during droughts. After stomatal closure occurs, cuticular control of transpiration becomes very important. Some species lose almost no water through the epidermis whereas others lose large amounts and therefore have little resistance to drought (40). In some species drought resistance often is vested in more than one structural feature in the same plant. In Brazil, for example, transpiration of certain trees and shrubs is greatly reduced by stomatal closure during early phases of drought, but as drought severity increases, leaf abscission follows (20).

Certain plants are able to conserve water by rolling of their leaves. In some grasses, with thickened epidermis walls reinforced by a ring of fibers and few stomata sunken in grooves, leaf rolling is very effective in preventing water loss. Such grasses, *(Stipa spp.)*, in the Mediterranean region reduced transpiration by 60 percent through rolling of their leaves. It should be emphasized also that in many plants leaf rolling occurs at high water deficits only and the leaf may die before the mechanism can prove helpful.

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BILL FLEMER: Thank you very much, Ted. As you can see this is a rather complex subject and one which is not conducive to being handled by a 10-minute talk.

Our next speaker is well known to us all — Dr. Sidney Waxman. Sid is going to discuss another aspect of the environment which we must manipulate in propagating plants, and that is light, its duration, its quality and its intensity; Sid.

LIGHT: DURATION, QUALITY, INTENSITY

SIDNEY WAXMAN

University of Connecticut
Storrs, Connecticut

Before discussing any of the various aspects of light or its influences on plant growth, it must first be understood that there are three basic factors: light intensity, light quality and light duration which all interact with each other. The overall influence on vegetative growth, flowering or some other response is the product of these three factors operating simultaneously. There are many other factors that may alter a plant's response to light; the most important one is temperature.

I. LIGHT INTENSITY

Jan Ingen-Housz, in articles dating back to 1779, was among the first to recognize that light was an important factor in photosynthesis. He reported on experiments in which he found that "plants purified the air only in light, whereas in the dark the same tissues made the air impure". He also noted that this process became more active with a higher intensity of light and that under heavily shaded conditions "the plants acted upon the air just as animals." In 1800 it was first considered by Jean Senebier, that the oxygen given off during photosynthesis came from the carbon dioxide absorbed by the plant. Senebier also reported, when using stained glass of various colors, that it was the red rays of the spectrum that were chiefly effective in the photosynthetic process.

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In 1804, Nicolas de Saussure, in his classic work "Chemical Researches on Plants" showed that water was fixed in the plant at the same time as the carbon and that this resulted in an increase in the plant's weight (7). He suggested that the process was probably of some nutritional value to the plant. More recently, radioactive isotope techniques have shown that all the oxygen released in photosynthesis is derived from the water molecule. It took a long time for the early botanists to recognize the significance of photosynthesis. This was probably due, in part, to their lack of interest in or knowledge of chemistry and, in part, to the great emphasis that was then placed on the naming and classification of plants.

One of the first to recognize that photosynthesis was a fixing of light energy was Robert Mayer who reported in 1845 that "plants form a container in which the fixed immaterial rays of the sun . . . . . . are stored" (33).

Over the years it has become apparent that the photosynthetic process is a highly complicated one and that it is the primary source of all organic substances.

In rooting cuttings we are concerned with providing an environment that will keep them in a healthy condition until they are lined out. The early propagator needed considerable experience and knowledge in the area of plant growth to furnish such an environment. He had to allow enough sunlight for photosynthesis and yet not so much that the cuttings wilted; a temperature high enough to encourage root initiation, but not high enough to cause an excessive rate of respiration and thus weaken the cutting, and a level of moisture both in the medium and in the air that would provide water as well as oxygen to the cutting. In creating this environment, he had to consider the levels of stored carbohydrates in the cutting, the stage of development at the time the cutting was taken, and the amount of leaf area it should retain. Another factor that would determine the amount of sunlight needed by a particular species is its ability to carry out photosynthesis under low light intensities. Some species such as the flowering dogwood, hemlock and American holly are able to photosynthesize at low intensities while others like the red pine, paper birch and sweet gum, are intolerant of low light intensities and would suffer if held there over a period of time (20).

The contemporary propagator, however, can enjoy the benefits of the mist system. He can now provide more than enough light to improve the carbohydrate content of the cutting without fear of its wilting. Hess demonstrated in 1956 that, under mist, cuttings propagated under full or nearly full sunlight actually accumulated seven times more sugars than cuttings placed under double glass and shaded (16).

The plastic tent, on the other hand, requires considerable shading to prevent excessively high temperatures from occurring. For rooting under plastic it may be wise to limit the species to those that are shade-loving, i.e., those that can carry on photosynthesis efficiently under relatively low intensities.

II. LIGHT DURATION

The duration of light or photoperiod has a considerable influence on the pattern of growth of a large number of trees and shrubs. It plays a part in the propagation of seed as well as of cuttings.

Although reports of daylength influencing plant growth were written as early as 1891 by Liberty Hyde Bailey (1) and 1914 by Klebs (19), it was not until the more comprehensive report of Garner and Allard in 1920 that it was clearly shown that the number of hours of light and darkness a plant received daily could actually effect its ability to flower (14). Since then there has been a considerable number of papers written on the various effects that photoperiodic treatment has on animals as well as plants.

Next to the regulation of flowering, the most dramatic influence daylength has is on the control of vegetative growth, i.e., on the induction and prevention of dormancy.

Long photoperiods prevent or delay the onset of dormancy and thereby encourage vegetative growth while short photoperiods either induce dormancy or merely slow down the rate of growth.

Several reports have been published in which various species were placed into certain categories according to how they responded to long and short photoperiods (4, 28, 40). For a great many species, short days will stop growth and long-days will produce continuous growth. Some of the species that fall into this category are *Weigela florida, Cornus florida, Cornus kousa, Betula paprifera, Acer palmatum,* and *Populus sp.*

Some species such as *Quercus borealis* (27, 40) and *Ilex opaca* (27) do not grow continuously but produce a series of flushes of growth under long photoperiods and under short photoperiods stop growth. However, not all photoperiod-sensitive species fall neatly within these categories. The European cranberry bush *(Viburnum opulus)* could fit into either the first or the second category depending on how long the long-day treatment was. If they were given 15 hours of light daily, they would grow in a series of flushes each of which would end with the development of a dormant terminal bud (40). The frequency of the development of the flushes would increase with the increase in the number of hours of light. The flushes occur more frequently under an 18-hour-day than under a 15-hour-day. Under continuous light, there are no obvious cycles of growth; no dormant terminal buds develop, and growth appears to be continuous (40). Such species as *Juniperus horizontalis* and *Thuga occidentalis* fall into a third category in which short photoperiods do not stop growth but reduce its rate. With these species, growth occurs under all photoperiods from 9 to 24 hours, but the greatest amount develops in the longest daylengths.

Although grouping various species into such categories is convenient, it is not accurate, There are many environmental factors which interact with the photoperiod and, consequently, could cause some confusion as to which category a particular species fits into.

It is not uncommon to hear of propagators, as well as researchers, who have experimented with photoperiodic treatments, and have come forth with different and sometimes conflicting results. The author, after having experimented with various light treatments on woody species for several years, all of which were carried out in greenhouses, decided to run a series of tests in the field. In the greenhouse, long photoperiods usually brought about spectacular increases in growth, while short photoperiods prevented it. Differences in growth between long-day and short-day-grown plants were sometimes tenfold after one year's treatment. In the field, however, there were hardly any differences in growth among the treatments. The plants given natural daylengths grew about as well as those given long-days. What happened was totally unexpected. The plants given light during the night were expected to continue growth long after the natural day plants became dormant, but they didn't because the night temperatures were very low. The mean night temperatures were from 50° to 60°F during the summer months of 1958 and 1959. There were no appreciable differences in growth even though the light treatments were continued through October, but there were differences in survival the following spring. Most of the species given continuous light or flashing light were injured or killed outright during the winter. The group that received natural daylengths had no serious winter damage. Apparently, the long-day treatments did have an effect on the plants, but the low temperatures that prevailed prevented their expression.

In another test, weigela plants were grown in four greenhouses having minimum night temperatures of 50°, 55°, 60°, and 65° F.There were considerable differences in the rates of growth among the groups of plants, all of which were illuminated with continuous light (Table 1). The weekly rate of growth at a minimum temperature of 65° F almost doubled the rate at 55° F.

Another factor that can be the cause of conflicting data is the origin of the species being tested. Vaartaja, in 1954, reported that he obtained differences in the growth of seedlings of *Alnus incana* (L.) under identical photoperiods because they came from two widely separated latitudes (34).

Table 1. Effect of temperature on the rate of growth of weigela exposed to continuous light.

Temperature[1] (degrees F.)	Growth (cm per week)	Number of leaves produced per week.
65	8.12	2.10
60	6.65	1.96
55	4.13	1.68
50	2.45	1.40

[1] Minimum night temperatures.

A. **Critical Daylength.** In determining a particular species' response to daylength, the question arises, what is its critical daylength? In other words, what is the demarcation line in time between a long-day and short-day? An experiment was conducted in which four groups of weigela plants, all in active growth while under continuous light, were transferred to photoperiods of 8, 12½, 13, and 13½ hours. The plants in the eight hour photoperiod produced two pairs of leaves and then became dormant after 18 days. It was easy to determine that the terminal was becoming dormant because the two uppermost leaves would always recurve at this stage. The plants in the 12½ hour photoperiod produced a third pair of leaves which recurved on the 21st day. In the 13 hour photoperiod four pairs of leaves developed, the last pair recurving on the 23rd day. The plants in this group, however, did not remain dormant because two additional pairs of leaves were produced, each of which recurved. By the 48th day the plants finally became dormant and remained so with the development of dormant terminal buds. The critical daylength for weigela probably is close to 13 hours, for at 13½ hours, leaf development continued long after the experiment was terminated. The fact that a weigela will stop growth in a 13 hour photoperiod and continue to grow in a 13½ hour photoperiod suggests that the plant can measure the length of day or night with an accuracy of 30 minutes or even less.

For most species subjected to various photoperiodic treatments, continuous light appears to be the most effective. Wareing, however, has demonstrated that the most effective daylength for *Pinus sylvestris* was 20 hours (35). He found that seedlings of this species grew taller under 20 hours of light, and four hours of dark than either 22 or 24 hours of light.

Long photoperiods can be provided in various ways:

1. Natural daylength plus artificial illumination to accumulate a total of approximately 14 hours or more followed by darkness for the remainder of the day.

2. Natural daylight followed by the dark period which is interrupted with two to four hours of light during its mid point, e.g. 10 pm until 2 am.

3. Natural daylight followed by the dark period which is continuously "flashlighted", i.e. illuminated with brief exposures of light throughout the night (42).

B. Rates of growth in long photoperiods. Many species can be grown continuously under long photoperiods in a greenhouse without the need for chilling temperatures to break the "rest period". *Cornus florida* (39), and *Betula paprifera* (unpublished), have been maintained in continuous growth for more than 18 months without having been chilled, The dogwoods during their most rapid period of growth grew at the rate of ⅜ inch daily, while the paper birches grew at a rate of ¾ inch per day. Seedlings of *Acer palmatum* were variable in their rates of growth. Some of the most rapidly growing ones maintained rates of ½ inch per day.

The pattern of growth was especially whip-like for the Japanese maple and the paper birch. Plants growing steadily over long periods of time at these rates usually require staking. Not all daylength-responsive species can be grown continuously, however. Some species will eventually set a dormant terminal bud after a certain period of growth. Wareing reported that seedlings of *Pinus sylvestris* and *Acer pseudoplatanus* responded well to long photoperiods but eventually formed terminal resting buds even while under continuous illumination (35).

Newly-germinated seedlings are relatively slow in their response to lights. The paper birch seedlings, for example, grew rapidly only after the plants were about 4 - 8 inches tall. Probably the young seedlings' food reserves were not sufficient to support a more rapid rate of growth.

C. Germination of seed. Another aspect of the photoperiodic influence on plant growth is the effect it has on the germination of seed. Ingen-Housz and Senebier, near the end of the 18th Century, wrote of the possible effect of light on seed germination (2). It has since been definitely proven that light does regulate the germination of many seeds. A paper published in 1908 by Kinzel records over 600 species of seed which were found to be light sensitive (18). Since then a considerable amount of work has been published mostly concerning the effect of light on the germination of seeds of herbaceous plants (6, 11, 12, 13). Relatively little research has dealt with the germination of ornamental trees and shrub seeds. Black and Wareing reported that *Betula pubescens* seeds could be germinated without chilling provided they were exposed to long photoperiods when held at a temperature of 59° F. At this temperature 95 percent of the seeds germinated in a 20-hour photoperiod, while only 30 percent germinated in an eight hour photoperiod (3). They might thereby be classified as long-day seed except that raising the temperature from 59° F to 68° F changed their response. At the higher temperature they germinated equally well in long or short photoperiods (3). Even a single exposure to light will cause them to germinate at a temperature of 68° F. If, on the other hand, the seeds are kept in darkness, germination will not occur unless the seed are first chilled for three to four weeks at 41° F (37).

The eastern hemlock also changes its critical photoperiod with changes in temperature. At 70° F the most effective photoperiod for germination was 8 to 12 hours, while at 80° F 16-hour photoperiods were most effective (32). Both the birch and the hemlock seed offer a good example of how temperature can interact with the photoperiod.

The germination of umbrella pine *(Sciadopitys verticillata)* differs from most other photoperiod-sensitive seed studied as of this date because it germinates most rapidly and at highest percentages in short photoperiods or darkness (40, 41).

D. Photoperiodic influence on the induction and breaking of dormancy and related phenomena. Long photoperiods can break dormancy in addition to preventing its onset. Many species that become dormant under natural conditions during the summer can be forced to renew growth by exposing them to long photoperiods. This can be accomplished provided there are functional leaves present (40).

Breaking dormancy in the autumn, however, would be very difficult because the buds would be in deep rest and would require a period of chilling temperatures before their rest could be broken. There are a few exceptions to this; some species in deep rest can be induced to renew growth without chilling. Wareing reported that unchilled buds of *Fagus sylvatica, Betula pubescens,* and *Larix decidua* could be induced to grow by exposing them to long-days (37). Bud-break of rhododendron also appears to be determined by the photoperiod (9).

The shortening daylength that occurs in late summer and fall is one of the most important environmental factors that bring about the induction of dormancy. Along with the stoppage of vegetative growth, short days have been found to bring about aging, fall coloration, and abscission of the foliage (15, 27, 29, 40). Daylength, too, has a strong influence on the growth of conifers. Long days have been reported to increase stem growth, needle length, and growth in diameter, i.e., increased development of early wood (22).

Winter hardening is another condition attributed to short days. Moshkov (25), in 1935, reported that artificial short photoperiods could bring about winter hardening provided it was done at a particular time. He reported that *Robinia pseudoacacia* of southern origin was regularly killed by early frosts in northern Russia unless it was given artificially short photoperiods. He found that 20 days of short-day treatment could increase hardiness considerably, provided they were given during July and August. In September, the 20 short-days were not effective because the 40° F temperatures that prevailed then were too low to permit a photoperiodic response (25). Irving and Lanphear recently reported that hardiness was induced in *Acer negundo, Viburnum plicatum* var. *tomentosum,* and *Weigela florida* by short photoperiods followed by low temperatures (17). They also found that hardiness could even be induced under long-days and natural fall temperatures if the leaves were first removed. This latter treatment, however, was not as effective as short days with leaves intact.

E. Effect on root initiation. Relatively little has been published concerning the effect of daylength on root initiation of cuttings. Moshkov and Kocherzhenko reported that long days caused an increase in both the speed and numbers of roots produced (26). The author found that the percentage rooting of *Salix blanda, Cornus florida* 'Rubra', and *Weigela florida* was similar in all photoperiods. However, the numbers of roots produced per rooted cutting were much larger under long-day than under short-day treatment (40). He also found that these differences occurred only on cuttings taken in the spring and early summer from actively growing shoots. Cuttings of *Cornus florida* taken late in September from dormant wood did not exhibit any differences in rooting percentage or in numbers of roots in either long or short photoperiods (40).

Lanphear and Meahl (21) made comparisons of the rooting of cuttings taken in the fall with cuttings taken during the winter. They reported that among the cuttings taken in the fall, the largest root systems developed on the cuttings given long photoperiods, while among those taken during the winter the largest root systems developed on the cuttings given short photoperiods. The species they experimented with were *Ilex opaca, Juniperus horizontalis* 'Plumosa' and *Rhododendron mucronatum.* Earlier, Snyder reported no differences in the rooting of *Taxus cuspidata* under long and short photoperiods on cuttings taken during November (3).

It appears that for some species rooting can be improved by long-day treatment if the cuttings are taken early in the season before the onset of dormancy. However, on cuttings taken during the winter, when the buds are at rest, long-day treatment may be wholly ineffective and even detrimental. Generally, species reported to exhibit improved rooting under long-days, in addition to those already mentioned are: *Rhododendron mucronulatum, Magnolia soulangeana* (40), *Camellia, Ilex crenata, Ilex glabra* (43), *Rhododendron caucasicum* 'Boule de Niege', *Rhododendron catawbiense* 'Album' (30). Species not affected by photoperiodic treatment are *Pieris japonica, Pyracantha coccinea* 'Lalandi', and *Buxus sempervirens* (40).

Another way in which the rooting of cuttings may be influenced although indirectly, by photoperiodic treatment, is by treating stock-plants before the cuttings are taken. Cuttings of *Cornus florida* 'Rubra' which were taken from stock plants that were given long photoperiods for 45 days had a rooting percentage and root number twice as great as that of cuttings taken from short-day-grown stock plants (40). Similar results were reported for *Salix undulata* which rooted 100 percent from long-day grown stock plants and 0 percent from 9-hour-day plants. The opposite response occurred in a different variety: *Salix pieroti* rooted best from short-day-grown stock plants, while *Salix babylonica* rooted best from stock plants grown under a 14-hour photoperiod (26).

It's apparent that much is to be learned in order to clarify the sometimes conflicting responses obtained in the rooting of cuttings under various photoperiodic treatments.

F. Applications of photoperiodic control. The various effects photoperiodic treatment has on growth suggest that there may be several ways in which it could be used as a tool to suit the needs of the propagator.

1) **Hastening the growing of seedlings.** The length of time required to produce seedlings large enough to line out could surely be shortened by subjecting them to long photoperiods. It would be practical to light those species that develop slowly and require a considerable period of time before they can be lined out. Rhododendron seedlings have been reported to make up to five spurts of growth during one year instead of the usual two.

Two propagators in Connecticut use lights from mid-winter through spring to hasten the growth of second year seedlings of rhododendron, deciduous azaleas, as well as leucothoe. The long photoperiod forces earlier bud-break and increases the amount of growth produced over unlighted seedlings.

2) **Increasing growth of rooted cuttings.**

Cuttings of deciduous species taken in the spring could benefit by an additional burst of growth after rooting to increase size and ensure survival the following spring.

A Rhode Island propagator has been using long photoperiods on deciduous azaleas to force the development of growth immediately after rooting to guarantee survival the following spring. Cuttings of Exbury hybrids taken at the end of May are rooted by late August at which time they are given long photoperiods until the end of September. The cuttings are lighted for 30 seconds every 6 minutes from nine in the evening until five the next morning. The cuttings then are over-wintered in frames held at a minimum temperature of 55° F.

Rooted rhododendron cuttings are given long photoperiods by two propagators, one in Pennsylvania and the other in Connecticut. Both place the rooted cuttings in cool temperatures for about one month after which they are given long photoperiods from January to April. Two, and occasionally three, bursts of growth are obtained by spring.

3) **Lighting of stock plants.**

Another application of photoperiodic treatment is the lighting of stockplants to keep them actively growing and producing new stems and leaves. This would be of value if one wanted to build up a large number of plants from a limited number of stockplants. The few stockplants being lighted have the potential to be a continuous source of cuttings. In a paper previously presented to the Society it was shown that within a two-year period, it was possible to produce 1200 dwarf arborvitae starting with only two cuttings (42). The original cuttings after having been rooted were maintained in continuous growth under long photoperiods. In a relatively short period of time the cuttings developed enough branches to provide additional cuttings which were then rooted. Throughout the two years, cuttings were constantly taken from rooted cuttings all the while being exposed to long photoperiods.

This species was well suited for this type of treatment because it grew rapidly and rooted easily under the long photoperiods.

III. WAVELENGTH

The major processes that go on in green plants are directly dependent on light. The sun provides a fantastic range of wavelengths, but of this wide range only a small portion is used by the plants. Within this narrow range are wavelengths of red, orange, yellow, green, blue and violet which, together, appear to us as white light. However, because of the pigments present in green leaves, plants have the ability to differentiate between the various wavelengths and can be highly selective in which ones they absorb. Once the pigments absorb their preferred bands, they are then able to carry out their particular role in the growth of the plant.

The relation between light and the rate of plant growth is extremely complex and is by no means dominated by its effect on photosynthesis. There are other light-dependent processes that play a part by using the substances produced in photosynthesis to direct the pattern of plant growth. Briefly, certain wavelengths are known to be absorbed by certain pigments which in turn activate specific processes. The wavelengths in the blue region are effective in phototropism. These are the wavelengths that cause plants to bend or grow towards light. If a series of plants are placed in black boxes and each is illuminated with a different color of light from one side only, the plants would bend and grow toward blue light, but would not be affected by red light. The pigments involved here are either carotenoids or flavins or both (23). Another pair of pigments called phytochromes absorb the longer wavelengths of red and — what is referred to as — far red. These two pigments which are close together in the spectrum oppose each other in their effects on plant growth. The germination of seed as well as the various photoperiodic responses of plants are mediated through these pigments.

A third group of pigments, the chlorophylls and the accessory carotenoid pigments are effective in photosynthesis (23). All the wavelengths that make up the visible part of the spectrum; the red, orange, yellow, green, and blue bands are all absorbed and used as sources of energy for the manufacture of sugars. Although blue and red light are more effective than yellow, orange and green, the latter ones do contribute a good share of the energy absorbed. There is no reason why fluorescent light manufacturers should concentrate on the removal of these wavelengths from lamps to be used for the growing of plants. The variability among species in absorption of the different wavelengths is so great, that it is doubtful those fluorescent lamps emitting certain portions of the spectrum will prove more beneficial to plant growth than those having all the visible bands.

Until there is new evidence that the spectral energy of the sun can be improved upon, it appears that the overall growth of all species would, under artificial light, suffer the least if the fluorescent light sources were similar to the sun in their spectral distribution.

IV. SUMMARY

We are learning more and more about the control daylength has on plant growth. We know that not all photoperiod-sensitive species react as uniformly as we would prefer. The different responses can be attributed to the genetic background of the species. Over the centuries, through natural selection, plants have become adapted to the peculiarities of the environment in which they originated. Many of the trees and shrubs we now propagate have been introduced from different latitudes and elevations throughout the world and therefore it is not surprising that their reactions to daylength and temperature are often different from one another.

All this leads to the fact that we have much to learn, not only about plants in general, but about their specific responses. We have to learn more about the mechanisms within plants that operate for their survival in order to know how to control their growth.

In order to obtain predictable patterns of growth, it would be necessary to reduce fluctuations of moisture, temperature and light. Controlling such factors in a greenhouse is extremely difficult but not so in an insulated building. A propagation house, well insulated and with an artificial source of light would enable the propagator to better manage the environment around the cuttings. Regulation of the amount of light would result in more uniform levels of temperature and moisture in the air, the cuttings, and the medium.

The problems that now exist in the use of an insulated structure are: (1) the cost of providing a high intensity of light for those species that require it and (2), the build-up of high temperatures that would occur as a result. The development of a more efficient lamp, one which would emit more energy as light and less as heat, would solve this problem.

In the not-too-distant future, problems in propagating woody plants by tissue culture may be solved. If and when this does occur, there will, no doubt, be specialists who will do custom propagation, producing large numbers of clonal material on order as it is now being done for the orchid growers.

In conclusion, I believe that future developments will lead to a more precise control of the environment which, along with the success of the tissue culture technique, will bring plant propagation to a point where it is dependable and predictable.

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BILL FLEMER: Thank you, Sid. It should be immediately apparent from this very interesting presentation that there are practical effects which can be obtained by applying to plant propagation the results of theoretical investigations of the effects of light duration and quality.

Our next speaker is better known to the Eastern Region members as an author than as a lecturer because he is the co-author of a very excéllent text on plant propagation. It gives me a great deal of pleasure to present to you Dr. Dale Kester, who will give us some of his observations and conclusions on the effects of temperature in plant propagation.

TEMPERATURE AND PLANT PROPAGATION

DALE E. KESTER
Department of Pomology
University of California
Davis, California

The pattern of temperature exposure resulting from radiation from the sun to the earth is perhaps the most significant environmental factor that controls plant growth and development and thereby determines what kinds of plants grow and where they grow (26). Likewise, control of temperature is one of the most important tools of the plant propagator. Or perhaps, we could better say that lack of temperature control can be the major limiting factor for plant propagation and subsequent growth of the plant for whatever use we make of it.

Temperature control is achieved by propagators in many ways, utilizing either the natural environment, artificial environments, or both. We can achieve control by locating our operations where the natural temperature regime is favorable and grow plants adapted to that location. We time our operations during the year when proper temperatures are available. We use many artificial methods to control temperature for both heating and cooling: greenhouses, phytotrons, coldframes, hotbeds, bottom heat, refrigerators, mulches, shading, mist systems, sprinkling, reflective materials, such as whitewash, etc.

To exploit these potentials of temperature control we need to know a great deal about engineering aspects of heat production, heat transfer and heat loss. We also should know something about the effects of temperature on the basic biology of the plant. As practical propagators, we need, most of all, to know the temperature requirements of particular plants and plant processes.

PLANT ADAPTATION

My purpose is to discuss some effects of temperature on the basic biological processes of plants as a background for more detailed discussions concerning individual kinds of plants and procedures that will be covered in other parts of these meetings. First, let us recognize

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PLANT ADAPTATION

My purpose is to discuss some effects of temperature on the basic biological processes of plants as a background for more detailed discussions concerning individual kinds of plants and procedures that will be covered in other parts of these meetings. First, let us recognize that specific growth requirements of plants have resulted from evolution through many generations in a natural environment where such characteristics contributed to survival. Such requirements become more or less fixed into the genetic system and are passed along to the offspring even when shifted to a new environment and whether or not the plant now needs them. When we transplant such plants to new areas and subject them to the demands of modern horticultural production, such requirements may be limiting. What can happen and, in fact, has happened is that through the same process of selective evolution as occurs in nature, plants adapted to the requirements of culture systems have gradually developed. This is really the essence of plant breeding, a procedure which has been exploited with varying degrees of success.

On what are some of the temperature requirements based? The most obvious is the **annual growth cycles** to which plants are subjected in various parts of the world. Compare, for instance: (a) Belem, Brazil, with a hot tropical area where the temperature stays around 80° F through 12 months of the year; (b) San Francisco, California, having a marine climate with cool (55—60° F) but relatively constant temperatures throughout the year; (c) Davis, California, with a distinct seasonal cycle of hot summers and moderately cool winters, where temperatures go below freezing but rarely less than 15° F; and (d) Ames, Iowa with a similar cycle but where winter temperatures can go as low as —30° F. Quite different kinds of plants grow naturally in each of these areas and, if one takes plants from one area to another, quite different kinds of temperature controls may have to be provided for successful culture.

Superimposed upon the annual cycle is the **daily diurnal fluctuation** in temperature from day to night. Knowledge of such requirements has become widely recognized both through scientific experiments (25) and also through plant growing experiences (20). These daily fluctuations are not only important for optimum growth but can be critical for survival. The lower or night temperature is very often (not always) the essential factor. Recommended night temperatures for indoor culture (20) range from 50° F for such plants as carnations and snapdragons; 60° F for roses and chrysanthemums; and about 70° F for warm season foliage plants. Daytime temperatures would be about 10° F higher. These day-night cycles are also important in locating outdoor production areas (16).

In addition to these two basic temperature cycles, a plant can be subjected to **localized microclimatic** conditions. The temperature of the top of the plant exposed to the sun during the day can be considerably higher than the surrounding air depending upon the degree of shading and amount of exposure; likewise the temperature of the same plant during the night can be considerably lower (due to radiation) than that of the surrounding air, depending again upon the degree of exposure. The temperature of the shoot system in both situations may differ considerably from the temperature of the root system, depending upon the depth grown into the soil and the type and depth of cover on the surface of the soil (26).

Let us consider some of the ways temperature affects some basic plant processes.

RESPIRATION AND PHOTOSYNTHESIS

During respiration, energy storing food materials are broken down to CO_2 and water through a series of chemical reactions and metabolic cycles mediated by enzymes (18). At low temperatures, the respiration rate is very low. We reduce temperature to near or below freezing to preserve dormant plants in storage for long periods of time. As the temperature is raised, respiration goes up at an increasing rate. As temperatures rise to 90° to 100° F, respiration becomes very rapid, materials are used at a rapid rate and the plant can literally "burn up". As temperatures get higher, into the range of 104° to 120° F, an upper limit is reached, cells are injured, and can be killed. There is a time factor associated with high temperatures. The plant may sustain these high respiration rates for only short periods; after a period of time the rate drops; the higher the temperature, the shorter the time.

This type of exponential response curve is typical of many found in the plant since many of the biological processes within plants are chemical reactions, controlled by enzymes. We can say that for respiration, the Q_{10} is 2 or higher. This means that for every 10 degree C rise in temperature, the reaction increases 2 or more times.

In contrast there are other processes, such as the diffusion of CO_2 into a leaf, photochemical light reactions, dissolving materials into water, etc., that are physical rather than chemical. These have a straight line relationship rather than exponential and have a Q_{10} of 1 to 2. At lower temperatures, enzymatic reactions tend to be limiting, whereas at higher temperatures, these physical processes are limiting, even though enzyme activity can be very high.

PHOTOSYNTHESIS

Light energy, plus water, plus carbon dioxide are converted into chemical products (sugars, proteins, fats, etc.) which are the raw materials to provide energy to run the machinery of the plant, build new parts, or are stored for future use. There are two kinds of reactions. First is a photochemical reaction where light energy is converted into chemical energy. This is a physical reaction with a Q_{10} about 1.4. Secondly, there is a "dark" reaction where this chemical energy is converted into various chemical products the plant uses. This is a typical chemical reaction with a Q_{10} of better than 2. At low temperatures the "dark" reaction is limiting and photosynthesis is low. At higher temperatures photosynthesis tends to level off because light becomes limiting. If one attempts to increase photosynthesis by the use of higher temperatures he must also increase light and, perhaps, the CO_2 supply. If light is reduced by shading at these higher temperatures, photosynthesis may be drastically decreased.

The net effect of temperature on the intact plant, however, results from the balance between photosynthesis and respiration. If respiration loss is greater than that gained through photosynthesis the plant will decrease in weight and may eventually die if kept for long periods at continuously high temperatures. The plant should have plenty of light, an efficient, healthy, leaf system, and adequate food reserves before being subjected to such high temperatures. The optimum temperature varies with different kinds of plants from 20°—35° C(68°—86° F).

This principle can be applied to the contrast between the mist systems which are so widely used today and the closed frame system formerly used (10, 11). An enclosed frame system, which is primarily designed to prevent water loss, is associated with low light intensity and high temperature and results in loss of weight in the plant and often poor rooting. Conditions of this system probably mean that a cutting made from a mature, semi-hardened shoot with adequate food reserves would have a better chance of surviving than a cutting that is more succulent and younger in age although with, perhaps, better rooting potential. In contrast, mist systems produce evaporative cooling that can reduce temperatures to 70°or 80° F in full sun and high light intensities, A wider variety of plant materials can be taken at various stages of maturity for optimum rooting with varying amounts of reserve materials and can not only be rooted but can increase in weight during the rooting period.

A second application is the preparation and hardening-off of plants for transplanting. Moderate temperatures with adequate light should provide maximum food reserves.

In either case, we also must recognize that the optimum temperature conditions will vary with different plants.

GROWTH-DORMANCY REACTION

Growth, by which I mean a permanent increase in size, length, or weight, is very responsive to temperature. Growth processes are largely biochemical, so that the temperature response curve is something like the photosynthesis-respiration curve. Figure 1 shows a temperature response curve for growth of an apricot fruit. The same curve could just as well be used for germination, root growth, shoot growth, or callus production. There is: (a) a minimum temperature where no growth takes place or is so slow that it isn't practical to measure; and (b) a rapidly increasing response to temperature, in that growth speeds up drastically. There is an optimum temperature where growth is most rapid and maximum response (for example germination) takes place. This is followed (c) by inhibiting effects that may decrease the rate or reduce the response. If the temperature is too high, of course, injury occurs and the entire system breaks down. The most favorable temperatures for growth, however, seem to be considerably lower than the point where injury occurs.

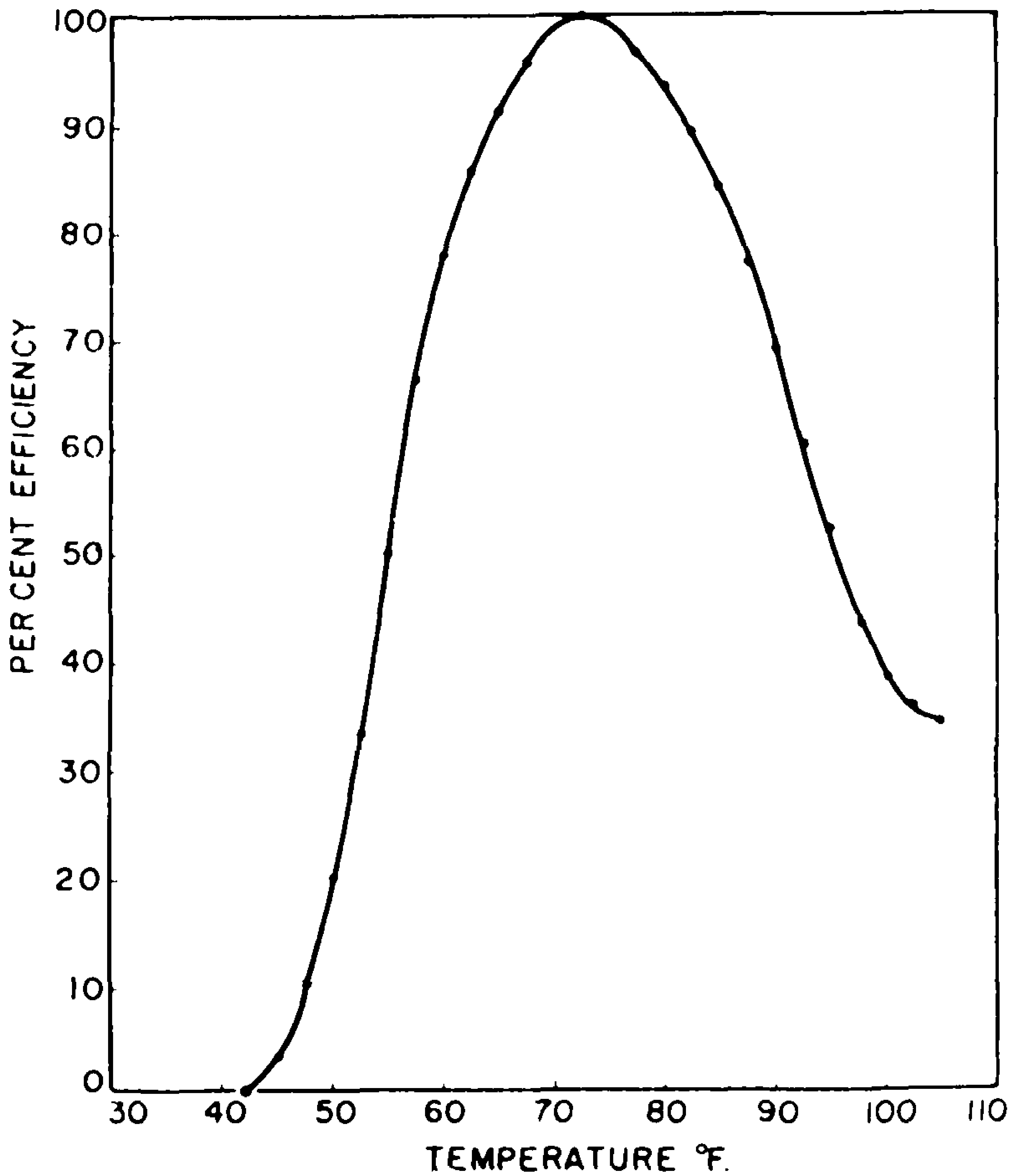

Fig. 1.
The effect of temperature upon growth of an apricot fruit is typical of temperature response curves for many growth phenomenon. From Brown (2).

There is much experimental data to show that the most favorable temperature range for root growth and root initiation in many plants is about 70° F, or slightly higher (4, 12, 13, 19, 23). (Fig. 2). Below this temperature, root growth is reduced and the rate lessened. If temperatures go above 75° or 80° F, at least for many plants, some inhibition and root injury can result.

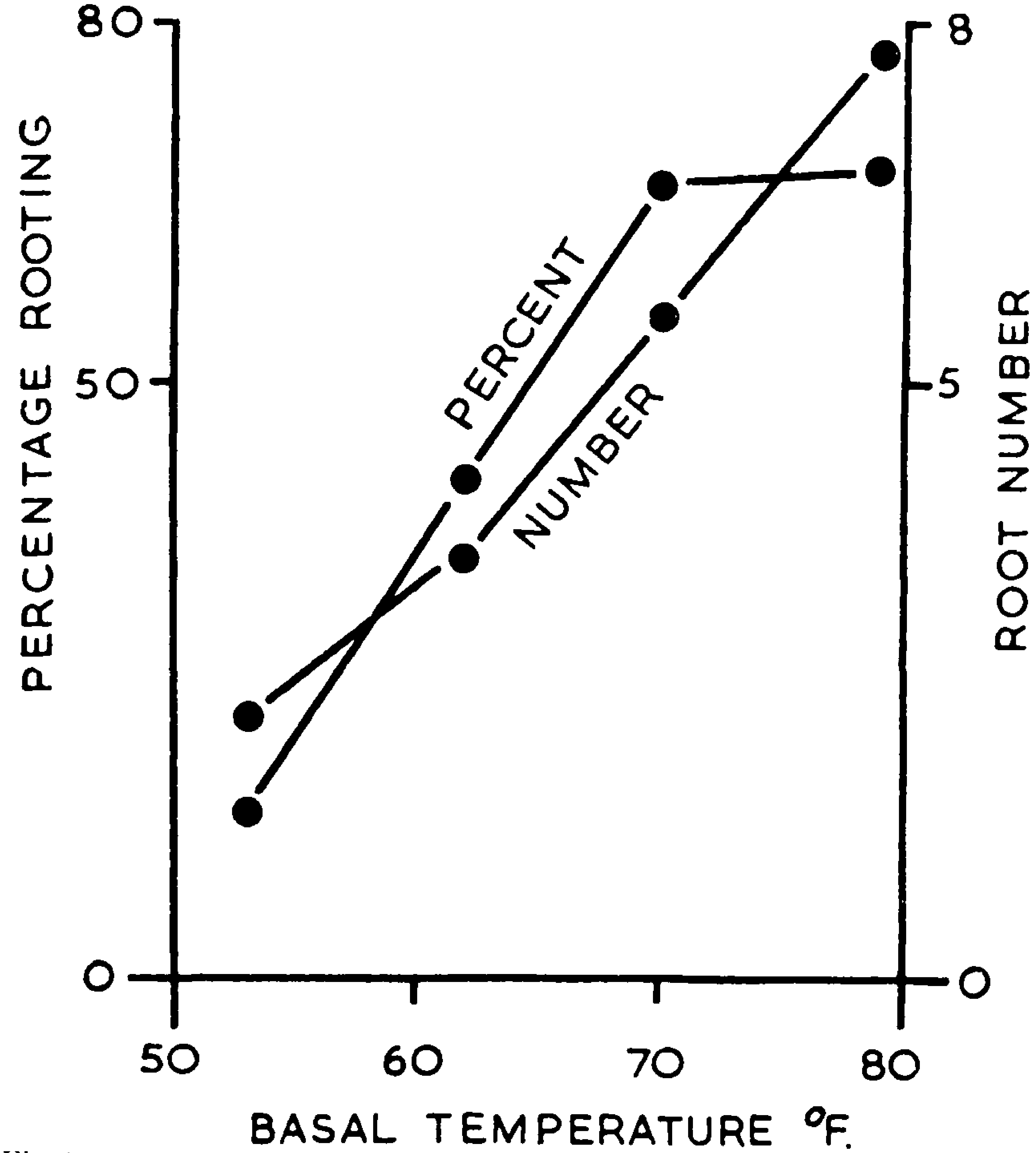

Fig. 2.
Effect of temperature on root initiation in 'EM 26' apple hardwood cuttings (From data of Howard, *J. Hort. Sci.* 43: 23-31. 1968).

Most of these data deal with so-called cool-season plants and may not hold for warm-season plants. For instance, some recent data on the effects of temperature on growth of different citrus rootstock species show that several of them responded to increasing temperature up to 90° F (21). A recent study reporting temperature effects on sunflower roots (3) showed that growth rate increased up to 77° F, declined at higher temperatures, and completely stopped at about 100° F. Growth rate depended upon (a) number of cells dividing, (b) speed of cells dividing, and (c) increase in length of cells. At temperatures less than 77° F temperature affected rate of cell division. Above this temperature, cell division continued to increase up to 85° to 95° F but the number of cells dividing and the size of cells decreased. This shows that both low temperature and high temperature decreased growth but for different reasons.

How about shoot growth? We have already discussed the importance of day-night fluctuations on growth in general. For rooting cuttings, recommendations based on much practical experience have been that the shoot temperature should be less than the root temperature (6). Stated another way, the top temperature should be the optimum for the plant, with bottom heat to give a 10° F differential (20). The explanation for this temperature differential has been that new shoots and leaves may develop before roots form and the cutting is subject to increased desiccation. One might suspect that these recommendations are more important in the absence of a mist system. If we lower the temperature of the tops by mist, we can also drastically reduce root temperature, particularly in continuous mist. Bottom heat may be desirable to keep root temperature from going too low. Certainly the temperature relationships between shoot and root within a mist system might be quite different than in a non-mist environment.

Heide (8) in a series of experiments involving root and shoot initiation on begonia leaves showed that differential temperatures of top and root may produce physiological differences (Fig. 3). Increasing temperature increased rooting but decreased shoot initiation. Temperature differences produced a difference in the physiology of the plant. Higher temperatures were associated with

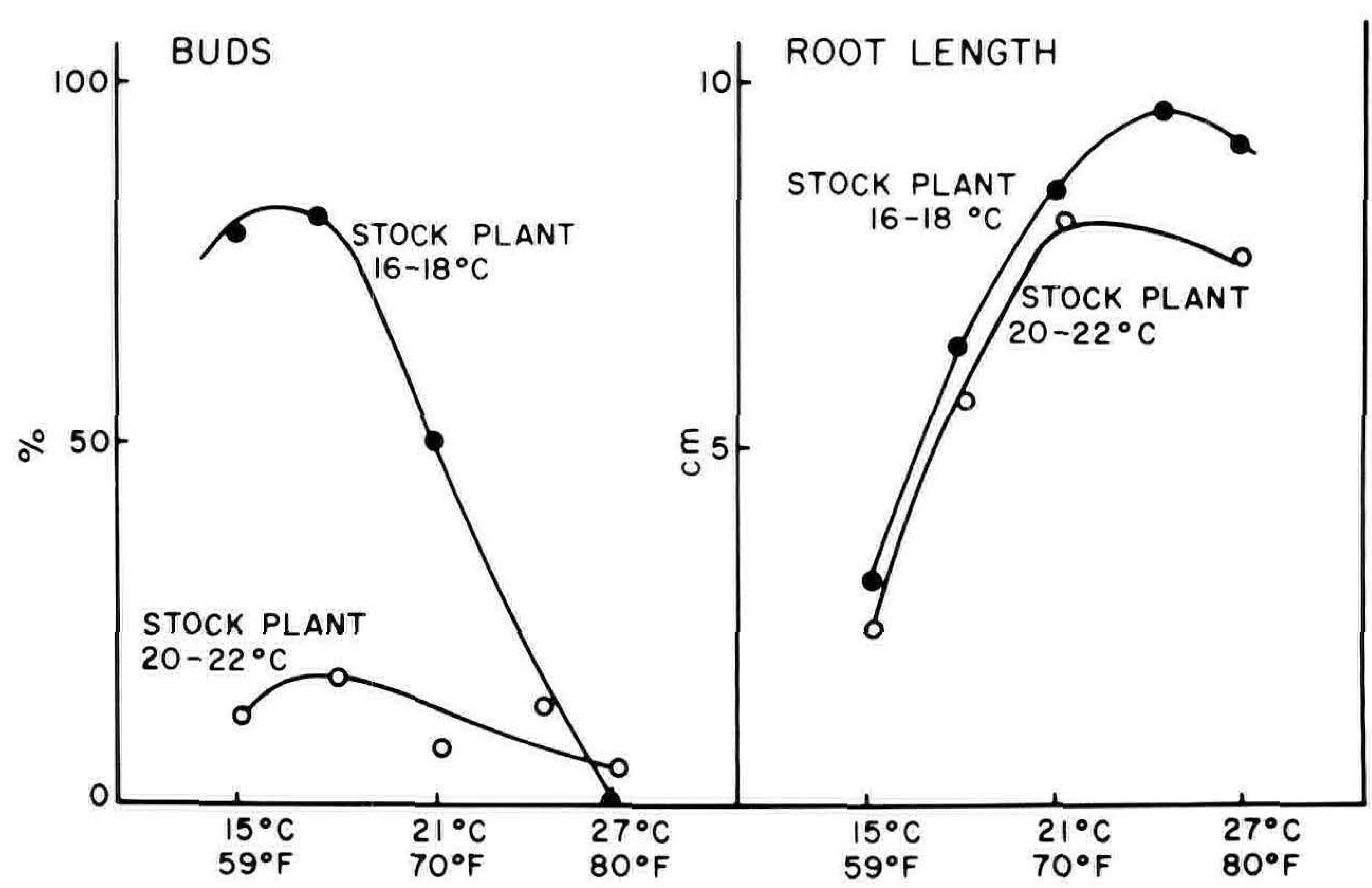

Fig. 3.
The effect of temperature on bud and root initiation in begonia leaves. From Heide (8).

high auxin / kinin ratios whereas lowering the temperatures reduced it. The applications of kinetin materials to these cuttings at the higher temperature increased bud formation (9).

Callus formation in grafting is also strongly influenced by temperature, but different species differ in the range of temperatures within which callus production takes place (15).

Relationship of temperature to growth rates as described is only a part of the story. We must consider the growth-dormancy relationship. Few plants (at least perennial plants) grow continuously but grow and cease growth in cycles of growth and dormancy. How does lowering the temperature affect growth? Many tropical plants exposed to 40° to 50° F, not only cease growth but develop permanent chilling injury; others, such as citrus, exposed gradually to low temperatures cease growing and become dormant. If properly hardened, they can withstand considerable freezing. When temperature increases these plants start to grow again. Deciduous trees and shrubs of the temperate zone enter dormancy as temperatures gradually lower in the fall. Other factors, as shortened days, also are factors. The buds of these plants, in addition to being dormant, will have developed a rest period which started earlier in the summer when temperatures were high. This rest period prevents the buds from growing until such time as the rest period is overcome by prolonged exposure to moderately cool temperatures (that is, 32° to about 45° F(. Such plants can withstand considerable freezing, e.g. down to 0° F. A fourth group of plants exists which not only go dormant and develop a rest period, but have the ability to develop hardiness to extremely low temperatures (—30° F, for instance) if they are first exposed to a period of time to temperatures around 0° F (24).

If the rest period has disappeared by the end of the winter season, the buds on the plant will respond to warm temperatures and grow. If the rest period is still in effect to some degree, growth may be delayed or sluggish to some extent, The significant point to us, as propagators, is that the physiology of the stock plant we are going to use in propagation changes throughout the year along with the shoot's ability to initiate roots. Timing of propagation operations is closely related to the stage of dormancy of the plant(6).

High temperatures can have an inhibiting effect on growth in many instances. Many kinds of seeds show dormancy, at least when freshly harvested, if germination is attempted at about 75° F or higher. At lower temperatures they will germinate without difficulty. Some kinds of seed requiring chilling, such as apple, also are adversely affected by high temperatures and fail to germinate except at moderate temperatures (14). Some seedlings of this group also show severe inhibition of leaves and stems if exposed to high temperatures at early stages of germination (21).

CHANGE IN NATURE OF PLANT (MORPHOGENESIS)

A third significant kind of effect produced by temperature are those cases where a more or less permanent change in the morphology (appearance or structure) of the plant is induced.

This effect is well illustrated by temperate zone bulbs (6,18). Flower and bulb development takes place in well-defined stages beginning with changes of vegetative buds to flowering buds. Progress from one stage to the next depends on exposure to a particular temperature for a certain length of time. Successful bulb production depends upon an understanding of this cycle.

Flowering is induced by exposure to cold in a number of plants. This reaction can be described as a signal the plant receives from the environment to the genetic system of the plant which causes a complete change in the physiology of the plant (18). These changes from a vegetative to a reproductive state can come about in the germinating embryo of some winter cereals (vernalization) or it may occur in the end of first season in the life cycle of biennial crop, e.g. celery.

The olive is an example of a woody plant that has a winter cold requirement to induce flowering (5). Trees may grow beautifully in the tropics but remain vegetative and never flower unless they receive an adequate number of days of the proper chilling regime.

HOST-PARASITE RELATIONSHIP

Much of our discussion in plant physiology assumes that temperature is affecting only the process or plant with which we think we are dealing. In practice, the natural environment or the propagating area with which we are concerned is an ecological system which may include a multitude of other organisms that we don't realize are there, such as fungi, bacteria, insects, viruses, etc. All of these organisms have their own temperature requirements. At certain temperatures these may be particularly active and pathogenic, whereas at others, they are inhibited. The success of a particular propagation technique may be partly due to control of the other organisms (1).

For example, Leach (17) showed that the temperature response in germination can depend on the relative germination rates of the seed as well as that of "damping-off" organisms, *Rhizoctonia* and *Phythium*, which are most active at 20° to 30° C. Consequently, seeds of cool season plants that germinate at lower temperatures can escape them. Because of this effect, treated seed in sterilized media may have different temperature responses than if they are placed in untreated conditions. We had some experience with this problem during 1969 when we were testing stored hardwood cuttings of *Prunus* species at various temperatures. Root initiation was actually best at 68° F but, because of the susceptibility to decay of the material we were using, cutting survival was much less at 68° F than at lower temperatures. On the other hand, 'Marianna' plum cuttings, because of their resistance to these fungi, survived best at 68° F.

This paper has outlined various ways that temperature affects plants. It is the role of the propagator to apply information such as this to conform to the specific requirements of individual kinds of plants.

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BILL FLEMER: Thank you very much, Dr. Kester. You have done a masterful job of compressing into too little time the very complex and very important effects of temperature on plant propagation and growth.

Our last paper of the symposium this morning will be presented by Richard Maire and will be concerned with mineral nutrition in plant propagation.

THE ROLE OF NUTRITION IN PLANT PROPAGATION

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Numerous researchers have been investigating the factors pertaining to nutrition in various aspects of propagation and some specific findings have been reported. However, it appears to me after reviewing the literature that this is a field that still offers considerable challenge to the plant propagator.

The nutrition of the stock plant prior to taking the cuttings is obviously a factor, but not much conclusive evidence is in the literature — granted that I may have missed some research reports. It appears that nutrient levels which produce reasonably vigorous growth of the stock plants, without signs of nutrient excesses or deficiencies, result in cuttings giving the best rooting responses. Either excesses or deficiencies of any element are apt to reduce rooting of the cuttings taken from stock plants grown under these conditions. O. A. Matkin of the Soil and Plant Laboratory, Orange, California, told me recently that in respect to feeding stock plants, cuttings taken from nursery stock on a good feeding program consistently out-perform those taken from less-cared-for stock. Results are faster rooting and this is generally attributed to softer wood. Crops which have demonstrated this include ivy, junipers, star jasmine and boxwood. In addition, we have experienced the same effect with chrysanthemums, carnations and poinsettias.

There has been much research in the area of nutrient mist and Dr. H. B. Tukey, Jr., of Cornell University, who is on our program, has been instrumental in conducting many of these studies. I do not intend to report on his research other than give you a summary of where we stand to date, based on the findings reported. If you wish more details regarding his research, contact Dr. Tukey directly. In the proceedings of the American Society of Horticultural Science meetings, Wott and Tukey (9) reported on the influence of nutrient mists on the propagation of cuttings. The abstract of this paper stated that hardwood, softwood and herbaceous cuttings of 29 species were propagated under a water and nutrient mist system. Cuttings increased in dry weight during propagation, softwood more than hardwood. The nitrogen, phosphorus and potassium content of cuttings under nutrient mist, particularly softwood, was higher than that of cuttings under water. Nutrient mist has little effect on root initiation, but did influence the percentage of cutting which rooted, as well as root quality. Cuttings under nutrient mist produced more linear stem growth and lateral bud growth following rooting than did cuttings rooted under water. In another paper Good and Tukey (2) reported that nutrients lost through leaching and growth of cuttings would be lessened with a feeding program, nutrition being beneficial in counteracting this effect during rooting.

Research by Kamp and Bluhm (3) in 1950 reported the effect of nutrients on the rooting responses of softwood cuttings and they concluded, in general, that nutrients increased rooting by 10 percent.

The importance of adequate nutrition prior to and during propagation was again emphasized by Good and Tukey in their report on redistribution of mineral nutrients in *Chrysanthemum morifolium* during propagation (3). Cuttings of *C. morifolium* 'Indian White' were rooted under intermittent mist (distilled water). Nitrogen, phosphorus and potassium were redistributed to new tissue as the cuttings grew, but calcium was not.

Sorensen and Coorts (5) studied the effects of nutrient mist on the propagation of selected woody ornamental plants. The abstract of their report stated that terminal cuttings of *Buxus semperviens, Ilex crenata* 'Microphylla', *Juniperus horizontalis* 'Plumosa', and *Taxus media*, taken in February, May, August, and November, were placed in three treatments: water mist, as well as two nutrient mists, each of the latter containing nitrogen, phosphorous and potassium. Cuttings of all species on all dates revealed reduced amounts of these elements under water mist at the time of callus formation and at root initiation. Cuttings under nutrient mist contained higher concentrations of these elements with increased rates of fertilization, both at time of callusing and rooting. However, all species, except *Buxus*, had more roots per cutting as well as a higher rooting percentage when the cuttings were rooted under water mist. Nutrients did contribute to a darker green color of the cutting.

In the April, 1970, issue of "The Plant Propagator", there is an excellent report by McGuire and Bunce (6) also of the University of Rhode Island, on the use of slow-release fertilizers in a propagating medium. They noted that, in most cases, studies with nutrient mists have demonstrated that root initiation was not greatly increased by the addition of nutrient mist, but once rooting took place, subsequent growth and root development was improved. They also noted that nutrient mists resulted in algae problems — thus their interest in incorporating slow-release fertilizers in the growing media. They found, in short, that in two species rooting was improved or not affected by fertilizers. In forsythia, rooting was decreased. Subsequent growth of rooted cuttings was significantly better in all treatments with slow-release fertilizers. Matkin has also reported (verbally to me from experiences at the Soil and Plant Laboratory) that cuttings stuck in a medium which includes Osmocote showed a considerable difference in growth and color 1 to 2 weeks after rooting. His growers are using 7 pounds of 18-9-9 Osmocote per cubic yard of mix.

Paul and Thornhill (7) at the University of California, Davis, studied the effect of magnesium on the rooting of chrysanthemums. They reported that when cuttings were rooted in peat at different levels of magnesium and calcium, and when the exchangeable magnesium was greater than 80 percent, rooting was severely impaired. Mist water containing increasing proportions of magnesium caused rooting failure in both sand and peat when the percentage of total cations was 70 percent magnesium. Calcium deficiency symptoms developed in the highest magnesium mist treatment. Leaching of calcium from the leaf is indicated. The New York State Agricultural Extension Service Newsletter on **Poinsettia Production** (8), first paragraph, reads as follows:

> "Propagation: The fertilization of a new poinsettia crop should begin in the propagation bench. Propagating cuttings with fertilizer injected into the mist will result in higher quality rooted plants with faster 'take-off'. In addition, less leaf drop due to nutrient deficient leaves at the base of the plants will occur if plants are properly fertilized to the point of sale. Two ounces of potassium nitrate plus 3 ounces of calcium nitrate per 100 gallons of water is sufficient in the mist to obtain those dark green and succulent cuttings."

In speaking with many knowledgeable people on this subject of nutrition in propagation, the statement was often made — "Metabolism problems in plants so often express themselves as typical iron deficiencies." This struck me as being so true because of a problem with which I had been involved for some time that had every indication of being an iron deficiency situation but finally was proven not to be related to nutrients levels.

For a number of years, chlorosis on the older leaves of Iceland poppy, primrose, and some other plants has been noticed in bedding plant nurseries in California. The chlorosis developed on both seedlings and older plants. The difficulty was particularly severe in one nursery which used a soil mixture consisting mostly of redwood sawdust and sand approximately a 50—50 mixture. This nursery added dolomite, potassium, phosphate, nitrogen, and gypsum, then steam pasteurized the mixture before using. The chlorosis appeared as irregular spots or blotches on the older leaves. In severe cases, the entire plant had yellowed. The plant did not grow, but survived. Seedlings in seed flats and small plants in "pony packs" or pots were equally affected. Usually the chlorosis disappeared after a period of time and the plant grew normally until it was transplanted into some fresh soil mixture of the same type in the nursery.

Related to this difficulty was the loss of roots immediately following transplanting of the seedlings. The roots were killed and a new root system had to regrow before the plant resumed its normal growth. Neither micronutrient deficiencies nor micronutrient excesses were responsible for the difficulty. Manganese, iron, zinc, copper, molydenum, and boron were studied singly, and in combination.

Whenever soil mixture without redwood sawdust were used the difficulty did not appear. Iceland poppy grew well without chlorosis in a Peat-lite mixture. When redwood sawdust was added to the basic Peat-lite mixture chlorosis appeared. Leaching the redwood sawdust with water before making the mixture reduced the incidence of chlorosis.

These facts suggest that there is a soluble toxin in the redwood sawdust responsible for the chlorosis noted on the Iceland poppy, primrose, and some other plants in the bedding plant nurseries. Since not all flowering annuals showed the same difficulty, there is the possibility that some plants are more tolerant than others of this toxin. Marigold, although it was used, as well as Iceland poppy, throughout these experiments, showed very little effect from the toxin. The bedding plant nursery where this work was conducted eliminated redwood sawdust from the soil mixture and the chlorosis problem disappeared.

In summary, I hope I have given some indication of the information now available on the effect nutrition has during various stages of propagation. I believe it warrants repeating that more work is needed in this area of research. I challenge both researchers and plant propagators to develop more of this much-needed information.

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BILL FLEMER: Dick, that was an amazingly complete job done in an exceptionally short time. We will proceed now to a critique which is a new innovation in our program proceedings and we are very fortunate to have Dr. Charles Hess and Dr. Andrew Leiser who will unite these four concepts into one pattern.

CHARLEY HESS: I would like to take this opportunity to supplement Bill's historic presentation from a little different approach by relating some of the significant events that have taken place in propagation as a result of the Society's activities. Probably the most significant one was the introduction of mist propagation. I believe this Society did more to spread the use of this technique in the industry than did any other group. The concept of mist propagation and its application to a wide range of plant materials would never have taken place if it were not for this Society. The concepts of constant mist, intermittent mist, time clocks, electronic leaf, the phytotektor unit, the burlap cloud, the vapor-proof chambers, are all things which were developed over the years from 1951. These are all milestones in our history.

Other things of lesser, but still great, significance were discussions of wounding and the use of bottom heat. Now as we move into the current decade I think the concept of tissue culture will be another area which may have equal significance to that of mist propagation in the future. Hopefully we will see the spread of a rather sophisticated technique from the laboratory into commercial operations. Just last year when we were on the West Coast we saw this concept of meristem culture being used in the commercial propagation of orchids and I believe we'll be seeing more of this in the future.

Finally, I think that we will also be seeing the use of the systems approach in nursery production. We have seen examples of this on the East Coast with Dick Vanderbilt's production of rhododendrons with all of the steps of production fitted into a precise pattern. And on the West Coast, George Oki has applied business management techniques These, then, are some very significant aspects of our history and I feel Society has made to the nursery and florist industry.

Our first speaker on the symposium program spoke on water relations. One aspect of his paper, which I would like to point out, is the dual role of water applied as mist which not only maintains turgor but also provides a cooling effect by the evaporation of the water film which covers the leaf. Another aspect of water which I don't fully understand, but I'm seeing more and more reference to, is the importance of the film of water at the base of the cutting and its role in stimulating rooting. Whether this is stimulating gaseous exchange or aiding the entrance of growth regulators into the cutting is not known, but it does seem to be essential that the base of the cutting be covered by a film of water. Perhaps the technique of putting the cuttings tightly into a sand medium has some relationship to the continuity of the water film. This is an area which would seem to have some research potential.

ANDY LEISER: One of the things which impressed me most from Dr. Kozlowski's paper is that we often forget in the day-to-day production of plants is that there is a very rapid and rather large fluctuation in the water relations within the plant or cutting. There is the old axiom 'take cuttings from plants early in the morning before plants are wilted', and this was dramatically shown by Dr. Kozlowski's presentation.

The effect of water on growth even after rooting can be very dramatic. Some recent work in California has shown that a constant dribbling irrigation produces a much greater dry weight gain in chrysanthemums than does irrigation twice a day. The soil in the twice-a-day irrigated plants never dropped below field capacity. Thus, theoretically there was always ample water; yet, apparently the water relations were not as good as with the constant drip irrigation. This is probably a more critical factor than we have realized in the past. With some look to the future, I would like to see some work done on the water relations of the stock plant and their effect on the rootability of cuttings.

At this time I would like to open the questioning with one of my own addressed to Dr. Kozlowski and that is—are there any effects of water deficits on the seed quality in fruits produced under severe water stress?

TED KOZLOWSKI: In general terms, yes. Any type of water stress which affects vegetative growth will in turn affect the growth of reproductive structures and seed development. The effect would be both on the quantity and the quality of the seed produced.

JIM WELLS: I'm wondering if there would be, on the basis of what we've just heard, any reason to consider going back to constant mist. I'm thinking in terms of the very fine mist nozzles which put out very small amounts of water, around one-tenth to one-fourth gallon per hour; perhaps Ted would like to reply to this briefly.

TED KOZLOWSKI: I believe that what is needed is some in-depth research on the different kinds of mist and what effects these have on the internal water deficits of the cuttings. This is the best way to get an answer to this question.

CHARLEY HESS: The second paper dealt with light relations by Sid Waxman. I would like to make one comment with respect to one type of light control which Sid did not cover and that is the absence of light or etiolation. This is a very important aspect of propagation because there is a powerful physiological effect of etiolation on enhancing the ability of cuttings to root. Cuttings which are nearly impossible to root can sometimes be rooted by etiolating the shoot before-hand. This is a negative aspect of light but a very powerful one.

ANDY LEISER: In respect to light control I'd like to tell you of some work we did on the West Coast. After looking over the older literature on light experiments, we felt that we could speed up the growth of several plants. We began a trial using genera and species which had not been used in the previous reports. We started the plants from seed and found that several plants did not respond to supplemental light, at least in the seedling stage. Looking to the future, I think we need to screen large numbers of plants to determine those which will respond to supplemental light, particularly at the seedling stage.

I would also like to re-emphasize Sid's comments with respect to the effectiveness of different wavelengths of light on growth and that there is no need to purchase special lamps which screen out certain wavelengths because much of this light can be and is used by the plant. You have to pay for the wattage of the lamp anyway so why pay extra for a special lamp, especially when some of this light which would be removed is beneficial to the plant.

CHARLEY HESS: We are about out of time and so all questions will have to go into the Question Box. I felt our third speaker, Dr. Kester, did an excellent job of covering the subject and I will defer any comments to Andy.

ANDY LEISER: My only comment is to emphasize the point that all of the factors of the environment interact and we need to consider all of them simultaneously.

CHARLEY HESS: I have only one comment in regard to Dick Maire's paper and that is that there are only two minor elements which have been associated with rooting. One is zinc, which is involved with tryptophane synthesis as a precursor of indoleacetic acid which is involved in rooting; the other is boron which seems somehow to be involved in oxygen relations in cuttings and is most efficient when there is an oxygen deficient condition in the cuttings.

We are out of time and so I'll turn the program back over to the program chairman, Ralph Shugert.

RALPH SHUGERT: Thank you, Charley and Andy. You did an excellent job. Our morning session is now adjourned.

WEDNESDAY AFTERNOON SESSION

September 9, 1970

The afternoon session convened at 1:30 p.m. with Hans Hess as moderator.

MODERATOR HESS: The symposium for this afternoon is entitled "Seedage: Past, Present and Future." The first speaker is Dr. Harrison Flint who will discuss the importance of seed source. It gives me a great deal of pleasure to present to you Dr. Flint.

IMPORTANCE OF SEED SOURCE TO PROPAGATION

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The problem of locating sources of seed for propagation of woody plants has not changed basically for many years. Solutions to the problem are gradually becoming easier, however, because of a better-organized commerce in seeds and better communications among plantsmen, largely through the efforts of organizations such as the International Plant Propagators' Society.

The related problem of deciding which of alternative seed sources to use is more complicated and less fully understood. It is sometimes thought that any plant or seed is equivalent to any other of the same name. Experienced plantsmen know that this is seldom true — in fact, have known for many years that selection of proper genetic material can be essential to success in plant cultivation.

What is a plant species? A plant species usually is a collection of individuals grouped together for purposes of classification because they have certain morphological features in common. This in no way implies that they are identical or even similar in all respects. An analogy can be drawn with *Homo sapiens*, the species that includes modern man. If we were to select an individual from this species to perform brain surgery, to compete in track events in the Olympics, or to write a poem commemorating an important occasion, we would not be content to accept just any individual selected at random. In the same way if we are to select an individual of red maple *(Acer rubrum* L.) for a specific landscape situation, why should we be content to use just any individual, knowing that this species, which inhabits most of eastern North America's temperate zone, is highly variable. For example, Dr. Thomas O. Perry of North Carolina State University's Forestry Department has observed tremendous differences in physiological response to temperature among individuals of red maple that are hardly distinguishable by outward appearance (24). Such differences can relate directly to problems of adaptability. In this same species, *Acer rubrum*, we see in the nursery trade a considerable number of cultivars (horticultural varieties) that have been selected for form and foliage color from the diversity that is available within the species.

Cultivars and seed sources. Mention of cultivars, which in most woody plants are vegetatively propagated clones, may seem out-of-place in a discussion of the importance of seed source, but both are parts of the same picture. In many cases. it has been necessary to select extreme genetic forms and propagate them by cuttings or grafting to uniformly obtain desirable horticultural material. A familiar example is that of blue forms of *Picea pungens*. When seeds are sown, only a small number, if any, result in plants equal in color to the parent plant, and vegetative propagation has become the accepted means of producing highly glaucous forms.

We are seeing more and more selection of vegetatively propagated clones as named cultivars. Some are highly superior forms — others no better than previous selections — some even re-selections of the same genetic material under a new name, the result of incomplete checking of existing cultivars. We need more truly superior cultivars, but we should beware of carrying this process to a biologically unsound extreme. Today we are beginning, on a national scale, to heed the conservationists' call for preservation of diversity in biological material — for the sake of the diversity itself and for such pragmatic reasons as maintaining genetic pools from which resistance to new diseases and insect problems may be drawn. I am not suggesting that we are in immediate danger of creating problems in this respect, but as plantsmen we have a special obligation to serve as good stewards of the biological resources that we are directly concerned with, and we should carry this thought with us as we proceed.

Selection of seed sources is a less intensive process than selection of clones. Seed lines are usually reproduced at less cost than those of clones, which are propagated by vegetative means. Seed lines are, of course, more variable than clones, yet may possess considerable uniformity, often enough to insure consistent usefulness in a given situation.

In many cases the use of clones as cultivars might be preferable to selection of seed sources, but such cultivars do not presently exist. In other cases, there is no clear advantage to the use of clones, either because relatively little variation exists within seed sources, or because of unresolved problems in vegetative propagation.

Kinds of variation. Even a cursory look at the literature turns up many forms of expression of geographic variation within species. Let's look at a few:

Form and color differences have been observed in many conifers, well documented by P. den Ouden and B. K. Boom (21) in **Manual of**

Cultivated Conifers.

Differences in habit have been documented in *Robinia pseudoacacia* (12), *Ulmus americana* (7), and many other deciduous species.

Growth rate differences among geographic sources have been observed in many species. The forestry literature carries many such accounts resulting from seed source studies.

Timing of annual growth and response to photoperiod are often interrelated (29). Variation in growth response to photoperiod within species has been observed in *Liriodendron tulipifera* (10, 15), *Pinus monticola* (27), *Pinus strobus* (23), certain *Populus spp.* (22, 30), and *Tsuga canadensis* (20).

Annual growth patterns can be related to hardiness, especially in early winter (19). In the case of *Cornus stolonifera*, Smithberg and Weiser (26), working at the University of Minnesota, found that plants of geographic strains from widely different locations all had the ability to harden to great extremes but that plants from sources having mild climates hardened much more slowly than did those from colder habitats, and so were prone to damage in early winter. Hardiness-related differences in growth patterns also have been found in *Juglans nigra* (6) and several southern pine species (17).

Differences in hardiness, without specific observations of growth patterns, have been seen in *Acer saccharum* (14), *Fraxinus americana* (34), *Kalmia latifolia* (13), *Pinus ponderosa* (28, 31), *Pinus resinosa* (2),*Pseudotsuga menziesii* (9), and *Quercus rubra* (8),

The case of *Kalmia latifolia* was shown graphically by Dr. Richard Jaynes, geneticist at the Connecticut Agricultural Experiment Station at New Haven, who carried seedlings from several geographic sources overwinter in a cold frame. Plants from Alabama sources were killed, while those from New England sources withstood the winter without damage.

In a study recently completed at Purdue (8), hardiness of twigs of 16-to-18-year-old trees of *Quercus rubra* from 38 different geographic sources was compared. Hardiness during early winter closely related to geographic source, trees from northern sources hardening more than trees from southern sources.

Also related to growth pattern is the time of emergence of buds from quiescence in the spring. Researchers at the U.S. Forest Service experiment station at Carbondale, Illinois, and cooperating forest physiologists and geneticists at Purdue and other mid-western universities are interested in the problem of susceptibility of new growth of black walnut trees to late spring freezes, and hope to find sufficient variation in this factor to form a basis for selecting late-breaking trees. Such variation has been seen in many other woody species having wide geographic ranges.

In cases where the natural habitat of a species includes large variations in growing-season rainfall or in soil water-holding capacity, differences in drought resistance within the species may be expected, but very few cases of such variation have been documented, only one to my knowledge in a woody species (18).

In the same way, variations in soil requirements may exist in woody species that grow on a variety of soil types. Differences in soil pH requirements have been observed in soybeans (3). It would be interesting to know whether similar differences might exist in *Quercus palustris*. If lime-tolerant strains could be found, the practical value to landscapers in much of the midwest would be considerable.

Other differences found within woody species include seed germination requirements (33), seed quality (16), specific gravity of wood (25) — of interest in lumbering — and leaf form (1, 4, 5) — of interest in plant taxonomy and ecology.

Over the past 20 years considerable information on seed source has appeared in our Proceedings. In 1954 Laddie Mitiska described collection of seed from outstanding selected forms of upright *Taxus cuspidata*. In 1956, Aart Vuyk stressed the importance of seed source in mass production of forest tree seedlings. The following year, D. J. Hillenmeyer pointed out that considerable variation in hardiness can be found in *Osmanthus americanus*, and in 1958, Richard O. Hampton mentioned the seed source problem as it applied to propagation of virus-free stone fruit varieties and understocks. In 1960 Thor K. Bergh answered the question "Will Seed from Northern Plants Produce Plants Hardier than Those from Southern Regions?" by pointing out the importance (and difficulties) of selecting the proper seed source. He stressed the importance of adaptation and listed a number of forest species (some also ornamentals) in which important variations are known, including red pine, Scots pine, Siberian elm, western hemlock, slash pine, Engelmann spruce, Sitka spruce, and white spruce.

In 1967, Philip G. Haddock, Professor of Forestry at the University of British Columbia, reported to the Western Region on provenance testing in forestry, an activity designed specifically to evaluate genetic variation in tree species and its interaction with the environment. He described the economic importance to forestry of selecting well-adapted races. While horticultural applications differ somewhat, horticultural plantsmen are quite familiar with the phenomenon of economic loss resulting from the use of inappropriate genetic material.

C. E. Heit, seed analyst at the New York Agriculture Experiment Station at Geneva reported on the importance of seed source as well as seed quality factors in the 1964 Proceedings, and has published additional information more recently, in **The American Nurseryman**

(11). He has stated that selection of seed source, in conifers, is second in importance only to selection of the species to be grown.

Selecting seed sources. Faced with the problem of selecting appropriate seed sources, what alternatives are open to the propagator?

1. **Local sources.** The propagator who is a plantsman of some experience can find local sources of many native woody species. He can find these by observation on local trips, by letting others in his area know what kinds of seeds he is looking for, and often by accidental observations, if he has trained himself to recognize their significance.

Most propagators are also interested in exotic (non-native) species. Good sources of seed of these species may also be available locally, in the form of plants that have been cultivated in the area for some time, on public or private grounds. Many propagators in our own organization have gradually accumulated knowledge of such sources and are obtaining many seeds in this way.

With local seed sources, as with any other, the propagator must contend with good and poor seed years. Several members of our Society have reported collecting seeds in good years and storing them for two to three years or longer. The 1956 and 1957 Proceedings include several excellent articles on seed collection and propagation practices, and are worth re-reading.

W. C. Sherman reported to our Society in 1957 that Forrest Keeling Nursery had established seed orchards to give a more reliable supply of seeds of certain species than could be obtained elsewhere. This practice allows careful selection of seed parents and insures comparable genetic material year after year. Other propagators with predictable needs for the same species over a number of years might well follow suit.

2. **Commercial sources.** The most convenient way to obtain seeds, and often the most economical is to buy them from a commercial dealer, Many propagators use a small number of relatively large dealers as their primary source of seed of woody species. Such dealers usually have information on sources and sometimes alternative sources, in an attempt to respond to the needs of their customers.

Seeds of certain species can be obtained from more specialized dealers — sometimes small companies specializing in collecting native plants and seeds. It may also be possible to obtain seeds of some species by arrangement with plant nurseries who are collecting for their own use, but sometimes have surpluses.

Seed dealers are regulated to different degrees by the various states. In the 1964 Proceedings, C. E. Heit outlined what purchasers can expect from dealers regulated by New York State. When dealing with an unfamiliar source, it may be advisable to do a little checking on the degree of regulation the dealer is operating under, and, if in doubt, the propagator may wish to arrange a germination test on his own.

3. **Non-commercial sources.** Seeds of woody species not available commercially sometimes can be obtained, in small quantities, from arboretums, botanical gardens, and other educational and research organizations.

Many arboretums and botanical gardens regularly exchange seeds on a reciprocal basis. Most of these are privately or locally supported, and are under no obligation to honor requests from outside individuals. Most attempt to honor reasonable requests if they are able to. It is probably a safe generalization that modest requests have a better chance of being honored than larger ones. Several commercial members of our Society have benefited greatly in this respect by establishing mutually cooperative stances toward arboretums and botanical gardens — including direct financial support in some cases.

There are problems and pitfalls in obtaining seeds from any source. Arboretums and botanical gardens are no exceptions. Most do a better-than-average job of labelling plants and seed collections correctly but few, if any, will guarantee identity of a seedlot. Likewise, germination and purity are not (and need not) be guaranteed as the seeds are not being sold. Some arboretums will send seeds that are of transient viability, if they are available, long after much viability has been lost, assuming that the propagator is aware of this and is interested in obtaining even a few seedlings. When seeds are from cross-pollinated trees, obviously no one is going to guarantee the identity of the male parent. When such seeds are collected from plants in large generic collections, the probability of hybridization in many genera is quite large. In other genera where hybridization seldom if ever occurs, the problem is less serious. Dr. Melvin Westwood, fruit geneticist at Oregon State University recently pointed out the magnitude of the problem he encountered in trying to obtain seed of natural species of *Pyrus* for his pear breeding program (32).

Summary. In summary, I would suggest that propagators should

1) be aware of the problems known to exist in selecting seed sources;

2) read and correspond with members of this Society as necessary to obtain as much up-to-date information as possible;

3) be alert to recognize new problems as they arise;

4) support the activities of arboretums, botanical gardens, and research institutions, read the information that they publish and discuss needed research with their staffs;

5) ask as many questions as necessary when obtaining seeds; and

6) occasionally look through back volumes of the I.P.P.S. Proceedings, to glean overlooked or forgotten information from them.

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MODERATOR HESS: Thanks very much, Harrison, for an excellent presentation. The next speaker of this afternoon's symposium is Dr. Bruce Pollock who is an outstanding authority on seed dormancy and storage.

DORMANCY AND PRETREATMENT

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This afternoon, in treating my assigned topic, "Dormancy and pretreatment," I face a difficult task. I am told that I must provide a "take-home" lesson. Unfortunately, most of you know far more about dealing with dormant seeds in practical propagation than I. Even more unfortunately, I have just completed two chapter-writing assignments on seed germination. At the conclusion of these assignments, I found myself depressed by the relative lack of scientific progress in the field during the last 30 years. If you review the scientific literature of the 1930's, you will find almost all the ideas we use today. Under these circumstances, I face the problem of providing a "take-home" lesson with some trepidation.

Therefore, instead of repeating old ideas which we all know are useful, I would like to speculate on newer ideas which I think **might** be important. Perhaps, at the close of the talk, some of you, from your intimate practical knowledge of seed germination, may be able to prove or disprove my speculations. After you leave, perhaps my speculations will help guide your observations in finding better ways for establishing seedlings from some of the species which are difficult to germinate.

The first point on which I would like to speculate is the importance of timing in seed germination. When we germinate seeds in the laboratory, we normally place the dry seeds under moist conditions at an "optimal" temperature and maintain that temperature continually until the seeds germinate, or until it becomes obvious that they will not germinate. In certain crops, the seed laws specify that this optimal temperature is a daily temperature alternation, but this is an alternation used continually from the beginning to the end of germination.

The thinking behind the use of constant "optimum" temperatures is based on the recognition that seeds respond to temperatures immediately during the period of exposure to the temperature in question. This is a direct type of environmental response.

Some years ago, I became interested in the phenomenon of physiological dwarfing in rosaceous seeds, particularly in

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peach. These seeds are dormant and require a period of low temperature after-ripening before germination becomes possible. If the seed coat and endosperm tissue surrounding the radicle are removed, the seed will germinate without after-ripening. However, the resulting seedlings are dwarfed, producing shortened internodes and frequently misshapened leaves. Such seedlings may continue to grow in the dwarf habit for as long as 10 years (3).

In studying this phenomenon, I found that dwarfing was a response to germination temperature (7). Seeds germinated at 27° C (81° F) or 23° C (73° F) produced dwarf seedlings, while seeds germinated at 19° C (66° F) produced normal seedlings (Fig. 1). More important for our purposes today, the response was time-specific, requiring an exposure of only one day at the high temperature for response. The one-day sensitive period occurred between the second and ninth day of germination (Fig. 2), at about the time that cell divisions begin in the apical meristem of the epicotyl.

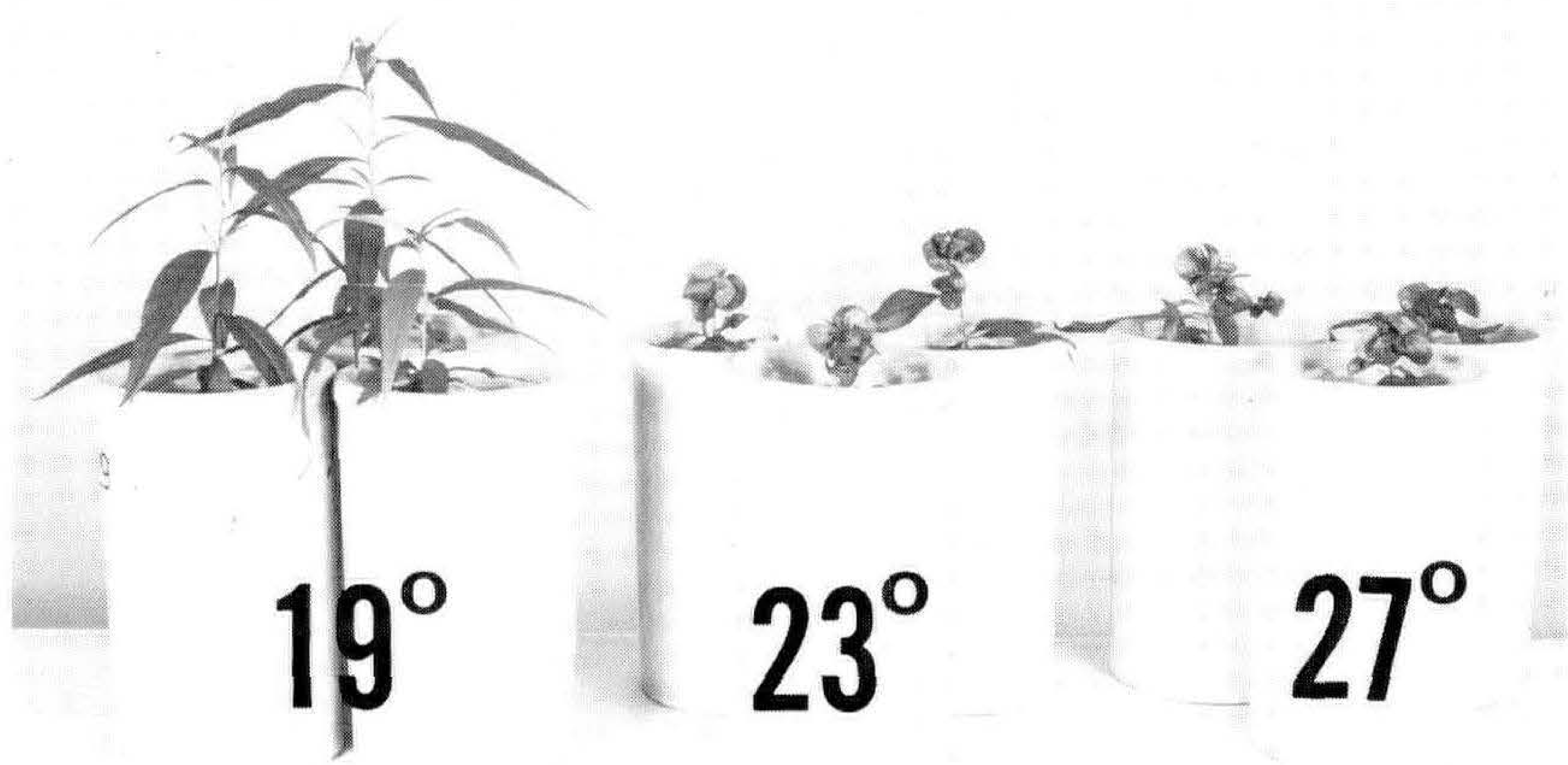

Fig. 1.
Peach seedlings grown from non-after-ripened seeds, germinated for 8 days at the temperatures indicated and then grown 4 weeks at 25° C under a 16 hr. photoperiod.

This is an example of a delayed response to an environmental exposure, as contrasted with the direct type of response with which we are more familiar. In a delayed response, the plant may receive an environmental exposure at one time but not respond to that exposure until a later time. Obviously, such delayed responses may be very difficult to recognize when we encounter them in plant propagation.

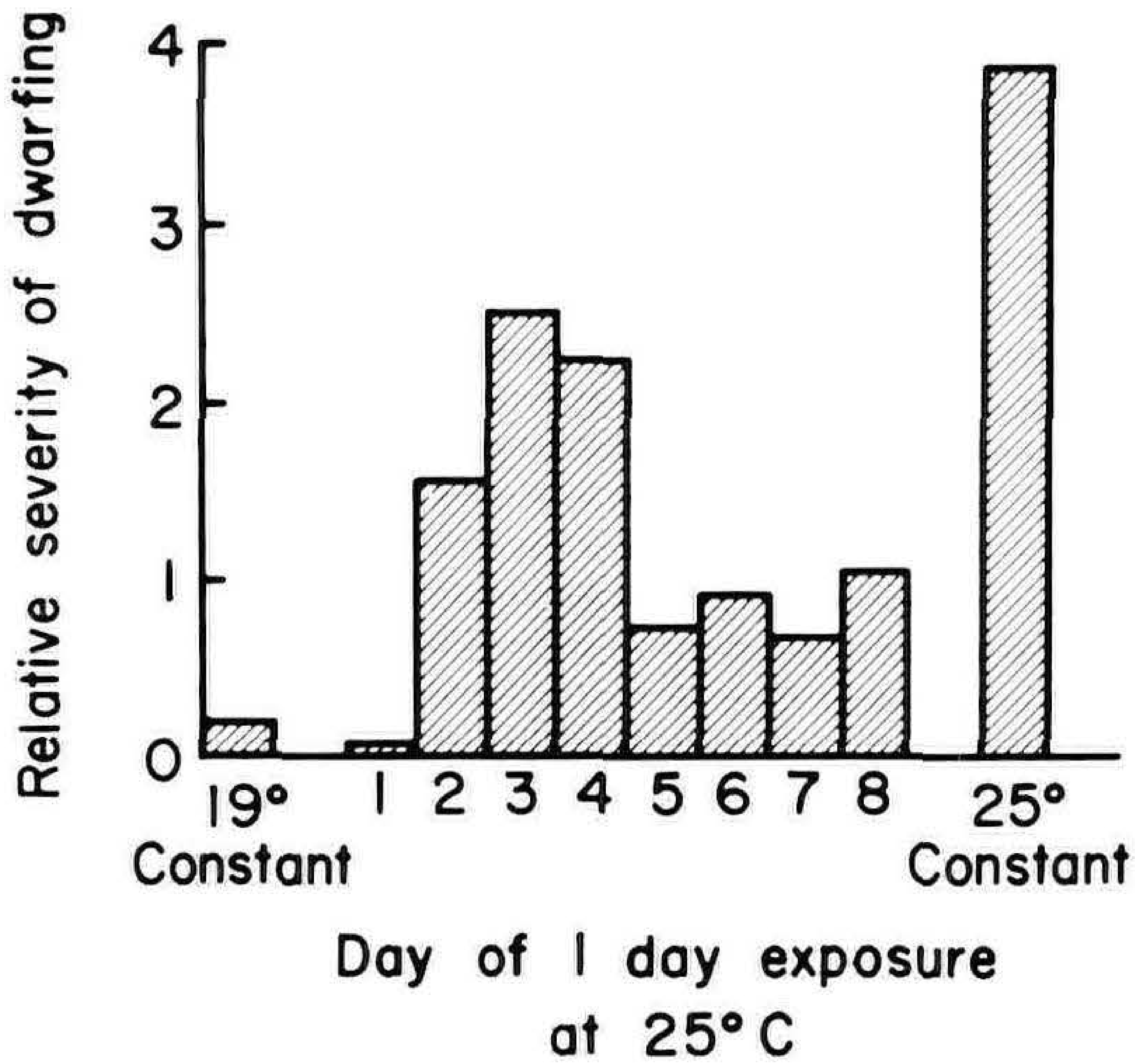

Fig. 2.
Dwarfing of seedlings from non-after-ripened peach seeds as influenced by time of temperature exposure. The severity of dwarfing was estimated on a scale 0 (normal) to 4 (severely dwarfed).

This experience should have alerted me to the possibility that time-specific stages occur in other germinating seeds, but it did not. Later, quite by accident, we discovered that there is a tem-

Fig. 3.
Lima bean *(Phaseolus lunatus* L. 'Thorogreen') seeds imbibed for 18 hr at 15° C (59° F) preceeded by varying periods of imbibition at 25° C (77° F). After imbibition, all seeds were germinated and grown for 7 days at 25° C. The number at the right indicates the number of seeds which decayed from a 15-seed sample. Green seeds in baby limas are high vigor seeds. Figures from *Plant Physiology* 41: 221-229, 1966.

perature-sensitive stage at the very beginning of the imbibition stage in germination of lima and garden bean seeds (8, 10). Imbibition at a low temperature results in death of many seeds and reduces the size of the surviving seedlings (Fig. 3). As little as two hour imbibition at a higher temperature (25° C), is enough to reduce or eliminate chilling injury, which is much more severe in low vigor seeds (Fig. 4).

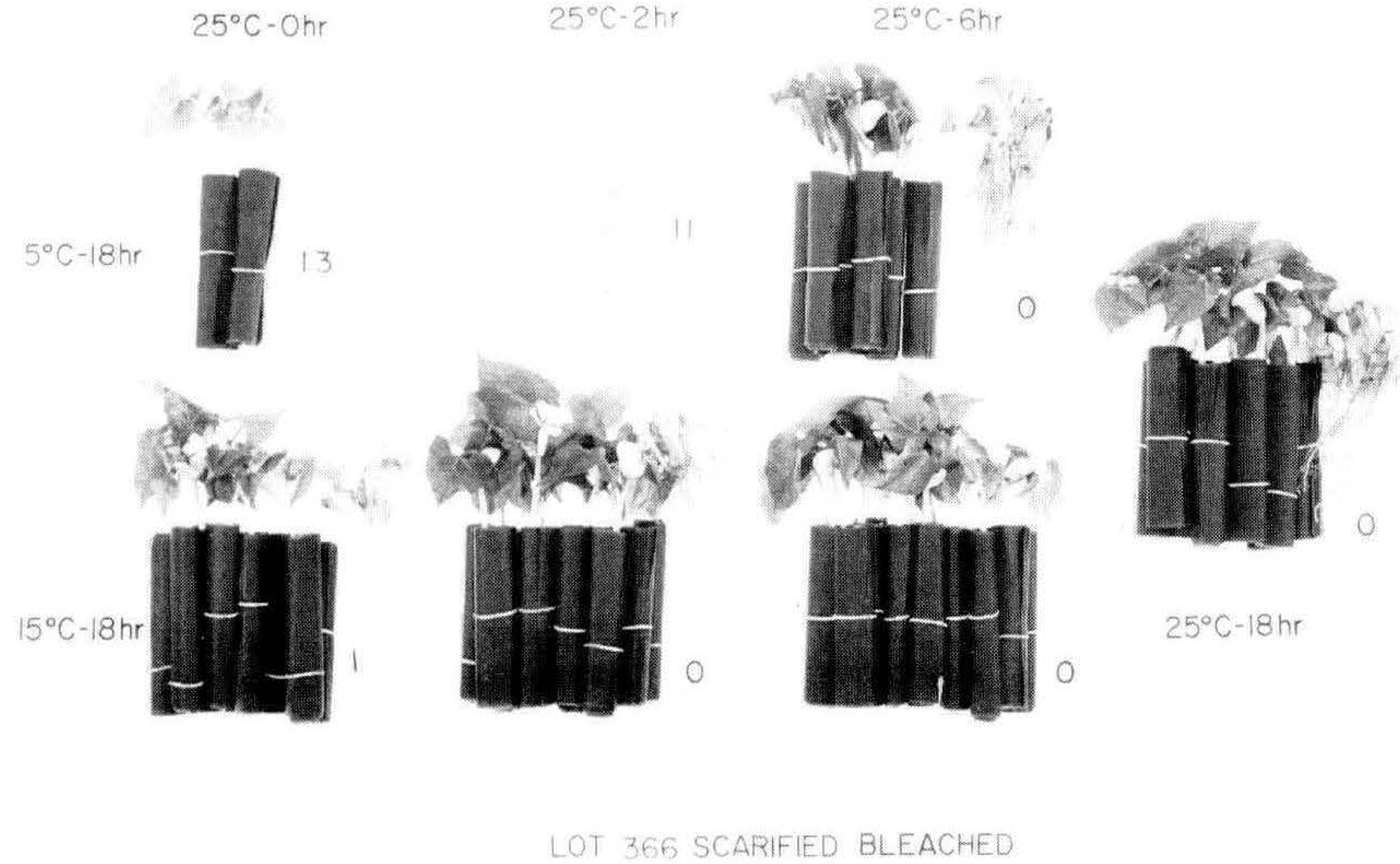

Fig. 4.
Seedlings from low vigor (bleached) seeds in the same experiment as those in Figure 3.

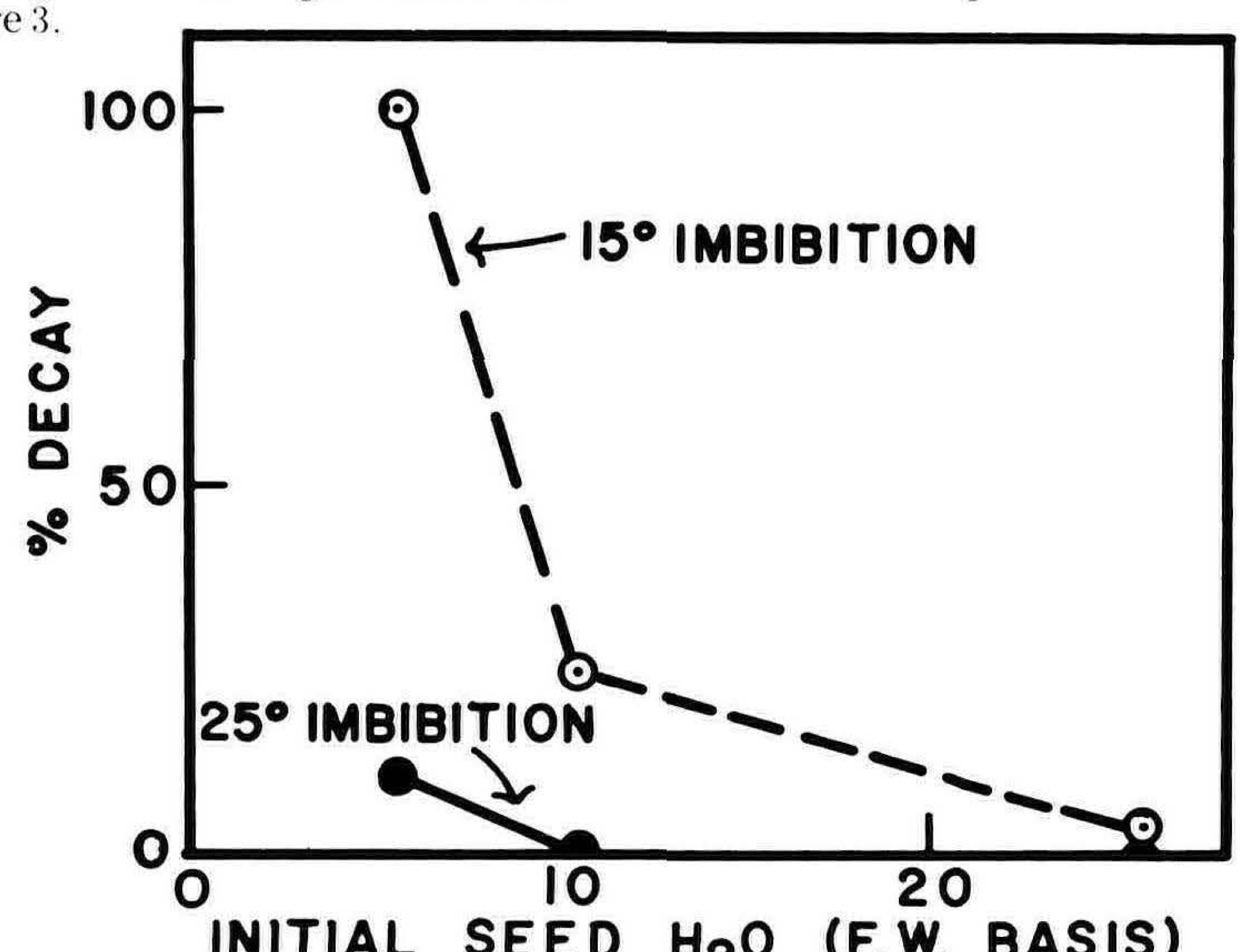

Fig. 5.
The effect of initial seed moisture on decay of lima bean seedlings as influenced by imbibition temperature. Figure from *Plant Physiology* 44: 907-911, 1969.

In further study of this time-specific temperature sensitivity, I discovered that sensitivity is a function of seed moisture at the time of planting (9). Increasing seed moisture to above 12% eliminates temperature sensitivity (Fig. 5, 6).

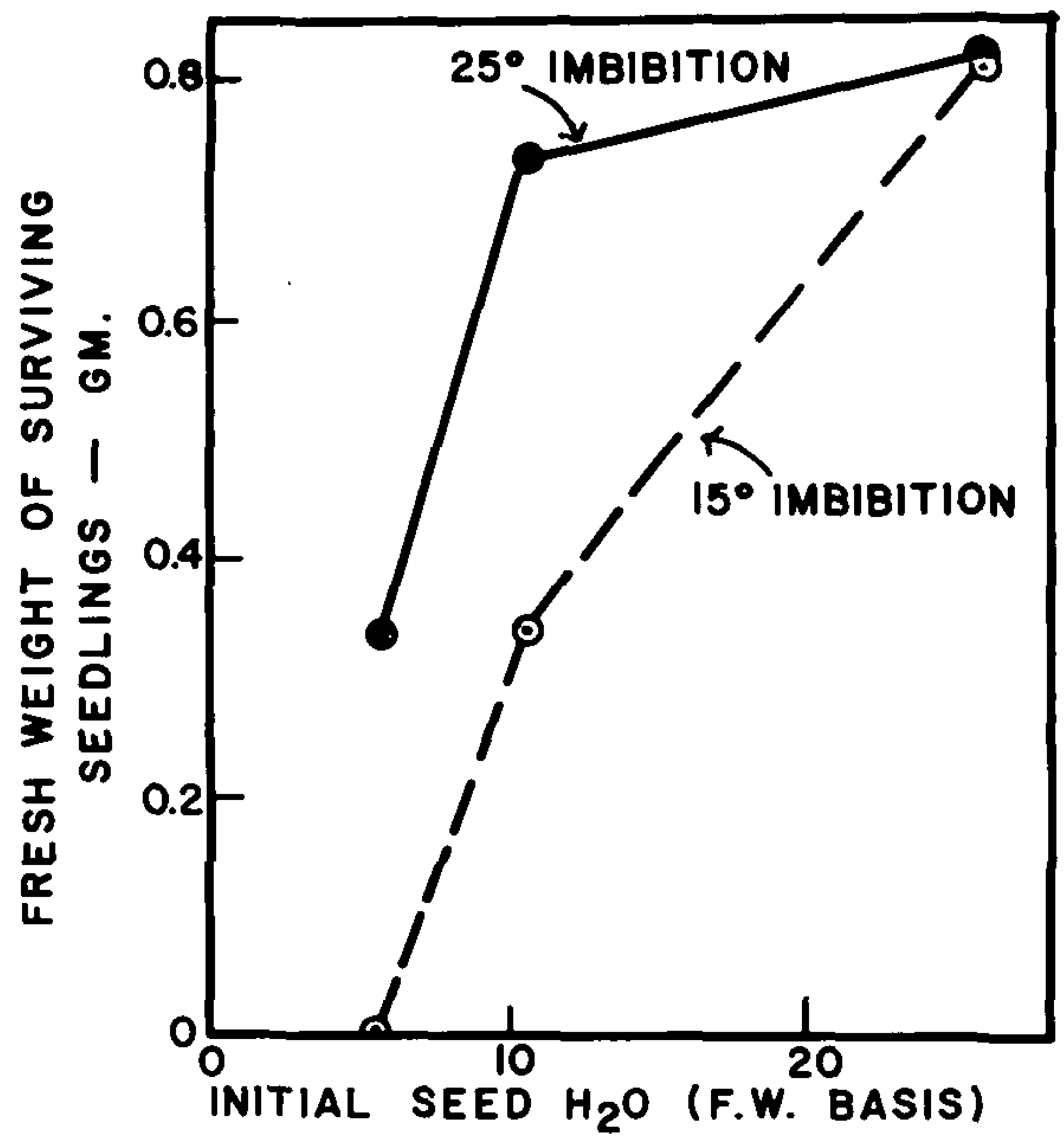

Fig. 6.
The effect of initial seed moisture on the size of surviving lima bean seedlings. Data from experiment shown in Figure 5. Figure from *Plant Physiology* 44: 907-911, 1969.

Table 1.....Effect of initial seed moisture on emergence of early planted garden bean seedlings.

Variety	Lot No.	Seed moisture, percent	Emergence, percent
White-Seeded Tendercrop	70-1	8.8	38.3
		13.1	70.5
”	70-2	8.7	17.7
		13.2	54.2
Kinghorn Wax	70-5	8.6	33.2
		11.2	55.7
”	70-6	8.7	31.0
		11.7	68.0

This year, in early spring planting of garden beans, my colleagues, Mr. Joseph Manalo and Dr. Eric Roos, found that increasing the seed moisture prior to planting approximately doubled plant establishment (Table 1).

Thus it is clear that, for the bean varieties studied, there is a time-specific temperature-sensitive stage at the very beginning of imbibition. Pretreatments which increase initial seed moisture above a critical level eliminate this sensitive period. These results have been extended by others to include soybeans (5), sorghum (6), and cotton (1). In the case of cotton, there are actually two temperature sensitive periods; the beginning of imbibition as described above and the period 18-30 hours of germination at 31° C.

Although many seeds are routinely germinated under a daily alternation of temperatures, the rules of seed testing (4) do not specify the initial temperature to be used. Recently Elkins, Hoveland and Donnelly (2) found that the initial temperature in an alternation is important in certain species and genetic crosses of *Vicia*. There are two responses: (A) Using an alternating 4.5 — 21° C (40° — 70° F) cycle they found that an initial low temperature greatly reduced the emergence in *Vicia sativa* and crosses of this plant type, possibly by the imbibition temperature sensitive mechanism previously described for beans. (B) In a 21 — 32° C (70° — 90° F) alternation, when the 32° C temperature was first, germination of *V. angustifolia* was delayed, although in the end this treatment had no effect on total germination.

Based on these observations, I would like to speculate that time-specific, environment-sensitive processes are common in seed germination. Because the responses to these processes are delayed responses, I suspect that many otherwise anomalous cases of plant behavior may be the result of this type of phenomenon.

In terms of practical seed germination technique, this means that we must be very careful to avoid introducing unrecognized and hence uncontrolled variables. One such variable is the temperature of the medium into which seeds are planted. For example, seeds to be placed at an after-ripening temperature of 5° C (41° F) might frequently be planted in a germination medium at room temperature and then placed in a refrigerator. However, because of the length of time required for the germination medium to reach 5° C, such a procedure means that the actual imbibition temperature is much higher than 5° C. In Figure 7 I have plotted the rate of change in the temperature at the center of a plastic box 2.5 x 12 x 12 cm (1 inch x 4½ inch x 4½ inch) filled with moist sand. You can see that it took approximately two hours to cool from 25° C to 5° C (77° F to 41° F). This period is long enough to obscure the existence of imbibitional temperature sensitivity. In the case of dormant seeds which require a low temperature after-ripening period, as far as I know we have no information available on the effect of initial imbibition temperature on subsequent plant response. However, it may well be of importance.

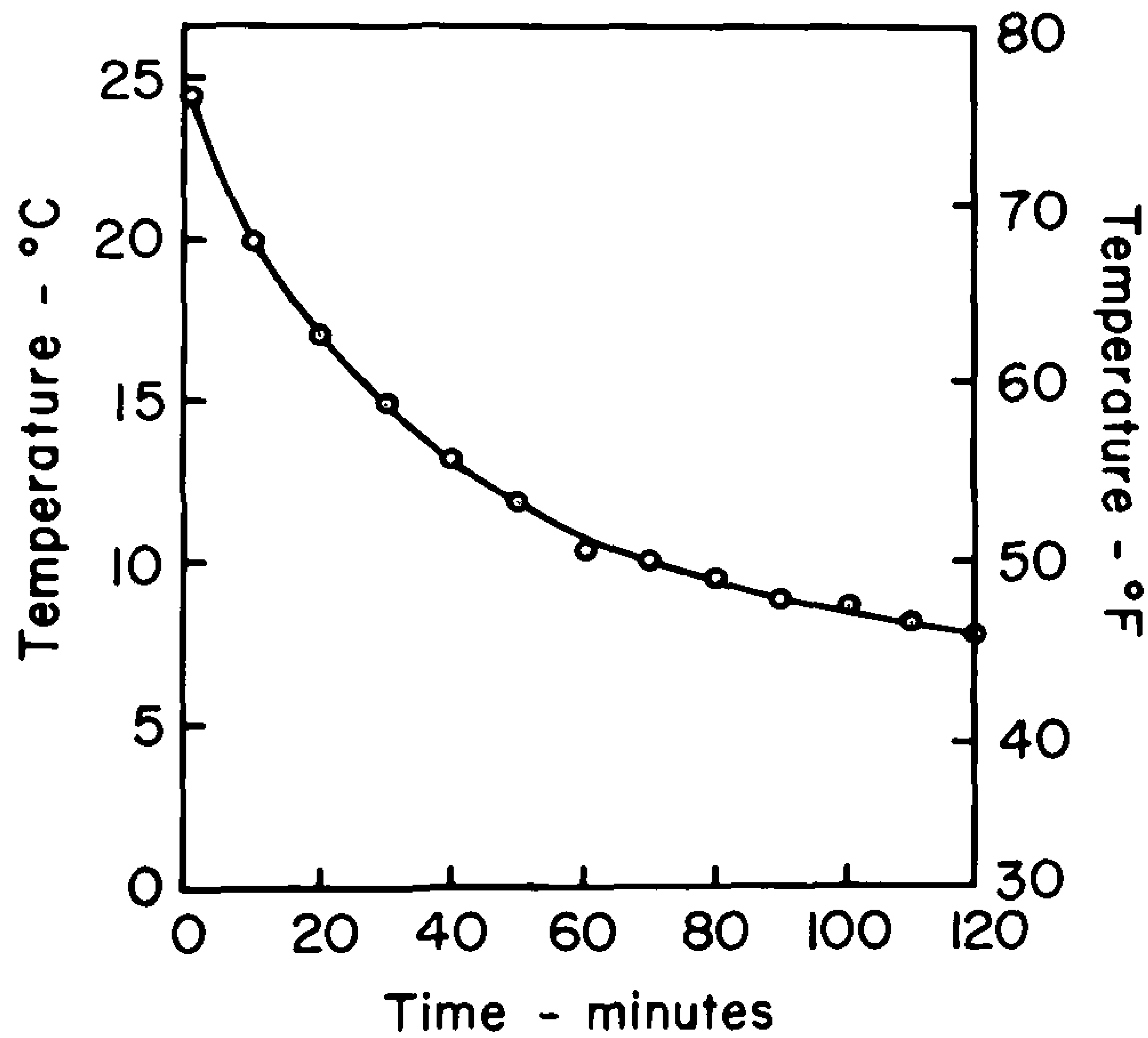

Fig. 7.
Change of temperature in a box of moist sand 2.5 x 12 x 12 cm (1 in x 4½ in x 4½ in) following transfer from 25° C to a 5° C cold room.

With this speculation on the possible importance of time-specific environment-sensitive periods, I would like to return to speculate on the general topic of dormancy. In so doing, I would like to return to the question of peach dwarfing. One of the symptoms of dwarfing is abnormal leaf development which is marked externally by the formation of white "knots" of abnormal leaf tissues (Fig. 8). One of my former students (now Dr.) Melvin Fine examined these abnormal leaf areas and discovered that they are full of fat globules. The peach plant normally produces such high quantities of fat only in the tissues of developing cotyledons. Therefore, this observation suggests that the abnormal leaf areas are functionally cotyledon tissue.

From our current understanding of biochemistry, we know that the formation of fat requires the participation of a number of highly specific enzymes. These enzymes are likely to exist in quantity only in cells which synthesize storage fat. To synthesize an enzyme, the cell needs information on the structure of the enzyme; this information is encoded in the DNA (deoxyribonucleic acid) of the gene. However, most genes are inactive at most times. Before the cells can use their genetic information to produce fat-synthesizing enzymes, the appropriate genes must be "turned on."

Fig. 8.
Leaves from normal *(left)* and dwarfed *(right)* peach seedlings. Figure from *Plant Physiology* 37: 190-197, 1962.

The "turning on" of genes during plant development is something we are just beginning to understand. We know from a variety of data that the process exists and that it is basic to the work of the plant propagator. For example, the changing of stem cells to produce root initials, the key process in rooting of cuttings, must involve the "turning on" of "root" genes in the cells. However, we know little of the details of the "turning on" process, nor how that process is controlled.

Similarly, the change from seed development to seed germination must involve a "turning off' of seed development genes and a "turning on" of seed germination genes. Seed development is primarily concerned with the synthesis of nutrient reserves in the storage cells of the seed. In peach, this means the synthesis of storage fat, and requires the participation of fat-synthesizing enzymes and hence requires that the genes providing information for fat-synthesizing enzymes be turned on.

These are speculations. However, I believe that most plant biologists would accept them as valid speculations on which to plan experiments. The importance of these speculations, coupled to the fat-synthesizing activity in the abnormal areas of leaves of peach seedlings grown from non-after-ripened (dormant) seeds is this: it suggests to me that some of the seed-development genes were not turned off during germination. Further, it suggests that dormancy itself may occur in seeds in which the development genes have not been turned off and the germination genes turned on.

If this is true, then all seeds must pass through a dormant, or resting, stage between development and germination. We can look across the spectrum of seeds, (A) from tree seeds which require long periods of low temperature after-ripening to break dormancy, to (B) grains which are dormant at maturity but which after-ripen in dry storage, to (C) many seeds which are dormant during development but which are capable of germination immediately after separation from the mother plant. From your own experience, I believe that you can name species to fit at all points in this spectrum.

This is speculation. However, I believe that it may be valuable in providing a unifying concept for our thinking and practices in handling dormant seeds. It may serve to focus our attention on what happens between the time that the seed reaches "physiological maturity" and the time that the new seedling is established. It provides a basis for appreciating the possible critical nature and long-term delayed effects of the time-specific processes of which I spoke earlier. I hope that you may find these speculations useful in your daily contact with seed germination problems.

MODERATOR HESS: Thank you very much, Bruce: You are truly an expert in your area.

The next paper was to have been presented by Mr. Brian Humphrey of the Great Britain and Ireland Region, but Mr. Humphrey was not able to be with us because of an unfortunate accident in his immediate family and his paper will be presented by Mr. Richard Martyr.

DICK MARTYR: Mr. Chairman, ladies and gentlemen, I know Mr. Humphrey is a very disappointed man today. He is one of the oldest members of the Society from Britain, having joined well before the G. B. and I. Region was organized and he had looked forward to coming over here and meeting with you.

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THE LARGE SCALE RAISING OF NURSERY PLANTS BY SEED PRODUCTION IN ENGLAND

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THE PAST

Apart from the nationally-owned Forestry Commission which operates several large nurseries mainly oriented toward seed production and the privately-owned forestry nurseries similarly organised, production by seed in most English nurseries has not reached an advanced stage of development or sophistication.

It is difficult to be certain of the reasons for this situation but some contributory factors can be isolated. In broad terms the monetary value of items raised from seed is not so high as clonal forms or rare species produced by vegetative propagation. This has an influence on the owner or management who perhaps erroneously imagines that the higher priced items are the most profitable. Most of the nurseries in England are small in physical size and turnover and also they are heavily biased towards the retail trade. This type of business has few resources for large scale seed production in terms of finance or land. The main requirements are for clonal forms to satisfy the retail trade and the policy, naturally enough, has been concentrated upon purchasing from abroad seed-raised items for use as understocks, etc., rather than attempting to produce them at home. The large and highly efficient seed production nurseries of Holland, Northern Germany,

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THE PAST

Apart from the nationally-owned Forestry Commission which operates several large nurseries mainly oriented toward seed production and the privately-owned forestry nurseries similarly organised, production by seed in most English nurseries has not reached an advanced stage of development or sophistication.

It is difficult to be certain of the reasons for this situation but some contributory factors can be isolated. In broad terms the monetary value of items raised from seed is not so high as clonal forms or rare species produced by vegetative propagation. This has an influence on the owner or management who perhaps erroneously imagines that the higher priced items are the most profitable. Most of the nurseries in England are small in physical size and turnover and also they are heavily biased towards the retail trade. This type of business has few resources for large scale seed production in terms of finance or land. The main requirements are for clonal forms to satisfy the retail trade and the policy, naturally enough, has been concentrated upon purchasing from abroad seed-raised items for use as understocks, etc., rather than attempting to produce them at home. The large and highly efficient seed production nurseries of Holland, Northern Germany, Belgium and Denmark have not been slow to exploit the situation and working largely through the expert Dutch sales organisation have supplied virtually 90% of the requirements in this country for seeding understocks from roses to forest trees.

THE PRESENT

Quite recently there has been a change in attitude in our nurseries and now far greater interest in seed production is evident. There are several reasons for this change. A rising standard of living enjoyed by continental growers has resulted in increased costs with subsequent effects on selling price. The wise English grower realises that this trend is likely to continue. During the last few years requirements for nursery stock, particularly trees, has increased enormously in Great Britain, and in many European countries shortages have occurred and are likely to become more frequent. An increasing trend towards co-operation among growers in England (of which the formation of our Region is just one example) has led to the formation of production and marketing groups with greater opportunities to capitalise, mechanise and rationalise their production. Mechanisation is coming to the larger nurseries also and with it a new approach towards row-cropping and mass production methods, many applicable to large scale seed production.

The grower now has more expertise in his handling of the seed and seedling crops. Members of this Society are able to refer to information made available at past meetings and discuss various problems with their colleagues, experimental work concerned with the production of rose seedlings for use as understocks is being carried out on governmental trial grounds and growers visits abroad have also made great contributions to our knowledge.

The production of small batches of seed under glass or broadcast in small beds in the open has not changed noticeably for many years. This system which is confined to the more exotic species has always been under the direct control of the propagator rather than a specialist seed raising department. Mainly due to the efforts of the Society, more is now understood about pre-sowing treatments, warm and cold stratification and sulphuric acid dips. This has served to raise the status of seed production in the mind of the British propagator who previously tended to look upon it as the "poor cousin," scarcely comparable with propagation by cutting and grafting. Knowledge gained from the application of new techniques to small batches of seed can normally be translated to large scale production.

THE FUTURE

The problems to be tackled in the future fall into the following categories:

1) **Obtaining Seed.** It seems obvious that in the future the seed of very many species previously obtained from collections made in the

wild will be either extremely expensive or unobtainable. The grower will be forced to accept seed collected from arboreta or man-made plantings which may show hybrid characteristics and possible reduced vigour. At the time of writing we are trying once again to obtain seed from the United States of several *Quercus* species including *Q. phellos* and *Q. ellipsiodalis*. The last time we had acorns of these two species was when some were brought back in a suitcase after a visit to the U.S.A.! Co-operation by nurserymen throughout the world could lead to worthwhile sources of native seed being made available.

Frequently the handling of seed by the seed companies is lamentably poor and seed arrives in a dead or dying condition. We now collect as much of our own seed as possible, where necessary using a homemade collecting platform with a lifting height of 28 feet for harvesting seed such as *Acer, Fraxinus, Sorbus* species, etc.

2) **Pre-sowing Treatments.** This is one of the technical aspects which can best be served by experimental work at government level and the normal exchange of knowledge between interested growers and particularly by members of the Society.

I expect to see English growers making much greater use of temperature controlled environments. The cold store will be used as a pre-conditioner to improve germination, and also as a management aid to enable prolonged storage of seed from one year to the next or to delay sowing until soil and season are at an optimum.

The chemical treatment of seed to aid germination by materials such as sulphuric acid is now in use by some growers. Fungicidal seed-dressings are being tried by nurserymen to improve seedling stands and growth. Materials, including Thiram and Captan, have been used. A recent trial of our own showed that a pre-sowing seed dressing of Thiram nearly doubled the stand and has so far increased growth by 50% in Norway maple *(Acer platanoides)*.

3) **Soil Treatment before Sowing.** One aspect of modern technology which will profoundly affect large scale seed production is the increasing use of soil sterilants which if properly used can result in larger, healthier seedlings and significantly reduce production problems by the virtual elimination of weeds and weed seeds. Two materials have been tried in some English nurseries. Metham sodium, either in liquid formulation — known as Vapam — or granular (prill) — known as Dazomet — and methyl bromide. The latter material appears the more successful but it is so expensive that its use is mainly confined to glasshouse conditions. Dazomet is now being used by a few nurseries including ourselves, but is is expensive and can only be justified if one is assured of a good crop. For this reason we tend not to favour it for seed crops. Allyl alcohol has been used by ourselves with variable results. For the present we intend to make our main efforts with this chemical because it has advantages over the other available materials. It is comparatively cheap, only a third the

cost of Dazomet, and a tenth the cost of methyl bromide. It has a short persistence in the soil — only ten days from application to sowing at 50° F, which aids flexibility in use. The main disadvantage of it is the toxicity hazard to the operator. Expensive protective clothing with industrial respirators must be used. At present we are the only commercial company in England with Ministry clearance for its use.

4) **Sowing Techniques.** Unless soil sterilants and residual herbicides of great efficiency can be developed, sowing in drills is likely to entirely replace broadcast sowing. Accuracy of spacing over a wide range of seed shape and size will be required. It is possible that pelleted seed applied by a precision seed drill will become the normal practice for some species as it is already in so many market garden crops.

5) **Care of Seed Beds and Seedlings during and after Germination.** Modern plastic nets and similar materials are likely to simplify and cheapen the problems of frost protection, and protection from the larger pests such as birds. Little work has been carried out in England to establish the value of water sprays against frost damage in broad-leaved seedlings.

More effective materials for use against root-rots and damping-off would be welcomed. At present a mixture of cuprou oxide and Zineb applied as a post germination drench are being used with fair results.

One of the great problems and probably the main limiting factor to seed production in England at present is the problem of weed control. Even if soil sterilants are used weeds are still a potential menace and few chemicals completely eradicate all weeds. The use of residual herbicides as pre-or post-germination treatments is in the long term an unavoidable necessity. Some nurseries, such as ours, are basing their post-germination weed control programme on the so called 'chemical hoes' such as Paraquat. These are mechanically guarded from contact with the seedling crop by some means. In our case this is achieved by a modified steerage hoe fitted with low pressure anti-drift spray jets, the whole being enclosed in sophisticated shoe-shaped cover. Obviously this type of system cannot control weed growth within the row, and we have considered trying a non-volatile, translocated type of herbicide such as MCPB instead of a contact material. In this connection we have been interested in Dacamine which is not marketed to date in Britain. We hope that the herbicide will control weeds in the row which spread out sufficiently to absorb some of the spray.

With the above system some degree of hand weeding is necessary, and regular passes with the chemical hoe must be made. Only a residual herbicide can give extended and effective weed control in and between the rows and in broadcast seeding systems is the only feasible method other than hand weeding.

In roses, PCP (Propachlor) has shown promise. Trials are in progress to screen several materials on a range of broadleaved seedlings at the Ministry Trial Station in Derbyshire. We ourselves have carried out trials with Simazine, Lenacil, Brasoran, and granular CIPC; none of these can, at this stage, be recommended without reservation. Trials with Lenacil over the past two years indicate that it is perhaps the most promising.

MODERATOR HESS: Thank you very much, Mr. Martyr; you did a fine job of presenting Mr. Humphrey's paper, and we are all sorry that he was not able to be with us.

The next speaker on the program is one who does not really need any introduction; he is a past-president of the Eastern Region and a well known seedling grower, Mr. Hugh Steavenson.

SEEDLING PRODUCTION IN THE FIELD

HUGH STEAVENSON

Forrest Keeling Nursery
Elsberry, Missouri

Some of our Western Region friends may wonder about the purpose of field-grown seedlings. I have visited many west coast nurseries, particularly in California, where trees and shrubs grown from seed never hit the "ground" until finally installed in their ultimate landscape location. There is obvious merit in container production and even some field production in starting seedlings in flats in the greenhouse, pricking off into pots and shifting to larger containers or field rows as growth advances; but there are also some limitations and some disadvantages to this procedure as against bare-root production of seedling liners in the field.

For some time — perhaps a few decades — arborists have projected that virtually all trees used in landscape plantings would be of selected clones. This, of course, would necessitate asexual propagation, usually by budding or grafting. Such propagation requires seedling understocks, except in those rare instances in which the clone is grown on its own root or grafted to a vegetatively-produced understock.

Though asexual selections are increasingly moving to the forefront in both shade and ornamental trees and though the merit of many such cultivars over the species is beyond question, it is remarkable that so much current production of trees, particularly shade trees, is of seedling rather than asexual origin.

Several years ago one of the leading arboriculturists of our area pointed out that approximately 80% of the major trees planted in the

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Several years ago one of the leading arboriculturists of our area pointed out that approximately 80% of the major trees planted in the

St. Louis region were either pin oak *(Quercus palustris)* or sweet gum *(Liquidambar styraciflua)*. The picture has changed in the meantime, but not much. This is by no means a healthy situation. For insurance against catastrophe, not to mention esthetic appeal, the distribution among species and cultivars in use should be much, much wider.

Again, though clones of both pin oak and sweet gum have been introduced, they have not really come into the picture in this central region. It is like "gilding the lily" to come up with something better than our native north Missouri pin oak. We have tried introducing the west coast cultivars of sweet gum with disastrous results — they proved tender in our harsh climate.

At our nursery we grow around 100 acres of caliper or "specimen" trees. We try to keep in production nearly all of the better asexual selections and patented varieties suited to our climate and we do not for a minute discount their merit; but from a strictly economic stance, we make more money from our seedling-produced specimens than we do our clonal varieties.

I much prefer a shade tree grown from a seedling rather than a graft **unless there is a marked improvement in the clone.** Among the major trees, no one questions the superiority of several clonal honey-locusts, maples, beeches, ashes, male ginkgo, willows, poplars, lindens and sophora, to mention some. But unless this superiority is definitely established, the problems arising from grafted trees offset minor "improvements."

In a recent meeting, one of our midwest nurserymen exploded in wrath when he described how a windstorm had neatly laid down a whole street planting of grafted trees, toppled right at the graft, after they had flourished for several years. We all know that compatibility problems may not be manifest for years after propagation.

Our mid-Mississippi valley region is rich in beautiful oak species that have been little exploited for landscape usage. We have grown several cultivars of sugar maple, but I can tell you that we have made our money on our seedling-grown sugars. The same is true with such species as amelanchier, white birch, Chinese chestnut, redbud, sweet gum, tulip tree, mountain ash, *Elaeagnus spp.* pines, firs, semi-dwarf maples, certain dogwoods and bald cypress.

We have tried just about all the recommended *Crataegus* varieties. The upshot of all this testing is that the easy winners in our region are the native species, especially Washington *(C. phaenopyrum)* and cockspur *(C. crus-galli)* hawthorns.

Some of the clonal lindens stand out head and shoulders — 'Greenspire', 'Redmond' and 'Princeton's Silver', for example. But we also have done very well with seedgrown American linden and the European *Tilia platyphyllos*.

Something else about field-grown seedlings of trees, shrubs and vines: growing under open field conditions, exposed to all the elements and full sun (we use no shade whatsoever) they are well suited for growing on in the field or container. We are convinced that a one-year seedling, size for size, is far superior as a "liner" to an older seedling. For example, a one-year 12 to 18 inch silver maple *(Acer saccharinum)* will simply run away from a two-year 4 to 5 foot liner. For that reason, we attempt to provide optimum growing conditions to produce a seedling liner of suitable size in one year. This entails a soil building program plus continuous feeding, irrigation, and a disease and pest control program. Needless to say, we strive never to let weed competition become a deterrent to growth. Because of the increasing demand for larger, heavier caliper seedlings, we continue to decrease stand population. We used to shoot for about 25 seedlings per square foot of bed. Now we are down to around 10 or 15.

We are mightily impressed with what some of our northwest friends are doing with electronically-controlled automatic solid-set irrigation and we are moving in this direction as fast as we can.

Many one-year seedlings, properly grown, harvested, stored, shipped and planted, yield amazing growth response. Certain species (by no means all!) can be planted in a 5 gallon container in the spring and grow into a 5 to 6 foot or even a 6 to 8 foot tree by autumn. While field lining is rarely this spectacular, we can point to a number of cases at our nursery where such seedlings have overtaken 5 to 6 foot or 6 to 8 foot branched tree liners within 2 or 3 years.

Another point anent field-grown vs. container-grown plants, whether seedlings or specimen: we in the East are getting a beautiful indoctrination into a problem long cognizant among western landscape planters — container-grown tree roots are loathe to leave their soil ball and grow out into the surrounding soil in which planted. This situation, commonly referred to as the "interface" problem, is supposed to be overcome by growing the container plant in a medium similar to that of the planting site and by allowing the plant to remain in a given container a minimum period.

Even with these safeguards many of us are having "the devil's own time" in getting container-grown tree roots to leave their soil balls. The problem is pernicious even with trees that have been in a container but a single season. Such trees will often desiccate and die while the surrounding soil is saturated. (This illustrates the fact that soil moisture moves vertically, not horizontally.) We can slit the ball in several places to discourage the encircling roots; we can devise elaborate means of injecting water into the soil ball, and still have trouble. Once the roots start encircling the container wall (and this can happen in a few weeks) the prognosis is for root girdling some years in the future.

Such difficulties with container trees have created renewed interest in field-grown bare-root or balled stock. We also observe that plants grown in containers with permeable walls such as peat pots, fiber containers, and possibly boxes, are less subject to the pot-bound condition associated with solid-wall containers. (If I sound a little uptight on container-grown trees, let me hasten to add that we grow, buy and sell them at our nursery. Their advantages are obvious and I only hope some genius will solve the interface and root-girdling problems.)

I will briefly cover some techniques for field seedling production. Seed source is obviously vital. If you cannot harvest your own fresh seed you must depend upon reliable collectors or suppliers. There is excellent literature available on the storage, pretreatment and after-ripening requirements of just about any species you might care to propagate. Even so, we run into sticky problems with certain species and have been aided greatly by communicating with our research fellow members, such as Al Fordham, Henry Heit, Harrison Flint and others. Certainly the basic guide in handling seed and securing satisfactory germination is to observe Mother Nature. You won't go far wrong in sowing when she normally disseminates. Of course, if she has arranged to perpetuate the species by having germination strung out over 10 years, you will prefer to fall back on one of the man-devised techniques for securing more prompt and uniform germination.

I have been growing seedlings for some 30 years, but I am happy to see the young fellows in our organization improve on my practices so we can usually count on regular stands of the so-called "two-year" species and other toughies; not that we come through with flying colors on all items we would like to grow. For example, we know how to germinate such desirable natives as paw-paw *(Assimina triloba)* and sassafrass *Sassafrass albidum* var. *molle;* Syn *S. variifolium)* but we have a frustrating time coming up with economic stands. We would like to hear from those who are successful with these species.

MODERATOR HESS: Thank you, Hugh. Our next speaker is Mr. Bruce Usrey who will speak on seedling production in structures.

SEEDLING PRODUCTION IN STRUCTURES

BRUCE USREY

Monrovia Nursery Company
Azusa, California

The seed propagator prior to 1945 believed that the only things that affected seed germination were viability, water, free oxygen, heat, age and maturity of seed, and it was with these things the seed propagator worked with to improve his stand. Once the seeds had been received, treated and sown, the propagator had only heat, and water to fiber containers, and possibly boxes, are less subject to the pot-bound condition associated with solid-wall containers. (If I sound a little uptight on container-grown trees, let me hasten to add that we grow, buy and sell them at our nursery. Their advantages are obvious and I only hope some genius will solve the interface and root-girdling problems.)

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During this time the propagator used lath or brush structures to protect his seeds from the direct sun and rain. Later he used frames that he filled with manure for heat and covered with glass sash or boards for protection from the elements. Prior to World War II the glass house came into great use for seed propagation and is still used as the primary seed propagating structure. The seeding techniques used in benches or beds prior to World War II has been eliminated by the ease with which flats and pots can be sterilized and moved through the nursery.

Today the germinating medium might be sterilized peatmoss, sphagnum moss, sand, perlite, vermiculite or a combination of these items. It has been found though that two parts peatmoss and one part sand is ideal for 95% of the propagator's requirements. Many growers use a sterilized cracked granite as a top dressing on flats, as it dries rapidly after watering and holds the seeds in place as they germinate, forcing the root into the medium. Seeds are treated for fungus diseases with Thiram or Arasan dusting at planting, or Captan when seeds are germinating. For damping-off disease control, use of cracked granite reduces chances of mycelial growth over the surface as a consequence of its organic-free condition.

Today the seed propagator has eliminated the brush and lath as shade, but uses Saran which diffuses the light and reduces drip damage. This structure is used for slow-to-germinate items (1 to 3 years for cotoneaster) that do not require winter protection or heat for germination.

Today the frames are used where heat is not required but protection from rain is required. The frames are covered when rain comes with either glass sash or polyethylene covers. This protects the seeds and young seedling flats of pines and cedars from becoming water soaked and promoting the damping-off diseases.

Today the modern greenhouse made out of glass, fiberglass or polyethylene with its automatic controls hardly resembles the glasshouse prior to 1940. The best material is still glass with its adaptability for shading and light transmission to fit the varying seasons' requirements, even though fiberglass or polyethylene is considerably cheaper.

In the glasshouse the propagator has control over light, ventilation and heat. Light is controlled by shading on the house, but when more protection is required portable covers of Saran, muslin, newspaper or polyethylene are used to protect the young seedlings from sunburn or rapid drying when seeds are sown on the surface. Light intensities should not be decreased to the point where etiolation of the seedling takes place or disease control becomes impossible due to loss of ultraviolet rays.

During the summer, high temperatures can be as critical as low temperatures during the winter period in damaging the young seedlings and seeds. For this reason ventilation during the summer should be adequate to maintain a temperature that doesn't exceed 90° F with the amount of light transmission desired to prevent burning of the young seedlings. In the industry this is done economically in the East with exhaust fans and in the dryer areas with exhaust fans and evaporative coolers to maintain at least 50% relative humidity. Throughout the year the ventilation system should be used in the morning after watering to provide air circulation in the house and to dry the seed bed surfaces rapidly to prevent the damping-off diseases from having a chance to establish themselves.

Most seed germinating houses contain two or three different heating methods to make the house more flexible for seed propagation. Direct heat from the sun is usually adequate to maintin the desired temperature during the day for most seeds. At night though, you find direct heat being supplied from electric cables or hot water heated benches, keeping the seeds at 70° to 85° F. The rest of the house will be in the range of 65° to 70° F, using indirect heat from hot water or steam in preference to gas heaters which have a drying effect as well as possible damage from leaks or poor ventilation.

In our fern propagation operation, most of the spores are gathered locally off of specimen plants at our nursery or specimens at botanical gardens in the area. The fronds are dried over newspapers where the spore will drop. These spores are not treated with any fungicide or treatment prior to being blown onto sphagnum flats that have been steam sterilized at 180° F for three hours to kill any diseases present. These spores are sown throughout the year and will take 9 months to reach the first transplanting stage, (the sporophyte stage) when they are moved into flats. Disease control is by airing and watering practices, as fungicides have been found to be extremely harmful to the spores. The transplanted ferns grow 6 months in the flats, then they are moved into a 2¼ inch pot for 6 months, and finally shifted into a 3 inch pot for another 6 months before sale or canning. In the fern house we use cooling fans, heavy whitewash, muslin covering and plastic cover to keep a low temperature and a high humidity over the young gametophytes and ferns.

Today the propagator uses a controlled environment structure, one that is economical and practical to control light intensity, temperature, relative humidity, air movement, water quality and nutrient watering.

The propagator of the future will have some of the following advanced things to work with in seed germination:

> The U.S.D.A. Phyto-Engineering Laboratory is now working with automatic surface and sub-irrigation systems that have been found to be beneficial with nutrient watering as

frequently as 8 times per day. This will replace the hand checking and watering of flats used today by most nurseries (1). They have also found that high intensities of light up to 2500 ft-c during a 16-hour day will almost double seedling growth.

The use of carbon dioxide enriched atmosphere has been found to be beneficial for some plants at concentrations of 1,000 to 2,000 parts per million. However, the concentration varies with temperature and the variety being grown and at the present time is impractical for the commercial grower (1).

The use of ultra-violet light to prevent disease on some highly susceptible varieties is impractical now but should be feasible in the near future.

We are now testing the feasibility of negative or neutral atmospheres by changing the positive ionization now found in propagating structures to stimulate seed germination and seedling development.

There is much that we have to learn in the development of a controlled environment house so that the research being done now can be put to economical use. But, the initial investment in research should be off-set by the return from faster and better germination, better disease control, and a strong and vigorous seedling for growing on. I believe the time from sowing to sale can be cut from 50 to 75% by correct utilization of a controlled environment house.

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MODERATOR HESS: Thank you, Bruce. Our next speaker is known to all of you having been on our program many times. He will speak on upgrading *Magnolia virginiana* seedling production. I present to you Mr. Joe McDaniel.

JOE McDANIEL: I wish to acknowledge two of our members who did much of the field testing upon which this paper is based; these are Tom Dodd, Jr., and Don Shadow.

TWO CULTIVARS FOR UPGRADING MAGNOLIA VIRGINIANA SEEDLING PRODUCTION

JOSEPH C. McDANIEL

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This paper concerns a magnolia species for which seedage methods are well established and in which the past American nursery production has been mostly by seedage or collected seedlings. Named clones now are becoming available, most of them adaptable to cutting propagation. Two of the new cultivars at least, and probably others still to be tested, offer seed sources with which seedling growers can upgrade their production in this species — for uniformity, for wide general adaptability, and for landscape quality — above the average obtainable from unselected seedlings. In this respect they parallel the superior seed sources which are being discovered in many other genera of ornamental trees and shrubs.

There is much botanical and horticultural diversity within *Magnolia virginiana* L., the sweetbay magnolia. First, botanically, there is the typical variety, *M. v.* var. *virginiana,* which is the one most frequently cultivated in America. Its natural range is along the Atlantic Coastal Plain, mainly northward from Savannah, Georgia. It occurs, or once did, from eastern Georgia to New Jersey and Long Island, with a northern outpost at Magnolia, Essex County, Massachusetts. This variety varies from a multistemmed, arching shrub to a small tree, largely deciduous when mature under northern conditions, and its plants are highly compatible to their own pollen.

Trees of the second botanical variety, *M. v.* var. *australis* Sarg. are less often cultivated but are found wild in large numbers near the coasts southward and westward from Savannah, going as far south as the Florida Everglades, westward into east Texas, and inland to outposts in Hot Spring County, Arkansas, McNairy and Polk Counties, Tennessee, and Polk County, North Carolina. In favorable southern sites *M. v. australis* grows to a large tree size. It is not always fully evergreen, but some clones of it are, even when cultivated as far north as U.S.D.A. Plant Hardiness Zone 5. Two characters that will nearly always separate the sometimes disputed *M. v. australis* from the northern variety are the stronger, more lemon-like odor of its flowers, and their general self-incompatibility. The typical northern variety and its pubescent form are both self-compatible.

Either botanical variety, I have found, will set seeds to pollen of the other, and at least some of my fertile intervarietal hybrids retain the self-compatibility of *M. v.* var. *virginiana.* Some individuals of both varieties will produce hybrids when pollinated by *M. grandiflora*;

they can also sometimes produce apomictic seedlings when stimulated by pollen of *M. grandiflora* or more distantly related species. Other hybrids, sterile or virtually so, have been produced by crosses between *M. virginiana* var. *virginiana* (as seed parent) and the species *M. tripetala* and *M. obovata (M. hypoleuca)*. Our hybrids with *M. guatemalensis* and *M. macrophylla* are too young to have flowered.

The cultivars, including interspecific and intervarietal hybrids, can be reproduced clonally by cuttings or by grafting. Grafting, so far, seems the only practical method for the hardy evergreen *M. v. australis* 'Henry Hicks'; several expert propagators have failed to root cuttings of it. Two superior cultivar forms of the northern variety, *M. virginiana* var. *virginiana*, on the other hand, have now been tested enough that I can recommend them not only as clones but as seed sources for the production of distinctive and quite uniform lots of seedlings. They have been tried in nurseries over a wide climatic range, from Zones 5 through 9. Both parent plants have long proved hardy in central Illinois upland prairie soils. Their grafts and seedlings have been adaptable also to more southern conditions. For one source, the known adaptation goes as far south as Tampa, Florida. The other is very good, at least to extreme southern Alabama, and probably would also grow south of there. I wish to thank cooperating members Tom Dodd, Jr., Semmes, Alabama, and Don Shadow, Winchester, Tennessee, as well as Tampa landscape nurseryman Jack O. Holmes for their rather extensive field trials which enable me to recommend both the 'Havener' and the 'Mayer' cultivars of *M. virginiana* as reliable seed sources. Treseders' Nurseries are now testing both cultivars in Truro, Cornwall, England.

Magnolia 'Havener' has recently been given cultivar registration with the American Magnolia Society. The original tree stands about 28 feet tall, full size for *M. virginiana* under Midwest conditions, in Mount Pulaski, Illinois. That little community probably has more old sweetbay magnolia trees for its size than any other Illinois or midwestern town. They are not part of the original flora there, but have been cultivated in Mount Pulaski since a local nursery propagated them some time in the late 19th century. *Magnolia* 'Havener' is extreme among all northern variety sweetbays I have seen for its large flower size to 5 inches across, and the high average number of petals per flower. Typically, in both *M. v.* var. *virginiana* and *M. v.* var. *australis*, the flowers have 3 sepals and 8 petals. Most *M.* 'Havener' flowers have extra petals, from 12 to as many as 20 on some. Their color also is rather unusual, being a light creamy shade, with some slight tinge of pink toward the inside base of petals. I have seen this flower coloration in other northern sweetbays, but without the "doubleness" of *M.* 'Havener' and its seedlings.

Don Shadow, of the Tennessee Valley Nursery at Winchester, Tennessee, now has raised several hundred seedlings from *M.*

'Havener' to flowering age. When I examined them there at the end of May, 1970, they were remarkably similar to the parent clone. While there were some variations in flower size, and in the degree of pink inner blush, nearly all flowers had more than 8 petals; all were creamy, and all showed some pink near their centers. Perhaps even more significant from the point of landscape value was their uniform habit contrast with hundreds of typical *M. virginiana* seedlings in adjacent rows, grown from a New Jersey native seed source. The *M.* 'Havener' seedlings were stockier, more fully furnished with lateral branches, and their larger flowers were more abundant than on the New Jersey source seedlings (one year older) under identical culture.

Magnolia 'Havener' is clearly a superior seed source for tree-type *M. virginiana*. The owners of the original tree have given me seed picking privileges in late summer. If there are not enough sample packets here to go around, write to me and I probably can supply you with a start. Scionwood also will be available in the winter season. At Semmes, Alabama, Tom Dodd finds that "cutting material of *M.* 'Havener' roots as well as other *M. virginiana* and certainly better than *M. grandiflora*. We have had good success with seed but prefer cutting-grown plants."

The second seed-reproducing source is a distinctly shrubby, precocious and free-flowering sweetbay form grown from Prof. Robert W. Mayer's plant in Champaign, Illinois. Indirectly, we can thank Mount Pulaski for this form, also. Prof. Mayer grew up there, and knew *M. virginiana* from his childhood. In landscaping his new home, he obtained two plants from a former Urbana nursery, whose original source is not known. The better performing one, progenitor of *M.* 'Mayer' is a multistemmed, narrow-leaved shrub, now mature at about 9 feet tall. Its abundantly produced eight-petalled flowers are in the average size range for the species. Its seeds are unusually small, the smallest I have seen in the genus, and lighter colored than most other *M. virginiana* seeds.

Open-pollinated (mainly selfed) seedlings from *M.* 'Mayer', reproducing its shrubby, precocious habit, are thriving in Mobile County, Alabama, and at Tampa, Florida, as well as in Champaign County, Illinois, and intermediate points. They frequently flower before they are a foot tall. In the lower South, they are nearly evergreen. Both the original *M.* 'Mayer' and its seedlings are readily rooted from summer cuttings under mist. They should fill a need for many nurserymen, north or south, who want a reliably shrubby, easily reproduced type of sweetbay. The Tom Dodd Nurseries can supply other propagators with seedlings of *M.* 'Mayer'. I also expect to be able to supply some seeds and cuttings of the original plant.

Both *M.* 'Havener' and *M.* 'Mayer' probably owe their uniformity of seed reproduction to the attainment of a relatively homozygous condition through past inbreeding. While they are both self-compatible, I have found that they are capable of outcrossing with other plants of the species. It is suggested, therefore, that plantings of either cultivar intended for seed production be established at a reasonable distance from other *M. virginiana* plants.

In my magnolia breeding, I have tried both *M.* 'Havener' and *M.* 'Mayer' as parents for controlled crossing. *Magnolia* 'Havener' has so far been difficult to use as a seed parent in several attempted crosses, but I do have one intervarietal hybrid lot from pollinating it with a *M. v.* var. *australis* clone from the Florida Everglades. When *M.* 'Havener' was pollinated by *M. grandiflora* or by *M. macrophylla,* the resulting seedlings all appeared to be apomictic, and not hybrid.

Magnolia 'Mayer' has been a more productive seed parent in crosses. I have seedlings from crossing *M.* 'Mayer' x *M.* 'Havener' (not yet flowered) and from several different *M.* 'Mayer' x *M. v. australis* and reciprocal combinations. *Magnolia* 'Mayer' x *M. v. australis* 'Henry Hicks', for instance, gave all intervarietal hybrids as judged by their pubescence and the intermediate odor of flowers. This lot of intervarietal hybrids has been as precocious and almost as dwarf as the presumably selfed seedlings of *M.* 'Mayer'. I am carrying it to another generation by selfing and by back-crossing to *M.* 'Henry Hicks' and other *M. v. australis* clones. Some clonal introductions are anticipated from this line of breeding. The F_1 hybrids are cutting-propagated as readily as *M.* 'Mayer' and most other *M. virginiana* var. *virginiana* clones.

MODERATOR HESS: I'm sure we all appreciated your talk, Joe. We now come to the critique portion of the symposium and I'll call on Charley and Andy to take over the program at this time.

ANDY LEISER: The first paper on this afternoon's symposium concerns seed source and was presented by Harrison Flint. He indicated that this was also my research interest and I heartily second his remarks. There is one point, however, which I would like to re-emphasize and that is the problem of hybridization between species and variations within the species, but particularly between species in domestic collected seed. This can be quite critical in certain groups, particularly in the rose family, hawthorns, cotoneasters, pyracanthas and, in California and the warmer areas of the world, it is particularly important in the eucalyptus. We have had some problems in California with seed of eucalyptus obtained from commercial sources in that at the end of an experiment we found there was more genetic variation between the plants than there was between our treatments. This can be very disconcerting; to the homeowner expecting a certain leaf type or form it can be disappointing and costly.

One other point of Harrison's talk which I would like to re-emphasize, and with which I have been concerned, is the so-called provenance selections, in which we are concerned with the variation among seed lots from different geographic locations. In ornamental horticulture I think we can come down to much smaller geographic areas than the provenance areas. We're finding considerable variation in seedlings from seeds which were collected only 7 or 8 miles apart. Thus, in some instances, even these small distances can result in extreme differences in the performance of the plant under cultivation. We are calling this "ecotypic" variation to separate it from the provenance designation which the foresters use. I feel that in the future we will become more and more concerned with this ecotypic variation.

One other point is that many of our main horticultural plants have been introduced only once and we have a very limited gene pool in these plants. *Pittosporum tobira* is an example of a plant which might have much more variation if it were re-introduced from the wild, particularly if selected over a wider geographic area. This would allow us to look for a wider seed source variation among these plants. The seed currently collected from domestic sources may have all been derived from a single original introduction.

CHARLEY HESS: I take exception to one thing Harrison said; "that it is cheaper to buy." I assume this was taking into consideration that there was a good seed source and that viability was good, etc. Borrowing from my brother Hans' experience with Japanese maple, he can select much better seed of much higher viability than he can import from Japan. There is also the possibility that a known source has limited controlled crossing and, therefore, the possibility exists of consistently obtaining a desired type of plant from seed propagation. As an example, some work being done at Rutgers indicates that we are leading towards a pink flowering dogwood which would come true from seed by having it cross with its own parents. Red maple is another example in that if the seed source is carefully selected you can often get populations with a high percentage of red-leaved individuals. Under these conditions there are distinct advantages for the nurserymen to collect his own seed rather than to purchase it. Harrison, would you like to challenge these remarks?

HARRISON FLINT: No, I don't wish to challenge your remarks. But my comments were made assuming equal qualities available.

CHARLEY HESS: Are there any questions or comments at this time?

RALPH SHUGERT: With seed that requires pre-treatment it is very important to keep records concerning the source and viability of that seed. You will find that with some seed the pre-treatment such as hot water soak and/or number of days in stratification can vary considerably depending upon the source of the seed; this is particularly true with *Robinia* seed. Whether you have a small amount or a large amount of seed, you should keep these records so that they can be referred to later.

ANDY LEISER: Since there are no further comments, we will move on to the next paper. As Dr. Pollock pointed out, very few new concepts in seed dormancy have been found in the last 30 years. This was one of the most exciting papers I have heard in some time because of the concept of the timing and interaction of temperature and moisture which he pointed out. In fact this was a take-home lesson for me because now I know why the beans I planted last spring followed by a week of cold weather, gave me a less than a 25 % stand, while with seeds planted out of the same package one week later I got nearly a 100% stand.

Charley, I am wondering if you think we can extend this idea of "turning on the genes" which Dr. Pollock mentioned in respect to his work to "turning on the genes" which changes the vegetative above-ground tissues into root initials and root promordia?

CHARLEY HESS: Yes, I do, but first I would like to say that I enjoyed Bruce's paper very much and I believe his approach is one that will lead to significant new developments in the concepts of seed germination and dormancy problems.

The concept of gene action regulating root initiation is very applicable to germination problems, dormancy, root initiation, and juvenility. Our present approach in studying easy and difficult to root plants involves taking a look at enzyme systems which are involved in the process of root initiation. We have tried for a number of years to find mobile rooting substances; these can be extracted and reapplied to the difficult-to-root cutting, but yet the plant still remains difficult to root. Under these conditions we feel that what may be limiting are certain enzyme systems which have not been "turned on." Are there any questions at this time?

MR. UHLINGER: What temperature do you use when imbibing the seed prior to giving them the experimental conditions?

BRUCE POLLOCK: We routinely use 25° C, though with some seeds a higher temperature might be better.

MR. UHLINGER: I would also like to ask what you think of high temperature during acid scarification treatments for hard seed coats during this critical time?

BRUCE POLLOCK: Your question touches on an area which I think we need to begin to look at with respect to high temperature sensitivity. As I pointed out, the only data I have concerns herbaceous species. There are a number of pieces of evidence accumulating which indicate that there are some problems in this area. I can't give any good answer here, but I do believe this should be looked into.

CHARLEY HESS: My only comment with respect to Brian Humphrey's paper is that I am sorry that he could not be here with us to deliver it in person. It was an excellent paper on the practical techniques used in England. Perhaps Dick Martyr would be willing to answer any questions concerning seedling production in England.

ANDY LEISER: I would like to know if there has been any attempt to use the field steam-sterilization techniques such as has been used in California with movable steam-rakes?

DICK MARTYR: Quick-steaming as we call it has been used only for frames. There has been a tremendous increase in chemical sterilization during the past few years.

ANDY LEISER: Are there any weed-control chemicals which you use in England which we do not use here?

DICK MARTYR: I don't think so. I assume you have used allyl alcohol in the past.

HUGH STEAVENSON: We used allyl alcohol several years ago but have somehow gotten away from it. We applied it through our irrigation system. It is considerably cheaper than some of the other fumigants. We had very good results with this material and I think perhaps we should take another look at it.

CHARLEY HESS: What is controlled by the use of allyl alcohol?

HUGH STEAVENSON: Essentially, just weed seeds. Ralph Shugert has had some amazing results with Treflan on seedling areas. I was wondering if he has any further report on this work.

RALPH SHUGERT: Hugh is referring to some work which I reported at Fresno, California and can be found in Volume 18 of the Proceedings. My work in Ohio has been on perennials. I've used Dacthal over the top of germinating seedlings of perennials. If you use Dacthal you must have true leaves formed or the seedlings will be killed. Two applications of 12 lb. of Dacthal per acre spaced 45 days apart on perennial beds have been subsequently maintained with four girls after the area was cleaned the first time. Dacthal costs about $18.50 an acre applied; this includes the cost of material, tractor costs, operator, and about a 16 % overhead figure tacked onto that.

CHARLEY HESS: While we're on the subject of herbicides, has anyone observed any problems with cuttings or grafts where the scions were taken from stockblocks which were treated with herbicides?

BILL FLEMER: In one case I am aware of, the problem involved rhododendron cuttings taken from the propagator's own stockblocks which had been treated with Casoran herbicide. He also had some cuttings which did not come from treated stock plants, which were made at the same time. Those from the Casoron-treated stock plants were a total loss while he got the usually expected rooting from the cuttings from the untreated plants.

ROBERT GARNER: I received quite a shock concerning some grafts of Mazzard cherries, *Prunus avium*. I had treated the stocks with Simazine when they were planted in the winter; then I budded them in August and this spring I was very disappointed in that in only a few cases did the buds start. Since then another similar situation has occurred in a nursery in England on ornamental cherries, I suspect the trouble may also be caused by treatments with Simazine.

CHARLEY HESS: If you are using herbicides on your stock-blocks it would be well to keep one area which is not treated so that you can know whether you are getting any deleterious effects from the use of herbicides on your stockblocks. I would encourage University workers to check this out under controlled conditions.

At this time I think we should discuss the next paper, that of Hugh Steavenson's, in which he brought up the problem of an "interface" which occurs in the case of planting canned stock. I was quite interested in this problem because theoretically one would assume that with a container plant you would not disturb the roots so it would carry on without interruption, but from what Hugh has reported it just doesn't work that way.

ANDY LEISER: Did you have the same kind of soil mix in the old and new container, Hugh?

HUGH STEAVENSON: The soils were similar but not necessarily the same. In my opinion, this is really not much of a problem with shrubs and evergreens, etc., in that the root binding will hold them back and keep them dwarfed thus making them salable for longer periods of time. But in the case of shade trees, if it is going to root girdle and die after about 10 years when it is just beginning to come into its own — then this is a different problem and can be a serious one.

ANDY LEISER: There are three problems, as I see it, with container-grown plants. One is the interface problem; that is, the problem between the difference in the soil in the container and that into which the plant is planted which sets up a water relationship problem. There is also a problem of actual or potential root girdling which is different from just pot binding; and there is a third problem which we, for want of a better name, have been calling stagnation. None of these problems are good and all of them need further study.

The stagnation problem is evidenced by plants which have been held too long in containers and are then planted out, and in some cases 2 or 3 years later the plants have still not started to grow. Sometimes drastic pruning will cause the plant to resume growth. We had a particular problem with Bradford pears in which one group was held in 3-gallon egg cans for 2 years and a second group for only 1 year. These were then lined out in the field and when measured three years later, those that were in the cans for only 1 year were uniform in size with a 4 inch caliper and 14-15 ft. tall, while those that were in the cans for 2 years were not uniform and only one of them was as large as the pears that had been in the cans for only 1 year.

BILL CURTIS: For a number of years I grew Colorado spruce *Picea pungens* 'Glauca' in beds until they were 12 to 14 inches tall and then transplanted them into the field. One year I grew some of the spruce in gallon cans as well as in beds and at the end of 1 year they were the same height. I then planted these into the field and at the end of 2 years in the field the plants which had been in the gallon cans were 2 grades higher than those which came directly out of the beds. I believe the problem you are encountering is the result of plants being too pot-bound. Once they become pot-bound they will just not strike out and grow.

CHARLEY HESS: Moving on now to the paper by Bruce Usrey I would like to start off by asking Bruce what is negative ionization?

BRUCE USREY: It's a system which is used to reduce static electricity.

CHARLEY HESS: Have you used these units long enough to see any results as yet?

BRUCE USREY: No, not as yet. We've had some problems in getting the units operating properly.

CHARLEY HESS: This is certainly an interesting idea and we'll be looking forward to reports in the future on this.

RALPH SHUGERT: I'd like to thank both Andy and Charley; this was a unique experience for the Eastern Region, that of critiquing the papers, and I think they did an outstanding job. I also want to thank Hans Hess for a fine job of moderating the symposium this afternoon.

I declare this afternoon's symposium adjourned.

GROWTH REGULATION: THEN, NOW AND HENCE

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I think plant propagators are among the most fortunate of men. In the first place, the work that they do doesn't add to the world's burden of pollution and misery; it works in the opposite direction.

More importantly, however, plant propagators work in the presence of the great mysteries of biology because certain aspects of plant propagation involve some of the most mysterious and remarkable phenomena in the whole world of biology. Of these we know very little. I am not referring to the processes of budding and grafting, because when you take a piece of a plant and apply it to another plant it is essentially tissue culture, except that instead of hiring a technician to make up the nutrient medium you hire a stock plant to do it for you. On the other hand, seed germination is an extraordinarily complex and beguiling phenomenon. Some seeds need only water and they germinate, but some seeds, as you know, go through a period of dormancy which is a term behind which we hide our almost total ignorance of the phenomenon. Such seeds require some sort of a triggering mechanism which in itself is mysterious and can be different in different seeds.

Some years ago I studied one of the seed types which requires light, the black-seeded lettuces like the variety 'Grand Rapids.' They require fantastically small amounts of light. If you soak the seeds and keep them in the dark about 30 seconds exposure to an ordinary red bulb at a distance of several feet is enough to give 100% germination. Without this treatment germination is about 5%. The seed are so sensitive that some lots which may germinate to the extent of 20% or more in the dark do so (I think) because on the day they were harvested it was either moist or raining and they received a small amount of moisture and light during this time; thus they were able to get a small fraction of the necessary light stimulation and give a higher percentage germination. The remarkable thing about this process is that if instead of exposing them to red light you dip them briefly in gibberellic acid solution it has exactly the same effect as light and you get 100% germination in total darkness; that is, you do not need any red light. We thought, perhaps naively, that this meant that red light stimulated the plant to produce gibberellic acid. Upon extracting the seed, however, it turned out that they produce no more gibberellic acid than normal and that while both light and gibberellic acid act on the germination process, they evidently act on different stages of it.

Gibberellic acid in seeds stimulates the production of enzymes which hydrolyze the endosperm. By breaking down the endosperm tissue it makes food available to the embryo and thus stimulates germination. One can do the same thing by taking a very fine needle and injecting a small amount of enzyme into the seed; this starts the processes and you get very good germination. This proved what we were looking for, namely that the triggering phenomenon which starts germination is the making of soluble material available to the embryo. Since this can be done then by the application of either gibberellic acid or red light, it follows that the effect of giving the seed light is, in principle, the same as that of giving it gibberellic acid in that it enables the embryo to push its way through the outside coating. If with a very fine needle you prick or break the seed coat in exactly the right place in total darkness you can get nearly 100% germination.

There are, however, a number of seeds which are just the opposite of lettuce in that they are inhibited by light. We studied several of these and curiously enough found the same thing, namely that gibberellic acid stimulates them to germinate; here gibberellic acid acts like darkness rather than like light. Once again we found that if you make little holes in them at just the right places, they will germinate in light without any other treatment. So in all these cases, we have to deal with this mysterious triggering reaction whereby either soluble material is made available to the embryo, increasing the tendency of water to enter, or else the seed coat is softened by enzymes so that the embryo can find its way out of the seed. It is these first reactions which are the most difficult to study.

The rooting of cuttings, I believe, is even more obscure because here we must deal with something whose very basis we have no way of understanding. Cells within the stem are perfectly happy to be stem cells — if they are near the epidermis they would make chloroplasts and turn green, if they are near the cambium they might participate in the formation of extra cortex — but in any case they are stem cells and they know that it is their job to elongate with the stem and be a part of the cortex. But then along comes some plant propagator who cuts off this stem and gives it some stimulus, whatever it may be, and these cells entirely change their whole habit of life and instead of being stem cells they no longer know how to make chloroplasts, they don't elongate with the stem, instead they divide like mad, perpendicular to the axis. They then grow out at a characteristic angle to the stem instead of being aligned with the long axis of the stem. They now have their own characteristic angle at which they grow out or even straight down, and they are now root cells instead of stem cells. Their genetics, of course, is unchanged; they have the same chromosomes they have always had, but there has to be some triggering reaction to set off this series of events. They may be set off either by wounding, by treatment with auxin, or by some other stimulus which acts as the triggering mechanism. We do know something about the triggering reactions but only in an experimental way.

The other day I was visiting a nurseryman in Santa Cruz and I noticed he was dipping cuttings into IBA (indolebutyric acid) to stimulate rooting. I asked him if he knew about the IBA and its basis for action; he said he did know a little bit about it, but not very much, and so it occurred to me that perhaps I should take this opportunity to share memories with you in regard to the work on hormone control of rooting which took place so long ago.

The scientific study began with a very energetic Dutchman, van der Lek, who studied the rooting of cuttings of grapes, willows, and some berries. Although he did not discover very much, he made one very striking observation, and that was that if the cuttings had an active leaf or bud, roots would almost invariably form directly beneath this active leaf or bud and on the same side. He deduced from this that some stimulus must come from the bud or leaf to make the stem cells develop roots. This phenomenon is not dependent upon light because similar experiments were run in the dark using willow cuttings and the same results were obtained. Two deductions were made by van der Lek: *first that the stimulus moves from the bud or young leaf to the* stem tissue to make it form roots, and secondly that the stimulus moves downward. That is, roots are never formed above the leaf or bud but always directly below it. It was this second deduction which put us on to the right track because one often sees the same phenomenon in trees, and particularly in plants in the tropics; for example, the pandanus or screw-pine puts out large numbers of prop-roots much as does corn. All of these are located towards the base and they grow out at a characteristic angle to the stem; this angle does not change very much, all of the roots coming out at about the same angle. In the *Ficus* group it is quite striking to observe the large number of roots which grow out from the base of the tree; these increase in number as the trees get older and in some *Ficus* species they grow out from the lower side of branches and form a forest of little pillars; people often congregate for meetings under these large *Ficus* trees.

It so happened that Dr. F. W. Went, who had spent a lot of time in the tropics, came to join us at Cal Tech. While he was in Java he had been working on this same phenomenon using *Acalypha*, an herbaceous plant, and he found that cuttings of *Acalypha* behaved much as the grape cuttings of van der Lek in that they formed roots in an obvious relationship to the growing buds. While still in Java he made extracts of rice polishings, which are rich in thiamine, and he tested these and found that they promoted the formation of roots on his *Acalypha* cuttings. When he came to Cal Tech, I had been working on the postulated auxins which were supposed to be the growth substances of plants, and we had derived from *Rhizopus*, a fungus, some very concentrated, nearly pure extracts of these auxins. At this point we decided that we would make a parallel study of the postulated rooting substance. The thing which was very interesting was that the auxins had the peculiar character of moving morphologically downward in the plant, that is, they move from the upper to the lower tissues irrespective of the placement of the plant in space. If the plant is placed upside-down the auxin still moves from the tip toward the base, indicating that it is a morphological movement, not a gravitational one. All of the work on the rooting substance indicated that it moved in the same way and so we thought that there might be some parallelism with the auxins. We soon found that our most purified extracts of auxins also caused rooting. We worked up a very simple little assay using pea seedlings because they root very quickly. With this bioassay system we could show that the auxins did make the pea seedlings root. Finally we isolated a pure crystalline material and found that it promoted both growth and rooting (i.e. it was both an auxin and a root forming substance), and subsequently we identified it as indoleacetic acid. We next synthesized this compound and found that it also caused rooting. So we knew that it was not a question of a contaminant or an impurity but that this one substance had two quite different functions. This seemed difficult to believe at the time, that the same compound could act to promote elongation of stem cells and also to turn stem cells into root cells and finally roots.

It so happened that I obtained some synthetic compounds other than indoleacetic acid which were near enough related chemically that I thought it would be interesting to see if they functioned as did the indoleacetic acid. As it turned out, they did indeed induce rooting showing that it was not a property of one special compound. About this time Dr. Went visited the Boyce Thompson Institute at Yonkers, New York, and told them about our studies and I sent them a small sample of indoleacetic acid. Subsequently they synthesized and patented some related substances, one of which, indolebutyric acid, has been very widely used in rooting ever since.

We made a series of rooting studies and it soon became obvious that there were a number of plants which would not form roots in response to auxin. These plants were of special interest because we deduced that perhaps rooting required more than just one substance. We knew the process required sugar since with etiolated cuttings one must supply sugar in order to obtain roots, but we also felt that other materials may be needed, and that if we studied these plants which would not root in response to auxin by supplying them with optimum amounts of auxin we might find out what else was controlling rooting.

As is so often the case in research, it did not turn out that way. But we did find some rather curious things. One of these was that among the most difficult to root plants, such as the spruces and pines, it always turned out that the dwarf forms were able to root though the normally growing plants were not. We had a rather large selection of horticultural varieties of these plants and there was never an exception to this rule; in general the ability to root varies inversely with the rate of growth of these plants. We also found a plantation of spruces which had been overgrown by hardwoods so that the spruces had become dwarfed for a number of years. The hardwoods had recently been cut down and we found that cuttings from these spruce plants, though they were not dwarf forms, but simply normal trees which had been physiologically dwarfed, would root readily, just as readily as regular dwarfs.

The problem of what the compound is in such trees which is necessary for rooting, has never been solved. But there is now a more specific problem in that if the dwarf forms can readily root, perhaps there is an inhibitor in the normal forms which prevents rooting. I was interested to learn that gibberellic acid applied to cuttings tends to inhibit rooting. Gibberellin does promote the rapid stem elongation of a number of plants and it is possible that a substance of this sort is involved; that is, that the material necessary for rapid growth acts as an inhibitor of root formation. I think, however, that it is probably not gibberellin, because most of the conifers do not respond appreciably to applied gibberellin, but they nevertheless may have some other compound which promotes their rapid stem elongation and yet inhibits their root formation. An interesting side aspect of this is that in normal, rapidly growing trees there are always some slow growing shoots. In spruces, for instance, the lower branches have often almost stopped elongating, and these can often be made to root. This is curious because when one looks at the tree one sees that these branches are heavily overshadowed, bear very few needles and generally do not look very healthy, yet if there is any rooting of cuttings it is quite apt to be these branches which will root. A classical example of this is shown by the short shoots of pine, which do not elongate very much at all. We found that the short shoots, in some pine species at least, will root fairly well while normal shoots will not.

One of the strange characteristics of the rooting of evergreens is their extreme slowness to root. We made some experiments with *Abies alba* (Syn. A. *pectinata*) in which the cuttings showed no rooting for nine months, even though they were treated with auxin and were supplied bottom heat. After nine months those cuttings which were treated with auxin began to put out roots; the controls, however, did not. This is one of the most striking examples I know of, of a physiological effect which had obviously been initiated but shows nothing of its effects for a very long time.

Incidentally, I came across a record for the opposite response; that is - instantaneous rooting - when I was on holiday in Italy a while ago. I don't know how many of you may be familiar with the story, but there was a young lady named Daphne who attracted the attention of Apollo, the son of Zeus. Apollo was a great girl-chaser in his day and he was much taken by Daphne. Daphne did not, apparently, care for Apollo and she fled into the mountains. Apollo chased after her and when he was about to catch her, Daphne called upon her father to save her. Daphne was the daughter of the River-God, Peneus, in Thessaly. Peneus, hearing his daughter's plea and not wishing Apollo to have her, turned her into a laurel tree. In the art gallery in Rome there is a statue showing the moment at which Daphne is being changed into a laurel tree, with the young Apollo about to catch her, and you can see her toes already rooting. This legend may be the first historical reference to vegetative propagation. This further suggests to me that since plants are so intelligent (that is, we hear about their responding to music and other things) that perhaps propagators should have a little statue of Daphne in each of their greenhouses and show it to the cuttings so that they would know what is expected of them.

I am supposed to talk not only about the past but also about the future and, of course, it is not easy to say much about the future of propagation, any more than it is easy to say anything about the future of any human activity. Also my own direction of work has gone almost in the opposite direction, in that I am getting interested in the area of senescence, and it turns out that senescence is also a mechanism which is under at least partial hormonal control. It is rather easy to study, because if one removes leaves from young plants and puts them in the dark they very rapidly senesce and turn quite yellow in a few days. This gives us a beautiful biological assay for experiments. Using this method we can measure either the amount of chlorophyll left or the amount of amino acids which are set free as a result of the breakdown of protein. The interesting thing that we found is that senescence, just like seed germination, depends upon a triggering mechanism. Something must happen in the leaf which starts the proteins breaking down, and as the proteins break down, the chloroplasts break down, and the leaf turns yellow. This initial reaction is very much like the initial reaction in seeds whereby the proteins must break down and furnish nutrition to the young embryo. Thus there is a surprising parallelism between senescence— the end of the story — and seed germination — the beginning of the story. It remains to be seen how this will turn out, but it may be that some of these triggering mechanisms will be the result of the synthesis of one particular enzyme which attacks one particular material in the plant; from that all the other things which follow as normal consequences ensue. The triggering mechanism may require only a few molecules to get started.

I suppose the only thing I can say about the future of plant propagation arises from my observations at this meeting, which is the first time I have ever attended a plant propagators' meeting, and the one thing that is very striking is the great enthusiasm everyone has for their work. So I think I can predict that the future of plant propagation will be very active and lively.

CHARLEY HESS: On behalf of the entire Society I want to thank you, Dr. Thimann, for your fine talk, which gave us an insight into the development and use of indoleacetic acid and other growth regulators in the rooting process. It was a real thrill to hear this story first-hand as well as other aspects of plant growth development. Thank you once again, Dr. Thimann. This concludes the program for this evening.

FRIDAY MORNING SESSION

September 11, 1970

MODERATOR SHUGERT: I am delighted to see you this morning after the beautiful day yesterday; the weather cooperated, as you noted, and we had an excellent tour. The site committee certainly did a beautiful job yesterday in presenting an outstanding tour.

You will note on your program that this symposium will be on vegetative propagation: past, present and future. It was to be moderated by Dr. Harold Tukey of Cornell University. However, due to the illness of his father he was not able to be here. So with your kind indulgence, I will moderate the session this morning.

Wednesday afternoon we discussed some of the phases of seedling propagation. Vegetative propagation is certainly as fascinating as seedling propagation and we are fortunate this morning in having a group of gentlemen who will explore various facets of this interesting phase of plant propagation. The lead-off speaker of this symposium is a dynamic, fine gentleman whom I have known since 1953; a man who has been extremely helpful to me and very patient at times in answering some ridiculous questions. I think this is the hallmark of John Mahlstede. John, as you all are aware, has served through the Society in various offices, and is presently at Iowa State University at Ames, Iowa. The title of John's talk is a fascinating one, "The Manipulation of Stock Plants and the Selection of Cuttings".[1]

MODERATOR SHUGERT: Next on the program this morning is a very fine nurseryman who is always willing to share his thoughts and ideas with Society members. He is an extremely well versed and a very, very competent nurseryman. Speaking on "Environmental Control in Rooting Leafy Cuttings", we have Joerg Leiss from Sheridan Nursery, in Ontario, Canada. Joerg.

ENVIRONMENTAL CONTROL IN ROOTING LEAFY CUTTINGS

JOERG LEISS

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As nearly everyone is concerned with the pollution of our environment by humans, it should come as no surprise that, as plant propagators, we have been at work for a long time to control, to a limited degree, the environmental conditions required for rapid rooting of leafy cuttings. I will not try to go back in history to find out

[1]Ed. Note: Dr. Mahlstede reviewed this subject for the audience.

when and by whom such controls were first used. However, let us find out a little about the conditions most conducive to rapid rooting of leafy or any other cuttings, and how we can control these conditions.

Prevention of wilting. This would be my choice as the most important factor. To prevent wilting of leafy cuttings, turgor within the cutting, once it has been taken, should be maintained. Suggestions have been made to take cuttings early in the morning when they are normally the most turgid and transpiration has had little effect. Collect cuttings in containers of moisture-preserving material, such as burlap-lined baskets or plastic sheets; moisten them as soon as possible and, upon arrival at the make-up area, keep them cool and moist. After being prepared as quickly as possible, with a minimum of handling, cuttings are inserted into their rooting environment, which should be so designed as to prevent moisture loss as much as possible. Sash, moist burlap, or plastic-covered frames, bell-jars mist-beds, greenhouses, or other structures which retain a high humidity provided by mist or by a humidifier can be used.

Control of moisture. Here we can start right with our stock plants by watering them, if necessary, before taking cuttings, or by placing them in a micro climate which helps them to maintain optimum moisture levels. I might mention here that even the time of year cuttings are taken has an influence on rooting in some plants. An example of this is *Hydrangea anamola* subsp. *petiolaris*; we do not take cuttings until we find, due to longer, cooler nights, aerial rootlets on the very thin wood.

Glass or plastic-covered windbreaks for mist lines, and the use of shade houses play a role in the conservation of moisture in the cutting environment. The application of moisture by mist lines, either continuous or controlled by such means as time clocks, electronic leaves, humidistats, photoelectric cells or thermostats, or controls such as the light-activated leaf described by the University of Connecticut around the beginning of the '60's, or a temperature controlled electronic leaf described as being used in a nursery in Belgium, and a similar set-up used at our nursery where electricity for the "leaf" is controlled by a thermostat in the line—all have a direct bearing on the leaf temperature as well as the amount of moisture supplied to the cuttings' leaf surfaces. Humidifiers are designed to control humidity itself to the desired degree. Placing the cutting into water or flooding of the cutting frame would exhaust the possibilities I can think of for moisture control.

Light and temperature. Light alone, supplementary to daylight, is being used to provide optimum daylength for such difficult-to-root items as Exbury azaleas and Japanese maples, as well as for continued growth of the cuttings after rooting. Increasing the temperature alone, as by bottom heat provided by manure packs, electric cables (low or regular voltage), hot water or steam all have proven to be of considerable help in rooting the more difficult-to-root leafy cuttings. .

Control of light and temperature. Shading comes to mind as the foremost control for the **exclusion** of part of the available light and lowering the temperature. Shading can be accomplished by such means as paint-on coverings, shade cloth in various forms, structures such as the Nehring frame, fiberglass, P.V.C., and opaque plastic coverings. Added light can be provided by incandescent, fluorescent, or mercury vapour lamps as described by Pfeifer before this Society.

Temperature control by air conditioning, by use of ventilators and mist evaporation are also effective in cooling leafy cuttings. The trapping of sunlight in houses, or frames covered by glass, plastic or other opaque material is not to be forgotten; it is this source which provides us with most of the required heat for rooting leafy cuttings during the summer.

The **condition** of the stock plant, both from a nutritional standpoint and in relation to freedom from pests and diseases, has a definite bearing on the failure or success of the leafy cutting. The stock plant should not be lacking in any of the major or minor elements; neither should there be an excess of any of them. The condition of the stock plants results from proper feeding and watering, and from good disease and pest control. Preventing the introduction of pests and diseases into the cutting bed by cleanliness and by sterilization of the cutting bed and the medium and tools and by the use of disinfectants is a cheap way to obtain healthy vigorous cuttings. Our Western Region members, in their presentations, and the U.C. System book by Baker (1), especially, show us why such preventative measures as disinfection by fungicidal materials, steam or gaseous materials are necessary. The dipping and washing of cuttings with substances such as Morton's Soil Drench, mercury, Terrachlor, Dexon, etc., all reduce the contamination of cuttings by disease organisms. Last, but not least, the painting of all containers and houses with a disinfectant should be done. As far as pests and disease go, proper spraying, selection and maintenance of healthy, pathogen-free plants is to be desired. I cannot see a good propagator trying to produce plants which are saddled with failure either before they root or after being sold and growing on unless, of course, he is not aware of his disease and insect problems. If he is not, surely he will not be successful for very long.

The **rooting medium**, even if its function is only holding the cutting up, has a bearing on success or failure in rooting leafy cuttings. It should be well-drained and as free from pathogens as possible. It can consist of any one of a number of materials, or of their mixtures which, by experience, have been found to be beneficial in rooting cuttings of specific plants. Such materials as sand, peat, perlite, vermiculite, ashes, calcined clays, sawdust, and their combinations have all been successfully used in rooting cuttings.

Nutrients in the rooting medium, while not necessarily beneficial to root initiation, are of help in establishing the plants from the rooted cuttings.

The water used in propagation should be as free of chemicals and sediment as it can be made. Bruce Briggs has previously discussed the addition of chlorine to kill fungi and bacteria in the water.

Lastly, the propagator himself and his experience in propagation — when and how to take cuttings — by feel, so to speak, is very important; this is where science has failed us so far — this feel cannot be described. It is an intuition which you either have or you do not.

I can see in the foreseeable future the development of a machine which will tell us, by inserting a sample cutting, what to do to root the particular sample cutting. It will probably be transistorized and incorporate a small computer. It would be measuring the electrical resistance and by a chart will tell us if the cutting is in a rootable condition — (I will not invent it).

We have had various speakers talking to us on new discoveries, especially propagation by cell or tissue cultures, with the production of healthy and clean plants. I can see the establishment of a so-called cell bank where, on demand by a specialist propagator, a nucleus stock of almost any plant will be available for propagation in completely controlled growth chambers, incorporating artificial light and atmospheres, heat to a specific level, and optimum moisture, all working automatically to root the cuttings with the required amounts predetermined by computer. However, the propagator will still be around most likely if our own environment has not killed him off.

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MODERATOR SHUGERT: That was great, Joerg. Great slides and a tremendous presentation. Thank you on behalf of all of us. We are fortunate now to have a member speak to us from the Great Britain and Ireland Region. Everyone in this room has heard of the Grafters' Handbook, and has heard the praises of the East Malling Research Station. The gentleman who is certainly well known for his work at the East Malling Station in England is Bob Garner. It is a delight to have Bob with us this morning, and he is going to discuss with you "Fruit Tree Raising in England Today". I present, with a tremendous amount of pleasure and honor, Robert Garner.

FRUIT TREE RAISING IN ENGLAND TODAY

ROBERT J. GARNER

East Malling Research Station

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England

Vegetative progagation only. Fruit trees and rootstocks in England are propagated entirely vegetatively. Seedling rootstocks faded away with Hatton's (1) publication of his classical trials in the twenties. Today the fruit tree raisers and growers are eager to exploit the latest findings of rootstock research just as they did the scion variety, but with more certain assurance. Today our growers demand trees on dwarfing rootstocks and at this moment there is a lively interest in the most dwarfing, in our country where winter killing frosts are no hazard. For apples, East Malling is now releasing the very dwarfing '3431', as 'M.27', which is considerably more dwarfing than 'M.IX', virus-free 'Quince C' for pears, selected St. Julien for plums and peaches, and growers are knocking on the door for our dwarfing rootstocks for sweet cherries.

Form of tree. Considerable attention is given to the form of tree grown. Low working, leading to scion rooting, has resulted in loss of rootstock control; now a minimum working height of 6 inches is the rule. Because of the incidence of collar rot (*Phytophthora spp.*), apples are now recommended to be worked at 12 inches and this demands long straight rootstocks. High-working is sometimes used for plums to provide stem-canker resistance but it is not common. Sweet cherries are still high-worked to lessen their susceptibility to bacterial canker (*Pseudomonas morsprunorum*). A number of East Malling mazzards resistant to bacterial canker are now going into field trials and scion varieties from the John Innes Research Institute, resistant to the disease, will shortly be in extended trials, the aim being to obviate the necessity for high-working and to facilitate low-working of bush trees having overall resistance. Twelve-inch high-working of apples ensures elevation of the lower strong maiden laterals into a usuable position, enabling the tree to form good basic branches in the first year, thus avoiding the need to manipulate in other ways.

Plant health and pedigree. Our Ministry of Agriculture has three schemes of special interest to fruit tree raisers. The first is that relating to purity, health and vigour of a range of apple, quince, plum and cherry rootstocks as seen in the season of growth. The next is a 'mother tree' scheme to register approved trees as sources of scionwood, whilst the most recent, now in its first year, involves continuous assessment of health and maintenance of supervised isolation of both rootstocks and varieties. The high standards set in this special stock scheme doubtless deter many small nurserymen and, in fact, only eight raisers are at present involved.

Rootstock propagation. The etiolation method of layering is now confined to the propagation of mazzard cherry rootstocks such as 'Malling F12/1' and its successors. Only really skilled work will provide the continuously high productivity of this technique and thus it tends to be confined to subjects not amenable to simple methods of propagation. Plum rootstocks are best propagated by hardwood cuttings, but a few layer beds remain in use. Apples and quinces are generally propagated by simple stooling. Output per acre is very variable due to differing attention to detail. At East Malling we regard 40,000 budable-grade apple rootstocks per acre as average but some raisers fall far below this through inattention to the basic requirement of harvesting while dormant, non-brutal cutting to maintain high shoot production, and moderate but well-timed earthing. Quinces are notoriously prolific on stools, good crops rising up to 100,000 per acre. However, even with good cropping, layering systems involve much heavy hand labour and are becoming relatively more costly year by year and this has led to a deep interest in other methods of propagation.

Hardwood cuttings. Hardwood, rather than softwood cuttings or root cuttings, have been chosen as the practical alternative to layering. Mist propagation of essentially bare-root material with overwintering difficulties and slowness to attain budable size, does not appeal to us. Neither do root cuttings because of slow development and the danger of mixtures and virus contamination inherent in nursery collection. Hardwood cuttings are amenable to 'factory-like' methods, economical size attainment where most readily grown, and they have an ideal straight axis form which can be compactly bundled, treated and mechanised. East Malling has pioneered this hardwood cutting work on this basis and we are still examining the behaviour of cuttings and their response to treatment. This has ranged from a demonstration of the value of vigorous hedge plants as a source of cuttings, cutting at the shoot base, specific periods of collection and auxin treatment, and planting in heated bins to obtain the necessary rooting before transference to the open field. Perhaps the most important lesson we have learnt is that no traditional technique can be taken for granted but that an open re-consideration of all factors involved is vital. The recent discovery of the significance of depth of dipping hardwood cuttings (2) is a typical example, for not only does this have immediate practical implications but it is also leading to a deeper understanding of the mechanism of auxin stimulation of cuttings. The widespread interest in rapidly multiplied trees for intensification of close planting may lead to a demand for the 'cheap tree' for a short life, and hardwood cuttings may well be exploited for this purpose.

Replant diseases. Suitable soils in nursery areas are increasingly difficult to acquire and when high cost buildings have been installed there is added reason to recrop the local land. This has often led to a lowering of tree quality and output due to replant diseases and nurserymen are seriously considering rehabilitation of such used soil by partial sterilization. One raiser has already contracted each year to have a substantial proportion of his land treated with chloropicrin; experiments at East Malling having shown that the normal maiden growth can be restored, or even improved, in this way. Our Ministry of Agriculture undertakes the testing of soils and advises on their likely response to treatment.

Mechanical aids and herbicides. Mechanical aids are less advanced in England than in the United States. Tree lifters are widely used and large growers are beginning to use blowers to clear between lined-out roses and this also has possible potential for cleaning out partially unearthed layer beds. Overhead spray booms are now fairly common but, in general, the development of high clearance tractors has been very slow in England. The use of herbicides, pretty well an essential accompaniment of mechanization, has come into wide use. Simazine and Paraquat are the most popular chemicals.

Jacketed cold stores. Hitherto the temperate English climate has not encouraged the use of stores or cellars, but with the need to use our limited skilled labour for a longer period, a number of jacketed cold stores have been built by every large scale raiser, after the pattern of those in Denmark. They are proving a tremendous success and their owners say that jacketed stores are the most worthwhile investment they ever made. Not only does the jacketed store help planning generally by extending the season, but material may be fully prepared for the planter and be ready on hand when the weather is right; scionwood can be held over from autumn to spring and scions can be prepared and accumulated during inclement weather for speedy grafting later. Most growers run their stores at 29° to 33°, but nearer the lower temperature is safer for holding over from season to season.

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MODERATOR SHUGERT: Thank you very much, Bob, for a great presentation. The next speaker on our program is one of our very fine members from the Western Region; he is from the state of

Washington and is affiliated with the Western Washington Research and Extension Service. It is a pleasure to introduce to you at this time, George Ryan.

SELECTION AND TIME OF COLLECTION OF MATERIAL FOR STOCKS AND SCIONS

G. F. RYAN

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The selection of stock and scion material varies with plant species or cultivar. For convenience in the discussion that follows, plants will be grouped under three headings: deciduous species, coniferous evergreens and broadleaf evergreens. There are some similarities in grafting procedures within these groups, but differences will also be noted. Plants of a wide climatic range, from temperate to tropical areas, will be considered under broadleaf evergreens.

Deciduous species. Grafting of deciduous species is most commonly done in late winter or spring using scion wood from shoots that grew the previous season. One-year wood is preferable in most cases, but two or three-year-old wood can be used. For example, two-year wood is acceptable or even preferred for figs (*Ficus*) and olives (*Olea*), and Leiss (18) reported that with *Fagus sylvatica* two and three-year-old wood gave best results.

The usual recommendation is to select wood from moderately vigorous shoots, and to use the lower or middle two-thirds. Some grafters prefer terminals, but this portion may be less well-matured and lower in stored carbohydrates or other reserve materials than the lower portion. The scion wood is collected while dormant and stored at low temperature until used.

Rootstocks may be seedlings or vegetatively propagated clonal material. Having the rootstocks well established in pots is important for indoor grafting. In some cases digging and potting in the fall allows enough time (4, 7), but a longer period for root development is preferred. Hess (10) suggested potting of beech seedling rootstocks (*Fagus sylvatica*) a year before grafting, but reported that if necessary they could be dug and potted in early September before leaf drop, and placed under intermittent mist for a week. This results in very little interruption of root activity, and the root system is reestablished in the pot before grafting time.

Grafting onto bare root stocks may sometimes be successful, but as noted by Humphrey (13), results may be unsatisfactory. When the growth rate of grafts onto established understocks was compared with grafts onto bare root stocks, the growth on the established stocks was considerably greater.

Timing of the grafting operation with deciduous species is based on evidence of activity in the rootstock. For example, Davis (3) grafts pecans when the terminal buds are swelling on the most advanced seedlings. This is before the cambium has become active enough for the bark to slip. Sometimes the start of root growth is used as an indication of when to graft.

For grafting in the nursery row, the stage of activity is dependent on the weather. Potted rootstocks can be brought to the proper stage of activity whenever desired by bringing them into a greenhouse or grafting shed a few weeks prior to grafting, or by adding heat if they are already in a cool house.

Rapid callus formation occurs when the rootstocks are ready to start growth. Sussex and Clutter (26), working with pieces of stem tissue cultured on agar, found that callus formation was greatest in the spring when new growth occurred. Activity decreased later in the season, and began to increase again during the winter, reaching a peak at the time of bud break.

Not all deciduous plants have to be grafted only in winter or early spring. One that is successfully grafted in the summer is grape (*Vitis*). Green-wood scions from slightly lignified shoots can be grafted in July or early August onto rootstock cuttings that are planted in the spring. Having the cuttings rooted and making good top growth was essential for success in studies by Harmon and Snyder (8, 9). Grafts made during July matured enough scion growth to be satisfactory for field planting.

Leiss (18) described summer grafting of *Aesculus hippocastanum*, and other deciduous plants grafted in the summer were listed by Leiss in a report by Halward (7).

Coniferous evergreens. Having the stocks well established in pots is considered essential for success with coniferous evergreens, the same as with deciduous species. Hess (11) suggested pine rootstocks should be potted in the spring—before the grafting season—rather than in the fall. Holst, *et al.* (12), Nienstaedt (20) and Wells (27) also recommended that stocks for pine and spruce should be potted nearly a year, or at least one full growing season, before grafting. Kyle (16), however, reported excellent results from grafting junipers (*Juniperus*) and other plants onto unpotted seedlings with the roots packed in peat.

Winter or early spring is the preferred time for grafting many coniferous species. Immediately prior to or just as root growth starts is considered to be the best stage of activity of the rootstock (2, 15, 24).

Pines, on the other hand, are successfully grafted in the summer, using semi-mature current season growth (21, 24, 25). Leskinen (19) in

Finland found summer grafting of pines during the period June 20 to July 15 to be superior to spring grafting.

Research workers in forestry have developed techniques for fall grafting of spruce and pine. Holst, *et al.* (12) were successful with fall grafting of Norway spruce (*Picea abies*) and white spruce (*Picea glauca*), and also with red pine (*Pinus resinosa*) and Scotch pine (*Pinus sylvestris*). Spruce scions from the uppermost part of the crown of middle-aged trees were preferred. Scions from the upper part of the tree gave a higher graft take, and produced grafts of more upright and better form than scions from the lower branches. Better quality scions of current season growth could be found on young or middle-aged trees than on mature trees.

Holst found pines more difficult to graft than spruces. Grafting in November and early December gave better results than in October. Nienstaedt (20) reported that Dr. C. Heimburger of the Southern Research Station at Maple, Ontario, had field-grafted white pine from mid-September to mid-October.

In his work on fall grafting of white spruce (*Picea glauca*), Nienstaedt started with the assumption that grafting success would depend on the amount of cambial activity of the rootstock and scion at the time of grafting and immediately thereafter. He therefore tried to control this activity through photoperiodic treatments and by chilling.

Contrary to expectations, dormancy at the time of grafting (mid-September), or during the following six-week period, did not interfere with graft take. Success was no greater with stocks that were active due to exposure to long days or ready to begin activity following chilling than with dormant, untreated stocks. Nor did chilling or exposure to long days immediately after grafting increase the graft take, as measured by survival the first year. However, breaking dormancy by chilling or exposure to long days was essential for ultimate growth of the scion and graft survival. Chilling plus long days resulted in maximum scion growth.

These results appear to differ from the observations with deciduous plants, that callus activity is greatest at the time growth starts in the spring. However, it may be possible that callus formation was slower with dormant than with chilled spruce stocks, but that there was enough activity for the grafts to be successful. Root activity of the chilled and the untreated spruce stocks was not mentioned. More information regarding the relationship between bud activity, root activity, and formation of the graft union in conifers and in other kinds of plants could perhaps lead to improved grafting procedures where satisfactory graft take is a problem.

Broadleaf evergreens. Plants such as *Camellia*, *Rhododendron* and *Ilex* are usually grafted in late winter or early spring before growth starts.

However, Leach (17) reported green-grafting of rhododendrons and found it was successful on some varieties that could not be propagated by dormant winter grafting. He used scions from half-ripe wood with leaves fully developed and firm, and protected the grafts with polyethylene bags. The period from June 20 to July 10 gave better results than later in the summer to early September.

Certain subtropical fruit and nut trees such as avocado (*Persea spp.*), litchi (*Litchi chinensis*), sapodilla (*Achras zapota*) and macadamia (*Macadamia spp.*) can be grafted at almost any time of year, but a greater percent of the grafts are usually successful in the spring than in summer or fall.

There is evidence that this seasonal difference in graft take is at least partially due to the amount of stored carbohydrates in the scion wood. Jones and Beaumont (14) found that girdling litchi scion wood 3 weeks before grafting greatly increased the amount of starch in the scions and resulted in 75 to 80% success with the grafts, compared with takes as low as 10% previously experienced with ungirdled scion wood. Beaumont and Moltzau (1) reported similar results with macadamia. Percent graft take was approximately in proportion to the amount of starch in the pre-girdled scion wood.

Fahmy (5, 6) reported that girdling increased the amount of starch and sugar in sapodilla and macadamia scion wood, and it increased the graft take at certain times of year. However, there was no definite relationship or correlation between carbohydrate content and graft take.

The Fuerte variety of avocado can be grafted with nearly equal success in spring or summer, while graft take with the Hass variety drops from 90% or higher in February to less than 50% in May, and then increases again later in the summer. Rodrigues, *et al.* (22) reported that carbohydrate content of the scions was higher in February than in May, but did not show an increase in August to correlate with the increased graft take.

Scion girdling increased avocado graft take to some extent at each of the three periods, and it also increased carbohydrate content, but again there was not a direct correlation between percent carbohydrates in the scions and grafting success. The effect of girdling was thought to be partly due to increased carbohydrate content and partly due to accumulation of some other material.

Further evidence that an accumulation of some material in the scion was critical for graft take was the greatly increased success when the length of the scion was doubled, from 3 inches to 6 inches.

Evidence that amount of carbohydrates was partly responsible for the seasonal variation in success came from an experiment in which the graft take during the summer months was increased 60 to 75% by applying a 0.3 molar (5%) glucose solution through the upper cut surface of the scion every 2 days for 6 weeks (Table 1).

Table 1. Effect of glucose treatment on graft take with Hass avocado. From Rodrigues, *et al.* (22).

Month grafted	Control	Glucose [1]	Water [2]
February	90	85	—
May	40	70	—
September [3]	60	95	45
September [4]	60	85	26

[1] The top of each grafted scion was wrapped with plastic tape to form a cup in which 0.3M glucose solution was applied every 2 days for six weeks.

[2] Water was supplied instead of glucose solution

[3] Scion wood from spring growth

[4] Scion wood from growth flush of previous fall.

In another experiment with avocado, the physiological condition of the scion wood, or its favorable balance of materials, was retained during 3 months of cold storage, but not after 5½ months (Table 2). Two years previously, graft take with stored scion wood was essentially as good after 7 months as after 3 months.

Table 2. Graft take with Hass avocado scion wood stored at 40° F. From Rodrigues, *et al.* (22).

Date grafted	Freshly-cut scions	Stored scions
February 9	92	—
May 13	30	90
July 28	78	60

Pre-girdling the scion wood contributed to success in grafting *Eucalyptus ficifolia* (23). Another consideration was the vigor of the rootstock. The observation was made that a higher percent of grafts were successful on young vigorous seedlings than on older less vigorous ones. An attempt was then made to influence the vigor of young seedlings by supplying different amounts of nitrogen. The N content of leaves varied from 1.2% in the low N treatment to 4.1% in the high N treatment. In two experiments, the percent graft take was highest with the lowest foliar N level, 1.2 to 1.3% nitrogen. Some other aspect of vigor besides response to an abundance of N apparently was involved in the initial observation. These results do indicate, however, that vigor and nutritional status of the rootstocks may also be important to the success or failure of a graft.

Further study of this aspect, and also of the physiology of the scion wood, could contribute information that would help to increase grafting success, particularly with difficult plants.

In any discussion of selection of scions and stocks, mention should be made of selecting scion wood true-to-type and free from viruses or other diseases. These are equally important in selecting material for rootstocks to be propagated vegetatively. Since most viruses do not come through the seed, freedom from virus diseases usually is less of a problem with seedling rootstocks. Trueness-to-type in the seed source is important, at least to the extent of using seed of the proper species for the desired rootstock effect. Where there is considerable botanical or horticultural variation within the species, selection of a particular variety or cultivar as a seed source may be important.

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MODERATOR SHUGERT: Thank you very much, George, for a very comprehensive and interesting paper. Most of us met the gentleman who is going to speak to us next, the year the meeting was held in Newport, Rhode Island. He is a propagator for the Rhode Island Nurseries in Newport and is a very dedicated contributor to the Society, an excellent nurseryman and a good personal friend. Speaking on "Environmental Control for Grafting", Larry Carville, from Rhode Island Nurseries. Larry.

ENVIRONMENTAL CONTROL FOR GRAFTING

LAWRENCE L. CARVILLE

Rhode Island Nurseries

Middletown, Rhode Island

Webster's dictionary defines environment as "that which environs; the surrounding conditions, influences or forces which influence or modify." The plant propagator defines environment as the conditions sustaining or contributing to the life or development of plant tissues. In our present age, it is fashionable to be concerned with our environment and much is being said pertinent to the national environment. As propagators, we are vitally concerned with this subject matter since proper management of the environment within our business establishment is a matter of necessity if we are to be successful in our profession.

A review of the Proceedings of the Society supplies a wealth of material dealing with all aspects of graftage dating back to the first published papers in 1952. I read with much interest these papers by Hoogendoorn (2), McGill(16), Burton (1) and Mattoon (15) and was amazed to find that environmental control in grafting presented the same problems then as face us today. The variety of plant materials dealt with in these papers is practically unlimited and the methods involved range from the most simple to the more complex. This review of the literature however merely serves to emphasize the realization that we have actually made relatively little progress in the field of environmental control for grafting. In view of the tremendous advances in horticultural techniques and construction, the real impetus in this presentation is to stimulate you to apply these newer techniques, to experiment with novel construction methods, and most importantly, to innovate with an inquiring mind. Truly, what does the future hold in the area of environmental management?

In my approach to this subject matter, a review of our accomplishments as propagators must be divided into three areas: stem grafting, root grafting, and budding.

The conditions or influences which we strive to control in stem graftage are temperature, light, moisture content of the media and humidity of the immediate surroundings. Initially, the accepted method used to control the environment was the Wardian Case.

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Problems inherent in this technique which has been used "successfully" over the years are incidence of fungus disease, and high labor and maintenance costs. Modifications of this basic method include use of plastic in place of glass (5, 12) and with the use of overhead mist when handling deciduous stock. It must be accepted that regardless of the method used and the plant material being grafted, the human element becomes apparent in terms of experience, labor costs, and efficiency. When to air the Wardian Case, when to reduce or increase bottom heat, when to apply or remove shading, and when to reduce mist intensity become environmental control factors in terms of dollars and cents based on available labor. The success of a given crop can be seriously affected by inattention at any period during callus formation. Further modification of the Wardian Case method is the use of newspaper (14), or Kraft paper, on grafts such as *Picea pungens* 'Moerheimi'. We have found the use of Kraft paper to be extremely adaptable and now graft all our cryptomeria and retinospora varieties in open benches covered during bright sunny days with Kraft paper.

The problems incidental to environmental control in root grafting are somewhat easier to control since we normally are using dormant scion wood so light intensity and ventilation are not as pertinent. The incidence of fungus disease may become a factor if too much moisture is present in the media or if the rootstock or scion is not clean. The standard propagation procedure currently in use at our establishment is to store completed root grafts in cool storage areas until planting time. Care must be taken that the sphagnum moss used for root-graft storage is only damp, not wet and, if a refrigerator is used for winter storage, the temperature controls are reliable. We use a recording thermometer in our cooler to insure that root grafts are not injured by too low a temperature and that growth does not commence too early in the spring.

Our techniques in stem grafting have not radically changed over the years and are still basically modifications of the Wardian Case. However, control of the environment begins well ahead of placement in the case if we apply the principles of environmental control which I mentioned earlier. Once scions have been cut from dormant stock during the winter, we must insure that they are protected from freezing, kept moist, and not subject to rapid changes in temperatures. We store all scion wood in a cooler at a constant temperature of 34° F until we are ready to graft them. Scions are often taken as much as 3 to 5 days in advance of grafting if weather conditions are unfavorable for daily harvest. Material is brought into the work area only as needed and is prepared as rapidly as possible for grafting. Scions are kept cool and moist during preparation but are normally dry during the grafting operation since we do not want external moisture present when the scion is affixed to the understock (10).

If we apply my principles of environment control in a strict manner, we must consider personnel as well as plant material. I believe that the immediate area surrounding the work force must be as pleasant, comfortable and clean as possible since these factors also contribute to the overall success of the propagator. We attempt to provide an adequate work area for each grafter which is well-lighted, well-ventilated and comfortably heated. Work bench surface should be at a comfortable height and should be cleansed each morning prior to the day's grafting operation. All rubbish and debris should be removed from the work area floor daily. These factors may seem trivial to the average nurseryman but, believe me, anything that can be done to improve the environment of the work force substantially improves production and ultimate success.

We do all stem grafting at a work bench where light and temperature are adequate and may be manually controlled. A flat of potted understocks is brought from the greenhouse to the work bench, grafted and immediately taken to the grafting case. Completed grafts are plunged in the dampened spagnum moss and then covered with glass sashes. At this point in the operation, environmental control becomes critical!

Light, temperature, and moisture must be manipulated to give us the highest possible yield on grafted stock. Cotton cloth is unrolled over the glass sash on bright sunny days and is left in place from 9 a.m. to 4 p.m. The grafting cases remain unopened for the first week but, thereafter, are opened briefly each morning for airing. Bottom heat is maintained at a constant 72 to 74° F which allows sufficient humidity to promote rapid callus formation. When grafts are sufficiently callused, sashes are raised and all material is syringed two to three times on sunny days. Air circulation is gradually increased as the completed grafts are taken out of the sphagnum moss and spaced. This operation normally takes place about 4 weeks after setting. Shading paint is applied to the greenhouse glass in early February as the sun intensity begins to increase with the lengthening day. Humidity is no longer a critical factor, but temperature and moisture must be controlled until the grafts are hardened off for planting.

These techniques used in stem grafting junipers are modified somewhat in our open bench grafting; we replace the glass sash with plastic tents when handling Japanese maples and dogwoods. When all grafts have been made and plunged in moist sphagnum moss, a temporary frame of 1 x 2 inch strips is erected over the bench containing the Japanese maples and dogwoods. We then staple 4 mil poly to the framework across the top, over both ends and along the sides. This poly forms a temporary moisture chamber which allows sufficient light without shading and at the same time creates an atmosphere with controlled humidity. The poly tent is aired once a week for the first 15 days then twice a week for the next 2 weeks. After 4 weeks, the poly is completely removed.

Cryptomeria, retinospora, and beech are open-bench grafted but are covered with Kraft paper during sunny days until callus formation is adequate to insure success of the graft, usually after three weeks. Top moisture is a critical factor in these three species and we strive to keep the scion and stem as free as possible from external moisture until callus formation is well advanced. This is particularly true of the beech varieties where blackening of the stem occurs if excessive water is applied to the plunged grafts. We prefer to have the potted understock well soaked prior to graftage and to have the sphagnum moss only slightly dampened when pots are plunged.

Spruce varieties are open-bench grafted without the use of double glass, plastic, or Kraft paper, but require frequent overhead syringing during callus formation. We do not wax or paint the graft union but, once again, insure that the understock is well-soaked prior to grafting. Our technique here seems to vary somewhat from that of Willard (19) who prefers to have his understock well-dried prior to graftage. Free air circulation is allowed in the spruce grafts to reduce the incidence of fungal contamination.

During every step of the stem grafting operation, control of the environment involves the use of manpower; the success of the propagator is directly related to the experience of this manpower.

The budding operation presents perhaps the greatest challenge to the propagator in his attempts to control the environment (16, 18). Since most budding of fruit varieties, nut trees, and roses is carried out in the field (13), we can do very little in controlling such factors as light and temperature. We become more concerned with the immediate environment surrounding the bud and must be content to manipulate the moisture content of budwood and seedling. The humidity factor may be controlled to a small degree by proper wrapping or painting. I must confess that, commercially, I have never budded but after reading Davis' paper on the modified patch bud (2), I am tempted to try my hand.

Briefly, I have attempted to summarize the methods we utilize in controlling the environment for our grafting operations. I am satisfied that we are achieving a moderate degree of success with our root grafts and with our stem grafts. But of all the factors involved in the total operation, labor continues to be the most significant element which defies change. Here we must face the challenge of the future. How can we, as propagators, more efficiently control the environment for grafting?

In recent years we have had stimulating papers presented in this society which should have aroused the curiosity of even the most adventuresome horticulturist (4, 11, 17). We have been privileged to visit commercial establishments which are experimenting and innovating untried techniques. At the University of Minnesota and at Bachman's on our tour yesterday we saw modern structures and semiautomation combined to make environmental control attainable. Are these brief exposures and experiences sufficient, however, to shatter our lethargic complacency of continuing the day to day operation within our individual greenhouse establishments? I will never argue that one should change merely for the sake of change but is there anything wrong in being more successful!

Let me take your imagination for a few minutes and explore with you some innovative techniques in environmental control:

Imagine a tower greenhouse such as we saw in Ontario, Canada in 1968. Completed stem grafts are inserted in wire racks on the conveyor assembly and are never touched again until callus formation is complete. Each graft is exposed to uniform light and temperature conditions merely by operating the conveyor assembly through its cycle. Watering of the understock is fully automated, the humidity of the tower complex is automatically controlled, and disease and infection are minimized in the controlled environment. Carbon dioxide may be injected as required (9) and fertilizers and hormones could be applied through an automated misting system. Impractical, you say? Prohibitive in cost? Perhaps not when we consider the increase in production possible with a controlled environment.

Imagine stem grafting on unpotted understocks (14) or on unrooted cuttings (3). Mr. DeGroot presented a paper on this technique in 1960 and described his work with plants in the genus *Juniperus*. I experimented with this method using the genus *Rhododendron* and found that control of the environment was facilitated, incidence of *Phytophthera* was reduced, and percentage takes of 'Mrs. C.S. Sargent', 'Boule de Neige' and 'Dr. H.C. Dresselhuys' were substantially increased. Mr. Gerald Verkade is presently stem grafting juniper on unpotted rooted cuttings and has appreciably reduced the problems of environmental control in his grafting house.

Imagine the controlled environment Mr. Krizek was able to maintain in his facility when he presented his paper on seedling production in 1968 (11). His use of growth chambers would seem to be the ultimate in effectively controlling such factors as light, temperature, humidity, nutrition, and carbon dioxide. Although his research primarily related to bedding plants and vegetable crops, much of the data is applicable to ornamental woody plant production. Can we justify these elaborate growth chambers in our business establishments merely for the production of horticultural nursery crops? Perhaps we must.

The rapidly increasing national problem of air pollution may be a factor in the future with which we have not been concerned in the past. If ozone, hydrogen fluoride, and sulfur dioxide in the atmosphere are affecting the growth of street plantings and city parks (18) will not eventually this same deleterious effect be observed in our greenhouses? Will we ultimately have no choice but to graft only in growth chambers?

Is the future role of the grafter to be reduced in scope to one of a technician who will be more concerned with the mechanical operation of his growing complex than with the propagation of plants? Are we to become test tube scientists "budding" virus-free tissues in *in vitro* culture? (8, 17)

This then becomes the real challenge. How can we best control the conditions sustaining or contributing to the life or development of plant tissues? The answer must come from within our Society. This challenge can be met by you, the members from the British Region, the Western Region, and the Eastern Region. We are here in St. Paul to face this challenge. From our deliberations must come the solution to future problems in environmental control for grafting.

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MODERATOR SHUGERT: Larry, that was an outstanding paper. Larry expressed many ideas he feels strongly about and we all benefitted from it without question.

We are now going to hear from a gentleman who is with the Pershore College of Horticulture, in Pershore, England, the Editor of the Great Britain and Ireland Region of the International Plant Propagators' Society. Richard Martyr is now going to speak to you on "Hardwood Cuttage Practices in England". Richard Martyr.

HARDWOOD CUTTAGE PRACTICES IN GREAT BRITAIN — A REVIEW

R. F. MARTYR

Pershore College of Horticulture
Pershore, Worcestershire, England

The term "hardwood cutting" in Britain is almost exclusively limited to denote the ripened wood of deciduous species and would not ordinarily include, for example, the autumn cuttings of narrow-leaved evergreen species — though technically this might be "ripened wood". Within this definition it is true to say that there is a much decreased (and probably still decreasing) use of hardwood propagation techniques in the production of ornamentals. In some nurseries it is a technique that has been dropped altogether and in most others it is

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It is now becoming known amongst nurserymen that 100% takes with hardwoods is a reasonable expectation with a much wider range of subjects than hitherto thought possible provided that material of high rooting capacity is used. Provided also that due consideration is given to season of taking, hormone treatment and to the rooting environment. It has been abundantly demonstrated that the best way of obtaining the right material is to have special stool or hedge plants and to maintain them annually by heavy pruning whether or not the material is needed for propagation purposes. On a rapid survey of nurseries recently I was surprised to find how few growers — fruit stock producers apart — have yet developed these stock lines.

It would seem, therefore, that the centre of the propagation department on these nurseries is more and more within the mist unit and this may well have simplified the work flow on many nurseries.

Traditionally hardwood cuttings were regarded as something that could be done at any slack period from October to March — now it is known that much more precision is needed in timing and technique; nurseries tend to run down their staff in winter and there are still important lifting, despatch and planting jobs to be done. It is often more convenient to get propagation labour peak requirements in the summer when student and other casual labour is more available. Thus, Humphrey has described how at Hilliers of Winchester hardwood cuttings have been run down to a mere 20 to 30 thousand compared with over half a million summer cuttings, all of which fits in with their labour requirements.

Nevertheless it must be surprising that this trend away from hardwood propagation should have not have been more affected by the work carried out by Garner, Howard and others at East Malling, which has had such an impact on the production of various fruit plants. Why has the temperature treatment and storage work in the heated bins as first developed at East Malling by Garner not been adopted for the more difficult rooting ornamentals?

Here it is essential to point out that critical research work in the field of hardy plant nursery stock is as yet negligible in Britain; so far as government sponsored research is concerned it has only just begun with the introduction of a very small nursery section and staff appended to the Glasshouse Crops Research Institute — a quite inadequate allotment but, at least, a start and perhaps, more significantly, the Ministry of Agriculture has this year appointed within the National Agricultural Advisory Service (the Government extension service) a senior advisory nursery specialist stationed at Reading near the main nursery production area. Some of the Experimental Horticulture Stations have begun to include some nursery crops and it must, of course, be mentioned that in Eire the Government Research Station at Kinsealy has opened a very active ornamental horticulture section. In England, four universities offer courses in horticulture or horticultural science and their interests in nursery problems is probably growing, particularly at Nottingham and Bath. But the nurseryman in our region must look with some envy at the abundance of directed research stemming from the universities in North America. We have no equivalent — and look more to work at Boskoop and Wageningen in Holland and increasingly, to Denmark and Germany.

Now an industry which is expanding and capitalizing as fast as the nursery industry in the U.K. is doing must be forward-looking and research-minded. It is, in fact, hungry for research. Bluntly speaking, the progressive nurseryman is frequently ahead of the research worker; but however much energy and enthusiasm, this is a state of affairs which brings its failures as well as its successes. It must also inevitably lead to delays in communications between research centre and grower. There is no better example of this than in the adaption of the "heated bin" work at East Malling, which obviously has tremendous possibilities for the rooting of a whole range of ornamentals, some of which may be very difficult to root by other means. Careful research here is overdue, for growers who have tried to adapt the techniques to ornamentals have almost invariably failed — although an abundance of roots may be developed, this is followed by an almost complete loss of plants afterwards.

It is obvious that there are wide differences between the optimum temperatures for root initiation and those for root development and that the temperature-treated plant is very susceptible to unfavourable environmental conditions. Garner and his co-workers have constantly emphasized that the desired product from the heated bin must be a cutting beginning or about to root as it leaves the store. Overstimulation is usually fatal. It is clear, therefore, that the precision temperature control and timing needed, with the probable variations between different genera and species, have proved too exacting for the early pioneers of this technique in rooting hardwood ornamentals.

Yet the encouraging root production which is produced by certain plants, which are difficult to root by other means, must offer some hope that we are on the brink of an important breakthrough once the blueprint for the treatment of hardwood cuttings (particularly after the root initiation stage) has been perfected.

Some investigational work has been done at Hadlow College and at the Ness Botanic Gardens (University of Liverpool). Hutchinson's work at Hadlow is recorded in Volume 19 of the I.P.P.S. Proceedings; he had encouraging rooting but subsequent heavy loss with *Tilia x euchlora*, *T. platyphyllos* 'Rubra' and *T. petiolaris*, *Corylus avellana* and *C maxima* 'Purpurea', *Prunus spinosa* and *P. cerasifera* cultivars, *Rhus cotinus* and *Malus* 'Profusion'.

Hulme at the Ness Botanic Gardens has had rather similar experiences over the past two years. Typical results are summarised in Table 1. All these hardwood cuttings were rooted in a peat-sand mixture at around 75° F; potted and plunged in the rooting media in early April. Shoot growth commenced in many cases but the plants then collapsed.

Table 1. Rooting results obtained with hardwood cuttings of several ornamentals. Peat-sand mixture. 70-75° F. bottom heat. J. K. Hulme, Ness Botanic Garden, 1969-70.

	Rooting	Survival
Alnus incana 'Aurea'	30%	total loss
Aronia melanocarpa	high percent	10%
Chaenomeles spp.	,, ,,	,,
Cornus stolonifera 'Flaviramea'	,, ,,	total loss
Prunus padus 'Watereri' *P. sargentii* *P. serrulata* 'Shirofugen' *P. s.* 'Shirotae'	20%	all died later
Pterocarya fraxinifolia (*P. caucasica*) *P. x rehderiana*	high percent	90% died by early summer

Few commercial nurserymen will have had wider experience in the use of heated bins than Jack Matthews (Matthews Fruit Trees, Limited, Thurston, Suffolk). He has adapted East Malling techniques during the past 14 years and streamlined them to fit into his considerable output of wholesale tree production. He soon learnt that it was impossible to control the moisture content of the peat and sand mix in the bins in the open, so he built a nursery barn with a section specifically designed for the storage of hardwood cuttings for long or short periods.

Large quantities of cuttings, mostly *Prunus* species, as listed below, are taken in October and November; they are all derived from stools or hedges grown specifically for the purpose and are given IBA dips of various strengths. They are stored in a peat / sand mix without any heat, the barn itself being the only protection. These are put outside in February. When these have been taken out the soil heating is switched on and another batch of cuttings, mainly apple rootstocks, are inserted which root in a few weeks.

Scientific name	Commercial name when sold as hedge plants
Prunus cistena	Crimson Dwarf
P. cerasifera 'Atropurpurea'	Blaze
P. cerasifera 'Atropurpurea nigra'	Purple Flash
P. x blireiana	Pink Paradise
'E. M. Myrobolan B '	Greenglow
Malus 'Profusion', 'John Downie' 'Golden Hornet', and others.	

Water is given as seldom as possible during storage but after planting out the success rate depends much on weather conditions; overhead irrigation is an advantage in order to keep the cuttings constantly moist until established.

One of the first difficulties was the build-up of replant diseases in the peat and sand mixture; it is now policy to change the mixture annually rather than sterilize, as the texture of the peat deteriorates under constant use. Evidence is accumulating that diseases can be more damaging to hardwood cuttings than to normal rootstocks under field conditions.

It has been established in this nursery that propagation by hardwood cuttings can be successful with a wide range of ornamental cherries and crabapples. In practice, however, they restrict the method to the rather cheapér line of plants sold for hedge plants or for cheaper site planting schemes rather than for those used in gardens or landscaping, where individual specimens are required. The reason for this, Matthew claims, is that the plants on their own roots, on the average, are not so good in quality and are susceptible to poor environmental conditions, with a number of deaths occuring after establishment.

Rose rootstocks are mostly imported from the Continent and are mainly produced from seed. There is considerable interest in the evaluation of different rootstocks for rose production in Britain today but most production is still on types of *Rosa canina*. Investigation proceeds, too, on the growing of roses on their own roots and dormant cuttings have proved quite feasible but such an uneconomical use of 'eyes' is not likely to commend itself to the average rose grower.

The Forestry Commission has shown how hardwood cuttings can be used to produce a range of trees; here again the technique is unlikely to prove economic, but there are exceptions, such as the production of the London plane *Platanus x acerifolia*, which is a hybrid between *P. orientalis* and *P. occidentalis* — the most popular of all street trees where atmospheric pollution is a problem. It is fertile but variable (in fact there are several varieties) and, therefore, is normally reproduced vegetatively. Humphrey has described how well-ripened 1-year-old wood taken from the hard-pruned street trees can be rooted by giving a 24-hour soak of 25 ppm IAA.

We are all out for quick results and in some instances hardwood propagation may actually save time. In a recent survey[1] on viburnum propagation carried out by the Great Britain and Ireland Region, Macmillan-Browse has pointed out that hardwood cuttings can produce more economical results than softwoods with a number of viburnums such as *V. fragrans*, and *V. x bodnantense* cultivars, such as 'Dawn' and 'Charles Lamont'. He has produced stock hedges with plants 15-inches apart which, in good conditions, produce clean straight stems 5 ft or more in length; these at leaf fall are made into cuttings 5 or 6 inches long, treated with Seradix 3 and inserted in a cold frame and protected from frost. Watering must be done carefully in the spring, the plants fed in the summer, and good "liners" are produced by autumn. Mickelburgh has also shown that one year can be saved in the production of a saleable plant by this method; he achieved a 90% success but results fell to 50% if the stock plants were neglected, emphasizing the importance of the quality of the cutting material.

Another labour saving possibility which growers must have in mind in this container age is the prospect of rooting a hardwood cutting directly into the container in which the plant will be sold. I am not aware of anyone who is doing this yet but we have found this to be feasible with *Tamarix*. It so happened that at Pershore we had a demand for an industrial landscaping job for *Tamarix anglica*, the English tamarix, a native of our southern and eastern coasts but not in commerce as it has less horticultural merit than *T. pentandra* and *T. tetrandra*. Bob Hares had to seek propagation material from the wild source. *Tamarix* roots readily from hardwood cuttings and, provided the material was thick enough (7-8 mm diameter minimum), results should be near enough 100%. This, therefore, seemed a good opportunity to speed up techniques by rooting them straight into the final container (4½ in) using 3 peat to 1 sand, with a good fertilizer feeding (Vitax Q4 at 4 oz / bushel). This has proved very successful and may

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[1] See page 378

well save one year besides the extra handling. The technique will be tried with other plants, such as *Spiraea,* where similar results might be expected.

MODERATOR SHUGERT: Thank you very much, Dick, for a very delightful discourse; your slides and the side remarks certainly helped the presentation. It was an excellent paper and it was fascinating to see what is being done in England in ornamental hardwood vegetative production.

I know you are anxiously awaiting the next paper that has the intriguing title of, "Can Grafting be Mechanized?" It will be presented by the Secretary-Treasurer of the Western Region, Curtis Alley, from the Department of Viticulture and Enology, at the University of California, Davis. Curt Alley, "Can Grafting Be Mechanized?"

CAN GRAFTING BE MECHANIZED?

C. J. ALLEY

Dept. of Viticulture and Enology

University of California

Davis, California

By grafting, for this report, I will refer to benchgrafting rather than field grafting. Propagators that produce plants vegetatively by small cuttings are indeed fortunate. This is completely different from what the nurseryman who grows grapevines has to do. Many parts of California have no nematode or phylloxera problems so it is possible to grow grapevines on their own roots. However, the nurseryman must resort to rooting a cutting that is at least 16 to 18 inches long. In the Coachella Valley of California, where the early maturing table varieties are planted and where the soil is very sandy, growers are not satisfied with cuttings only 18 inches long. A few prefer to have them 3 feet long. This is because they dig a hole 2 feet deep and then bury the cutting so that only the top bud remains above the soil. The lower 1 foot of the cutting is bent over at a right angle at the bottom of the hole to provide a greater surface for root development. However, in many parts of California (along the coast), and in practically all of France, it is not possible to grow grapevines on their own roots because of phylloxera.

French nurserymen probably have developed benchgrafting to its highest level. In the early vineyards of France most grapevines were planted on their own roots. However, because of problem soils, such as those with high lime, a few of the more enterprising growers found that well save one year besides the extra handling. The technique will be tried with other plants, such as *Spiraea,* where similar results might be expected.

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French nurserymen probably have developed benchgrafting to its highest level. In the early vineyards of France most grapevines were planted on their own roots. However, because of problem soils, such as those with high lime, a few of the more enterprising growers found that from the southern part of the United States they could obtain rootstocks from native, wild, *Vitis* species that were resistant to these high lime soils. They were happy to get such valuable rootstocks. However, unknowingly, along with the importation of such stocks resistant to these conditions, they also imported the grape-root louse known as phylloxera. It practically wiped out the French vineyards. To combat this malady they then had to resort to the use of phylloxera-resistant rootstocks, and primarily to benchgrafting in order to develop their vineyards. Incidentally, the French later got even with the Americans. The French immigrants to the United States then brought their premium quality vine stocks with them to California and established phylloxera in this state in the coast counties. Practically this entire coastal region of California must now use phylloxera-resistant rootstocks. However, this is not the full story. In the central valley of California, where the soils are sandy, phylloxera does not thrive. Instead there is another soil pest — the nematode. So the grape grower must then use resistant-rootstocks that can ward off the ravages of nematodes. Also there are a few areas where there are not only phylloxera but also nematodes. This necessitates the use of still another type of rootstock.

With this necessity of having different rootstocks for different types of soil pests and conditions, the only way to develop such plants on resistant rootstocks is to resort primarily to benchgrafting or field budding. How can benchgrafting be mechanized? Let us consider the various phases involved in the developing of a benchgraft and see where mechanization is possible.

The first phase is the collection of understock as well as scion wood. This generally requires hand labor and shears. However, mechanization is possible in pruning by using pneumatic shears to facilitate the operation. Actually the shears operate so rapidly that there is a tendency for the pruner to cut first and think afterwards — where he made a cut — possibly the wrong one. The pruner learns very quickly not to have his free hand close to the operating shears. After the pruning wood has been collected, generally in bundles of 100, it is then placed in large fruit bins 4 x 4 x 3 feet high in moist wood shavings until time for benchgrafting. At the time the propagating wood is collected it should be graded according to caliper, as this will facilitate and speed the benchgrafting operation.

The resistant rootstocks have a bad tendency to sucker. To prevent this they must be disbudded. The disbudding operation precedes the actual benchgrafting operation. The rootstocks are cut to the desired length of about 12 inches and disbudded. Disbudding may be accomplished by shears, knives, or if one wants to become mechanized, by the use of a benchgrinder having wire wheels on either end to rub off the buds. Following disbudding, the cuttings are graded, if this is not already done, and made ready for benchgrafting.

Benchgrafting: This is already mechanized. There are several different types of machines available. A German machine involves the use of a motor having a double shaft and a series of saw blades and spacers or milling cutters and spacers on each end, to cut the slots in the ends of the stock and scion about ¼ inch deep. Stock and scion then will fit together very closely. This does not allow very much space for tying the benchgrafts together with budding rubber or other tying materials. With such a machine the benchgrafts have to be handled very gently to prevent their breakage.

There are two types of French grafting machines available. Both employ the use of knives which make cuts that are very smooth and clean. One machine cuts a very short whip graft. This, too, is very hard to tie in order to hold the two parts together. The best machine that I have seen so far is a French machine that cuts a deep saddle notch or "V" graft about ¾ to 1 inch long. This graft is long enough to tie very easily with budding rubber or raffia and, once tied, is very strong and can be handled roughly. The use of budding rubber requires cutting at a later stage, otherwise it will girdle the graft union. Some growers have used staple guns to staple the stock and scion together and this, too, is satisfactory. The understock and scion should be matched as closely as possible to the same diameter. However, if this is not possible, then the scion is generally the smaller and matched to that side of the scion having the bud.

After the benchgrafts are made they must be callused. In France, and some of the other European countries, extremely cold winters usually occur. Nurserymen in these countries resort to the use of hot-room callusing. This can be easily accomplished and mechanized by placing the newly made benchgrafts in large fruit bins as previously mentioned. During the filling of the bins with grafts, moist wood shavings are placed in the bins and sheet plastic on top to prevent drying. The bins can then be easily moved by fork lifts into hot rooms maintained between 70° and 80° F. The benchgrafts are allowed to remain for 2 to 3 weeks. During this time callusing begins. After this time the bins are removed and placed at lower temperatures to permit the benchgrafts to continue callusing but to prevent the top bud from pushing until the grafts are planted. Where growers make smaller quantities of benchgrafts, rather than using the large fruit bins, callusing boxes may be used. A callusing box is a large box that is approximately 18 inches wide, 16 inches deep and 22 inches long and has a side that is hinged. This permits the placing of the benchgrafts into the callusing box and covering with moist wood shavings. These boxes can then be easily placed on pallets and moved into the callusing rooms.

In California, where winter temperatures are mild, hot-room callusing is not used. The common practice is to make the benchgrafts which are placed in bins, boxes or stacks, then covered and packed with moist wood shavings and allowed to callus slowly inside a barn or storage shed. Benchgrafting starts by the end of January, and continues through February and part of March. Planting is done from the end of March through April.

The planting of benchgrafts is an arduous, labor-consuming process. Generally trenches are made in the ground and the benchgrafts are planted deeply so that just the graft union is above the surface of the soil. At planting time the union should be well-callused with some evidence of roots at the base of the stock; the shoots should be starting to push or even developed up to ¾ inch. The entire benchgraft must be covered with a mound of loose soil that will not pack.

Although the planting operation has not been mechanized this should be possible. Planting machines are available. A common type of planter is a machine-drawn sled on which the planter is seated with his benchgrafts. He operates directly behind a goosefoot plow which opens a furrow. The benchgrafts can be placed in the furrow directly behind the goosefoot. After the goosefoot passes, the soil then falls in around the plants. The union should be slightly above ground level. Another type of machine that has been successful in planting grape seedlings is a single-row tomato planter. This is a revolving wheel that operates directly behind the goosefoot plow. The wheel has a series of two small arms which lightly contact the stem of the tomato plant or grape seedling. As the wheel revolves directly behind the goosefoot it places the base of the seedling root or benchgraft, if used, gently into the soil to a depth of 2 to 3 inches. After this has been done the arms open and release the plant to remain in place as it continues to rotate in its upward position. Following the planter is an over-the-row tractor which carefully fills soil in — and around on either side and over the benchgraft to a depth of 1½ to 2 in. above the top bud of the scion. In California this covering depth of the scion seems very critical. Generally if the soil is not maintained greater than ½ inch above the buds, they tend to dry out. If the bud is deeper than 2 inches below the soil surface the shoot has difficulty in reaching the surface.

After the vines have been planted they are allowed to grow until the shoots reach a height of 10 to 12 inches; this generally occurs in California around the middle of July. The grafts are then uncovered for the first time and any scion roots are removed. Actually scion roots are very beneficial during the early development of the graft; they support the shoot until a good union occurs between the scion and the stock. However, once a union does occur then the scion has to be encouraged to develop upon the understock rather than on its own roots. After scion roots and budding rubbers, if used, have been removed the vines must be recovered with soil to the original height in order to prevent the burning of the etiolated shoot tissue that was under the soil. The vines are uncovered for a second time about the middle of September. If there are scion roots again, they are removed. The vines are now left uncovered in order to harden the basal part of the plant to withstand winter conditions.

As far as digging is concerned, this operation is mechanized just as most nursery operations. Following digging, grading is primarily done by hand labor except where bins can be used to carry the material from one area to another.

Benchgrafting is a successful operation with grapevines and it certainly seems such an operation could also be used with certain types of fruit trees requiring special types of asexually-propagated understock. The present procedure with such fruit trees is to root hardwood cuttings or produce stool bed layers the first year and then take the second year to develop the tree after either budding or grafting. If the rootstocks will root easily as hardwood cuttings, it seems quite probable that an operation similar to that used with grapevines could be used whereby the grafted trees could be produced in one year from grafted cuttings, as is the case with grapevines, rather than the two years presently required for this operation.

FRIDAY AFTERNOON SESSION

September 11, 1970

RALPH SHUGERT. The moderator this afternoon was on the program committee and did an outstanding job; he is a gentleman who has been extremely active in our Society, currently serving as vice-president of the Western Region. He is a good friend and an outstanding educator with the University of California at Davis. Dr. Andrew Leiser. Andy, the afternoon is yours.

MODERATOR LEISER. As you have probably noticed by now the sessions this year are a little different from those in previous Western Region meetings and are different from the two or three Eastern Region meetings I have attended in the past. So, in this afternoon's session, in keeping with the trend of being different, we are devoting the full afternoon to a discussion of plants for the future. As moderator, I suppose it is my job to stage a little for the speakers that will follow, but I am not going to steal the thunder from any of them. I will not be talking about plants for the future but would like to review briefly the sources of our present day plant materials.

PLANTS FOR THE FUTURE

ANDREW T. LEISER, Moderator
Department of Environmental Horticulture
University of California,
Davis, California

As moderator, it is my job to set the stage for the speakers who will follow. Therefore, I will not be talking about plants for the future but will briefly review the sources of our present plant palette.

Nurserymen come in all shapes, sizes and kinds. In this complex industry there is the back-yard gardener turned nurseryman, the second or third generation nurseryman, the business entrepreneur engaged in the profession as he might be in any business, and all combinations of these. This industry has many trade organizations at national and state levels. At the national level there are the American Association of Nurserymen, the Mail Order Association, the Plant Patent Owners and perhaps others. At the state level are many state associations.

But there is one organization that is unique, our International Plant Propagators' Society. It is unique in that it is truly an international organization. But more importantly it is unique because the membership is composed almost entirely of those who are true plantsmen — plantsmen in the best sense of the word — those who are engaged in their work because they love plants. The concern of the members of this Society doesn't end with putting roots on a cutting or begin with having a saleable commodity. We are interested in the plants as plants and as objects which enrich our environment. We are interested in plants as things of beauty and of utility.

Of all the nursery-oriented organizations of which I am aware, none seems to have the broad spectrum of interest from propagation, through production, to sales as does this group. For example, the California Association of Nurserymen avoids propagation or production subjects in their annual meetings but concentrates on management problems, employee relations, business law, marketing, etc.

The International Plant Propagators' Society, however, has a broad interest covering most phases of the industry but primarily in plants, their propagation and production. This interest extends to the plants themselves, to new plants, in addition to our already rich plant palette. The Eastern Region has been particularly aware of this interest. The plant forum has been a regular part of their annual programs.

For this first international meeting, the program committee decided to make the "new plants" portion of the program a full half-day session. Let us look briefly at the source of our existing plant palette and then our speakers will discuss what is occurring now and what we might expect in the future. These talks will be followed by the new plant forum under the able direction of Al Fordham.

Where did our present plant palette come from?

Recognizing that in this brief introduction I must over-simplify and generalize, let us trace together the historical background from which our present rich plant lists arose.

As explorers from Europe discovered then unknown lands they brought back new plants from the four corners of the earth. It is fascinating to read books of 150 to 300 years ago and see the names of plants, new at that time to the gardens of Europe, which resulted from these explorations. Many of these are still among our most useful plants. From North America, for example, such plants as sweetgum, *Liquidambar styraciflua;* flowering dogwood, *Cornus florida;* and sugar maple, *Acer saccharum* were early introductions. Later as explorers moved west Douglas-fir, *Pseudotsuga menziesii;* Lawson's cypress, *Chamaecyparis lawsoniana;* Oregon grape, *Mahonia aquifolium* and many others were added to the plant palette.

Later, expeditions were sent in search of plants suited to particular climates and uses and for particular genera. For example, the early 1900's saw much activity in southwest China searching for new Rhododendron species.

Another source of new plants has been the chance variations which have been found in the wild and in cultivation. These chance variations continue to be a source of new plants.

A third source of new plants has been the plant breeder. In the area of ornamental horticulture we have perhaps lagged behind other areas of horticulture and agronomy with the exception of certain plant groups such as iris, roses, rhodendrons, camellias and others.

These three sources of new plants, plant exploration, chance variation, and breeding will continue to be the ways in which we enrich our plant palette, but in new and exciting ways. Our speakers will now tell us of some of them.

MODERATOR LEISER. David Paterson, from Longwood Gardens, Kennett Square, Pennsylvania, will now start our symposium, speaking on plant exploration. David Paterson:

PLANT EXPLORATION

DAVID B. PATERSON

Longwood Gardens

Kennett Square, Pennsylvania

If anyone had doubts as to the importance of the plant explorer to ornamental horticulture, a careful reading of the catalogs of nurseries, seed houses, and house plant growers would quickly dispel them. It is obvious that without their valuable work in introducing trees, shrubs, and flowering and foliage plants from all over the world, there would be no ornamental horticulture as we know it.

People have been bringing plants from one part of the world to another since the earliest days of civilization. The earliest recorded expedition specifically planned for plant hunting took place in 1495 BC before the establishment of Athens or Rome. Queen Hatshepsut of Egypt sent five ships to the Land of Punt (Somalia) to obtain living specimens of the tree which produces frankincense. Thirty-one living trees were brought back and established in the garden of the Temple of Amon at Thebes.

Sailors, soldiers, traders, and later missionaries and government officials often brought or sent home plants, both of economic and ornamental interest. Many of the explorers of the 17th and 18th centuries had naturalists accompany them on their adventures. Many collected specimens of animals, birds, and fish as well as plants. Sometimes the ships' doctor also carried on the naturalists' duties. In fact, often the botanical work was strictly an extra curricular

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Although these gentlemen often collected quantities of seed and sometimes even live plant specimens, their main interests were scientific and their main contributions were to botany and to medicine.

It is the horticultural plant hunter, the man interested in introducing living plants to the garden, who interests us here. This is not to say that the distinction is easily made. Many of the botanical explorers sent in valuable plants, and the horticulturist prepared many herbarium specimens of scientific value.

The 18th, and particularly the 19th centuries (and the early decades of the 20th), were the halcyon days of the plant explorer. The invention of the Wardian Case in the 1830's alleviated the problem of shipping live plants, and the rates of survival became much more satisfactory. Prior to this invention the mortality rates had been astronomically high. One gentleman involved in shipping plants from China to England declared in 1819 "that 1,000 plants have been lost for one which survived the trip to England".

At any rate, from the late 1700's on, a vast array of brave and hardy men combed the world for plants to add to the beauty of the gardens of England, Europe, and America, and incidentally to add to the growth and well-being of the nursery industry. The adventures and hardships some of these men endured read like adventure fiction. Bodily injury, chase and capture by unfriendly natives, starvation, extreme loneliness were only a few of the hardships that these men were subjected to. Several died in the field, a few of them violently.

To recount fully the adventures of even one or two of these men would require much more time than could be allotted in a program such as this. However, it might be interesting to you as propagators, who are so in debt to these adventurers and dedicated horticulturists for the wide selection of plants you now work with, to sketch very briefly the accomplishments of a few plant hunters. Since most of us work in commercial nurseries or botanical gardens or similar institutions, an attempt will be made to show the role played by such organizations.

Amateur gardeners, either as individuals or as members of syndicates have sponsored many fruitful plant hunting expeditions. Plant societies in both Britain and the United States have also been responsible for financing plant explorations.

Peter Collinson, a Quaker linen draper of London, imported many seeds and plants from the American colonies. One of his correspondents, perhaps tiring of this extra activity, recommended John Bartrum, a Quaker farmer, amateur physician, and self-taught botanist, of Philadelphia as "a person whose business it should be to gather seeds and send over plants". By approximately 1735 the two had settled into a regular business arrangement. Bartrum sent over boxes containing 100 species of seeds, mostly trees. Collinson distributed these boxes to patrons for five guineas each. Ultimately, Bartrum had orders for about twenty boxes a year. His major contributions to British gardens were: *Magnolia acuminata, Chionanthus virginicus, Epigaea repens, Leucothoe racemosa, Rhododendron maximum, R. nudiflorum, Iris cristata, Phlox divaricata, P. maculata, P. subulata, Lilium superbum, L. philadelphicum,* and many more.

In 1823 the newly formed Horticultural Society of London hired David Douglas of Scone in Scotland to go to North America to find new plants. Douglas made several trips for the Horticultural Society and brought back many seeds, dried specimens, and living plants. The details of his experiences, hardships, and disappointments read like a 19th century soap opera with overtones of high adventure. He came to a violent death in Hawaii in 1834. In his short and tempestuous career he made valuable contributions as a plant collector, explorer, geographer, and alpinist. He is particularly remembered for the Douglas-fir and the sugar pine.

In 1843 the Royal Horticultural Society sent Robert Fortune to China at the standard rate paid for plant hunters, 100 pounds a year plus an expense allowance. Because of the difficulties of travel and the hostility of much of the population to Westerners, he never traveled more than 30 miles from any treaty port. However, he was an excellent organizer and made extensive collections. Most of the collection was done by Chinese "engaged at a small daily remuneration." Included in the list of plants collected during this and later trips are: *Weigela, Deutzia scabra, Jasminum nudiflorum, Forsythia viridissima, Ilex cornuta, Lonicera fragrantissima, Viburnum dilitatum, Dicentra spectabilis, and the amoena azalea.*

Undoubtedly, one of the most important collectors was George Forrest, like Fortune, a Scot.

In 1904 Forrest traveled by way of Burma to Yunnan, which was to be his headquarters for 28 years. During this first journey he established the procedures he followed in all his subsequent explorations. He chose an area, established the best methods of collecting, trained a large and competent staff, established friendly relations with the Chinese, and combed the area for plants. On this trip he found among a number of valuable primulas: *P. bulleyana,* named for his principal backer; *P. beesiana; P. forrestii;* and *P. littonii.*

Forrest was interested in collecting plants for the specialist, the rock gardener, alpine enthusiast, and the gardener interested in primulas, rhododendrons, and the like.

In 1915 the Rhododendron Society was formed. Forrest made all his subsequent journeys with this society as the chief backer. He was offered a bonus for each new species he introduced. He made more than 5,000 collections of rhododendrons and introduced so many new kinds that the whole genus had to be revised. Besides the introduction of rhododendrons, he will be remembered for *Camellia salvensis, C. cuspidata,* and the single form of *C. reticulata, Meconopsis spp., Lilium spp. Primula malacoides, Abies forrestii,* and *Malus yunnanensis.*

A great many nurseries have been involved in plant exploration. When one thinks of the contribution made by nurserymen to plant exploration, the name of Veitch immediately comes to mind. Let us just briefly mention one member of this famous family, several generations of which contributed personally to the collection of new and rare plants. John Gould Veitch was the great-grandson of the founder of the original firm at Exeter and the son of James Veitch who started the Chelsea Branch. Although he died at the early age of 31, his visit to Japan resulted in the introduction to Britain of such plants as *Lilium auratum, Magnolia stellata, Primula amoena, P. japonica, Ampelopsis veitchii* (now renamed *Parthenocissus*), *Cryptomeria japonica* 'Elegans', and *Juniperus rigida.*

In the 19th century the Veitch firm sent out such famous explorers as Charles Maries, who introduced *Daphne genkwa, Abies mariesi, Schizophragma hydrangeoides, Hamamelis mollis, Enkianthus campanulatus,* and *Viburnum plicatum* 'Mariesi'.

Others were sent to various parts of the world to bring back orchids, *Nepenthes* (tropical pitcher plants), and other exotics.

Perhaps the most famous of all plant explorers, Ernest Henry "Chinese" Wilson, got his first commission from Veitch's to find seed of the dove tree, *Davidia involucrata.*

One immediately thinks of botanic gardens and arboreta in connection with plant exploration. Let us examine briefly the contributions of a very few of the many men who collected for the Royal Botanic Garden at Kew and the Arnold Arboretum in Jamaica Plains, Mass.

Sir Joseph Banks, himself a botanical explorer on the famous voyages of Captain Cook, established a "mart and exchange of plants" at Kew. He trained many gardeners in the art of plant hunting and sent them to various parts of the world and distributed the resulting plants. Most were planted at Kew, but some went to botanic gardens in Jamaica, St. Vincent, and Ceylon. To name just one collector, Francis Masson collected twice in South Africa and on the Iberian peninsula, Madeira, the Canary Islands, the Azores, the West Indies, and finally in North America where he apparently froze to death in 1805. He introduced Cape heaths, Cape pelargoniums, the forerunners of the garden geranium, and several proteas and aloes.

In the mid-1800's Dr. Joseph Dalton Hooker made explorations to India and Sikkim undergoing many hardships and frustrations, some caused by terrain and weather, others by political situations. Together with Dr. John Thomson, he collected and introduced many plants including species of *Primula* and *Meconopsis.* He found 43 species of rhododendron; *R. campylocarpum, R. ciliatam, R. cinnabarinum, R. falconeri, R. griffithianum, R. maddeni,* and *R. thomsoni* are just a sampling.

Arnold Arboretum. Dr. Charles Sprague Sargent made an important contribution to the Arnold Arboretum by his own plant explorations and introductions from Japan. He was particularly interested in trees and found many new species as *Malus sargentii* and *Prunus sargentii;* he became extremely interested in the flowering cherries of Japan and was later instrumental in introducing them to England and the United States. His introductions also include *Rhododendron schlippenbachi* (as a cultivated plant).

As has been mentioned earlier, Ernest Henry Wilson had collected plants in China for Veitch on two occasions. In 1906 he was invited by Professor Sargent to revisit China on behalf of the Arboretum and some private subscribers. This visit produced *Magnolia wilsonii, Lonicera nitida, Corylopsis willmottiae,* among many others. In 1909 he migrated to America and became a permanent member of the Arboretum staff and launched a new expedition in 1910.

The contribution he made to our plant lists is astounding. Imagine American nurseries without *Berberis candidula, B. gagnepainii, B. julianae, B. triacanthophora, B. verruculosa, Buddleia davidii,* 'Magnifica', *Buxus microphylla* var. *koreana, Cornus kousa* var. *chinensis, Cotoneaster apiculata, C. dammeri, C. salicifolia* var. *floccosa, Davidia involucrata, Evodia, Ilex pernyi, Juniperus conferta, Kolkwitzia amabilis, Malus theifera, Picea asperata, P. wilsonii, Pieris taiwanensis, Pyrus calleryana, Rhododendron ambiguum, R. discolor, R. keiskei,* Kurume azaleas, *R. williamsianum, Sarcococca hookeriana* var. *humilis, Stewartia koreana, Viburnum rhytidophyllum.* This is only a partial list, but enough to show how indebted we are to this famous plant collector. Mr. Wilson died in an automobile accident in 1930.

The United States government has been involved in plant introduction officially and unofficially since its early days. At one time the introduction of economic plants was a function of the Patent Office which sponsored one of Fortune's expeditions in 1854.

In 1898 the Section of Seed and Plant Introduction of the USDA was formed. David Fairchild was its director from 1903-1928. He was a prominent collector of economic plants, being responsible for the introduction of the soybean from Japan in 1898.

He hired Frank Meyer and Joseph Rock, two plant hunters who, although their primary purpose was the introduction of economic plants, did introduce many ornamentals. Meyer introduced *Aesculus chinensis, Rosa xanthina, Syringa meyeri, Juniperus squamata* 'Meyeri'. He was the first to find *Ginkgo biloba* growing in the wild, although it had long been known in cultivation.

Joseph Rock, an extremely versatile scholar and scientist, explored in Indochina, Taiwan, and Burma in addition to his work for the government. He also collected for the Arnold Arboretum and the Howard Museum of Comparative Zoology. He sent home nearly 500 species of rhododendrons. Many were not new introductions, but included many superior forms, not only important for their own sakes, but in hybridizing.

Frank Kingdon-Ward explored for plants for a nursery firm, private patrons and syndicates, and for the New York Botanical Garden. His journeys took him to Yunnan, Szechwan, Upper Burma, French Indochina, southeast Tibet, and in the Assam Himalaya, an area already explored by Hooker. Between 1909-1957 he introduced hundreds of species. He specialized on primulas and rhododendrons, but collected many other genera.

Plant exploration continues today. Since World War II many amateur growers and members of plant societies have been active in bringing in new plants.

Dr. Ira Nelson of the Louisiana Foundation for Horticultural Research made three trips to Latin America. His main interest was in plants for the deep south. Among his introductions was a yellow amaryllis from which a series of pastel colored flowers have been bred. He also introduced *Demerocostas uniflora* and *Passiflora coccinea*, the beautiful scarlet passion flower. His very promising and productive work was ended by a fatal automobile accident.

A professor and four graduate students from Wye College in England are raising money through subscription for an expedition to areas of Afghanistan that have never been explored. Though their main purpose is to collect herbarium specimens, they plan to send back bulbs, seeds, and succulent materials.

In 1956 the Longwood Gardens—USDA Plant Introduction Program was started for the introduction of ornamental plants. The restrictions imposed by Federal plant quarantine procedures, necessary as they are, and the difficulty encountered by individuals in getting cooperation from certain foreign governments, made this program seem worthwhile. Necessary negotiations are made through counterpart departments of the foreign governments and the United States, through the State Department.

The botanists and horticulturists involved have been either fulltime employees of the USDA or staff members of botanic gardens or other scientific institutions. These were on loan to the Plant Introduction Office and collected as collaborators or temporary employees of the USDA Agricultural Research Service. Longwood Gardens provides grants to maintain the plant explorers in the field.

Twelve explorations have been made. To —

Southern Japan	1956	by Dr. John Creech
Southern Europe	1957	by Dr. Fred Meyer
S. Brazil and Argentina	1958	by Dr. Llewelyn Williams
Australia	1958-1959	by Mr. George Spalding
Northern Europe	1959	by Dr. Meyer
Northern Japan	1960	by Dr. Creech
Nepal	1962	by Dr. Creech and Dr. Francis de Vos
Russia	1963	by Dr. Creech
Sikkim (West Bengal)	1964	by Dr. de Vos and Dr. Edward Corbett
Korea	1966	by Dr. Corbett and Dr. Richard Lighty
Taiwan	1967	by Dr. Creech
New Guinea	1969	by Dr. Harold Winters and Mr. Joseph Higgens

An exploration was planned for July, 1970, to collect plants in Siberia which would be appropriate to the Great Plains area of the U. S. and for re-vegetation of the "dust bowl" area. The trip was postponed until August 1. Just prior to that date the government of the U.S.S.R. again postponed it for a year. The reason given was that the Russian party Dr. Creech was to join had run into unusual drought conditions and collecting was impractical.

Every plant explorer likes to bring new and unknown plants into cultivation, and present plant hunters are bringing some in and will continue to do so for some time. An important goal of present and future plant explorations is often not clearly understood. That is the expansion of germ plasm pool of extant material for breeding for such characteristics as drought resistance, cold tolerance, good flowering and growing characteristics, and for disease resistance.

Many of our ornamental plants are descendants from one or a very few collections. Their future use could be much improved by breeding with similar plants collected from other latitudes or elevations.

Plant exploration has had an exciting and valuable history, has a viable present and a promising future.

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MODERATOR LEISER. Thank you very much, David. We, in the Department of Environmental Horticulture at U. C. Davis, are quite excited about the possibilities of bringing in more germ plasm, more variation. But once a new plant is introduced, the problem is to evaluate it and determine whether it is worthwhile, then get it into the trade. Perhaps those of us in educational institutions look at things quite a bit differently than nurserymen. Since there is a combined need for both plant evaluation and getting the plants into the trade, and since it is largely the nurserymen who will have to get the plant into the trade, they will have to do the plugging, advertising, and so on. Our next speaker, Bruce Briggs, is currently president of the Western Region and is vice-president-elect to the International organization. He will discuss the evaluation of new plant materials from the nurseryman's standpoint. Bruce.

EVALUATION OF NEW PLANTS

BRUCE A. BRIGGS
Briggs Nursery
Olympia, Washington

In man's continuing search for new plants, there is an increasing need for more selective evaluation. There is no special merit in "newness" alone. Sometimes, we rather need a "new" look and evaluation of an "old" plant. Our greater mobility today now allows us to evaluate first hand the plant materials of other areas, to bring some back to adapt from other climates, and sometimes to discover improved variations within the species and new cultivars. Improved cultural practices and laboratory facilities give us greater controls over our immediate environment, so that new plant introductions can now take a course and a direction. We can work more directly toward selecting, shaping and breeding the plants required to fill the predicted needs.

As plantsmen, propagators and nurserymen, I feel that we have a special obligation to evaluate the "growing" as well as the "aesthetic" aspects of these new plants. As a practicing nurseryman, I consider the basic concerns are: 1) that the plant is capable of being propagated and grown commercially, and 2) that the plant has good sales appeal and potential market demand.[1]

[1]Ed. Note: Mr. Briggs showed a number of excellent colored slides of plant materials to illustrate these points.

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CAPABILITY OF BEING PROPAGATED AND GROWN COMMERCIALLY

Ease of propagation. As propagators, many of us pride ourselves on our abilities to propagate difficult plants by various special and often tedious methods. Nevertheless, when we are working toward quantity propagation, we must consider ease of propagation as a factor. If the plant is to become a financial asset to a nursery, it must be reproduced in a reasonable length of time and with a standardized system which the employees are capable of carrying out.

There are a few plants which warrant difficult and special propagation techniques because of their very superior qualities and high demand. For instance, nurseries still propagate *Acer palmatum* 'Atropurpureum' and *Cotinus coggygria* in its red forms because the public is willing to pay the premium for these desirable items.

On the other hand, difficult to propagate cultivars may lose their high demand as other cultivars take their places. *Rhododendron* 'Britannia' and *R.* 'Goldsworth Yellow' once considered the best are now used less often (at least in our area) where other good reds and yellows are now readily available. Likewise, our nursery passed over a very fine form of *Chamaecyparis nootkatensis* 'Pendula' which we obtained some years ago from Holland. It proved too difficult to propagate commercially by cuttings, so we have gone on to more easily propagated strains which were found in this country.

I do not mean to infer that we should entirely discard a fine plant because of the difficulty in propagating it. A plant of real merit should be kept in a private collection or arboretum with the hope that some new technique may be developed which would make its propagation more feasible. It might also be sent on to another climate or growing condition to check possible propagation under these varying conditions.

Hardiness is a somewhat relative factor which must be considered. As the more tender plants always seem to be the most attractive, we are constantly tempted to grow plants just a little more tender than we should.

Breeding programs may eliminate too tender varieties by exposing young plants to cold temperatures in growth chambers, or may test hardiness by subjecting tissue samples to artificial cold in the laboratory (3).

Breeders might consider selecting seeds, cuttings or scions from areas in the northern latitudes and the higher elevations when possible, as these plants will maintain their built-in early period of dormancy, regardless of where they are later transplanted (6).

A cross breeding with native plants of an area will sometimes increase hardiness. Institutes such as the Saratoga Horticultural Foundation, Saratoga, California, are constantly working on hybridizing and selecting improved and hardier strains of needed plants. Currently, the Willamette Valley Experiment Station, Aurora, Oregon, is working on a program of selecting superior strains of the native *Ceanothus prostratus* and *C. procumbens*.

General vigor and disease resistance. When we are evaluating plants, we should consider their general vigor and their resistance to damage from insects, pathogens, diseases, and chemicals used in general culture.

a. **Insects.** Damage from the same insect may vary considerably among different cultivars of the same genus. Work by Dr. Joseph L. Saunders on the effect of the obscure weevil (*Sciopithes obscurus*) on 20 varieties of rhododendrons commonly grown in the Washington and Oregon areas, showed a wide variation of leaf damage ranging from 0.8% defoliation on *Rhododendron* 'Ivery's Scarlet' to 32% on *Rhododendron macrophyllum* (4).

In areas where black aphids prove very destructive to *Picea pungens* 'Glauca', plantsmen may consider it more desirable to substitute a plant such as *Abies lasiocarpa* 'Arizonica Compacta' to create a similar blue effect.

b. **Diseases and pathogens.** It will truly be a breakthrough when and if we could find plants entirely free of all disease problems. In the meantime, we can at least be somewhat selective and avoid those with known serious problems.

For the last five years, the Western Washington Research and Experiment Station, Puyallap, Washington, has been carrying on research to select varieties of lilac which are resistant to *Pseudomonas syringae*, a lilac blight (2). This type of research is very important especially where there is no known cure or satisfactory control of the disease.

We can sometimes choose between two plants of similar character to avoid a known problem. In our area, *Juniperus sabina* 'Tamariscifolia' is sometimes bothered by *Phomopsis juniperovora*, the juniper twig blight, which causes unsightly brown areas to form. A satisfactory substitute might be *J. chinensis* 'Pfitzeriana' varieties which do not seem to be attacked by this blight. We can choose to use *Photinia* 'Fraseri' rather than *Photinia serrulata* because it is more resistant to mildew. We might consider forms of *Chamaecyparis obtusa* or *Thuja* in place of *Chamaecyparis lawsoniana* to avoid damage from *Phytophthora*.

c. **Chemicals and pollutants.** In this day of a generally wide use of herbicides and other agricultural chemicals, we find some plants which are susceptible to some damage from them. Of the perhaps, 400 varieties of rhododendrons which we grow, we find that *R.* 'Mrs. A. T. DelaMare' is particularly subject to damage from Atrazine and Simazine. As these chemicals are a part of our normal nursery operation, we probably will gradually phase out this particular variety. The *Rhododendron X loderi* hybrid group of plants will defoliate within hours after their foliage has been sprayed with Ethion.

With the present interest in ecology and environment, we need to work two ways at the same time: 1) to develop plants which will require fewer chemicals in their culture, and 2) to make selections and develop new cultivars which will tolerate the polluted air in the industrial areas. Successfully established plantings in these areas can help to tip the scale and actually work toward air purification (1).

Transportability may become a limiting factor in a nurseryman's evalution of some plants. He must be able to transport the finished product to the market in a saleable condition. The fact that *Calocedrus decurrens* and *Cornus nuttallii* are exceedingly hard to transplant limits their otherwise potentially wider usage. The brittle branches of *Rhododendron* 'Jan Dekens' limit its use for successful long distance shipping.

SALES APPEAL AND POTENTIAL DEMAND

Saleability is the final and, perhaps, the most important test a plant must pass for a nurseryman who wants to stay in business. There would seem to be little purpose in growing plants without a ready market.

While most plants are attractive when they are of good general vigor and health we need to strive for "extras" in better foliage, growth habit, and bloom.

Better foliage may mean an increase in size, color, sheen or indumentum. *Picea pungens* 'Hoopsi' cultivar increased the intense blue color of the foliage. The *Magnolia grandiflora* 'St. Mary' forms increased the color and amount of indumentum on the underside of the leaves.

Better form and growth habit is something for which nurserymen and propagators are constantly striving. Forms of *Chamaecyparis obtusa* which outshine their parents, such as *C. obtusa* 'Nana' *C.o.* 'Gracilis' and *C. o.* 'Kosteri', can be vegetatively propagated to preserve their unique characteristics. The small needled *Pinus mugo,* which used to be selected entirely from seedlings, can now be propagated by cuttings to preserve the compact quality (5). *Prunus laurocerasus* 'Zabeliana', *P. l.* 'Otto Luyken' and *P. l.* 'Mt. Vernon' are newer cultivars in demand for their more compact habit and greater foliage sheen. Fastigiate, weeping and prostrate forms have been developed from native pines, so that they can be used in residential gardens and will complement newer architectural trends.

Irregular and unusual forms are in demand for landscape interest. Specimens such as *Sequoiadendron giganteum* 'Pendula', *Picea abies* 'Pendula' and *Cedrus atlantica* 'Glauca Pendula' require considerable age to become attractive. Used as singles in a landscape, they are in more limited demand, but grown to a mature age and shape, they do bring a premium.

Flowers. Improvement in the various aspects of flowering lead to a higher evaluation of the plant. Flowers may be increased in size: consider *Rhododendron* 'Crest' compared to its parent, *R. wardii*. Flowers may be improved when the color is heightened; compare *Kalmia latifolia* 'Dexter No. 5' to the native *Kalmia latifolia*, or *Daphne cneorum* 'Ruby Glow' to *Daphne cneorum*. Flowers may be improved by changing their form; we have had the double bloom of *Rhododendron* 'Fastuosum Flore Pleno' and now one of the hybridizers has a new double pink form. The blooming period of the plant may be lengthened, as *Rhododendron* 'Hardyzer Beauty' blooms longer and larger than either of its parents, *R. obtusum* 'Hinodegiri' and *R. racemosum*. The plant may be brought into bloom at an earlier age, such as *Magnolia grandiflora*'St. Mary' over the straight *Magnolia grandiflora*. The amount of bloom may be increased, as in *Fuchsia magellanica* 'Papoos' and *F. m.* 'Santa Claus' over *F. m.* 'Riccartonii'. Plants may be developed to bloom in periods when the flowers are especially in demand, such as the fall bloom on *Hebe* 'Autumn Glory' or *Sedum* 'Sieboldii', or the winter bloom on *Hamamelis mollis*, or on *Jasminum nudiflorum*.

CONCLUSIONS

So then, these are some of the qualities a commercial nurseryman looks for in evaluating plants. As the hybridizers, plant introduction centers, and arboretums bring new materials to our attention, we can work closely with them in evaluating these "growing" aspects. As the designers, ecologists, and consumers bring new demands to our attention, we can work with them in "creating" the plant materials best suited to their needs. All plantsmen join together in their appreciation of a good healthy plant of fine physical properties planted in the proper location for full mature development.

More selective evaluation at the various stages on introduction, testing and growing will serve to raise the whole general level of the quality of available plant materials. We will, indeed, need to develop superior plants if we are to meet the ever more demanding requirements of our future environment and our future generations.

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MODERATOR LEISER. Thank you, Bruce, for a real nice presentation. Now I know why it is always nice to have a back-up job. If Bruce ever goes broke in the nursery business, he can always hire out as a photographer, or teach color photography. I really enjoyed those slides, Bruce. Bruce mentioned a topic that is a nice lead-in for our next speaker; this is the point of their breeding program having a goal — objectives — what you want to breed into a plant. Our next speaker is not a member of the Society and I have known him for a relatively short time. He came to the University of California at Davis this year for a short sabbatical leave; in that time we thoroughly enjoyed having him and appreciated the contributions he made to our Department. When we were looking for a person to have on the program to dig into some of the new ideas in plant breeding, I asked a geneticist in our department who the best person in the country would be to do this — not necessarily the oldest, nor the one in plant breeding the longest, but the person who had novel ideas for really moving ahead and breeding commercial plants. He said, "That is easy — that would be Ken Sink". So without further ado, Dr. Kenneth Sink, from Michigan State University, formerly from Pennsylvania State University. Ken.

KENNETH SINK. I don't know if all those comments are true, but I will try to live up to them. The title of my talk is "Hybridizing New Plants", and I am sure you realize, as well as I do, that it would be almost impossible for me to cover all the facets of plant breeding of woody ornamentals and annuals in 25 minutes. So I have chosen four areas to dwell on in particular, and will give you some of our ideas and concepts and a little bit of our research results that we think will be valuable in producing really unique and valuable new plants.

THE FUTURE IN ORNAMENTAL PLANT BREEDING[1]

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The breeding of new ornamental plants is beginning to gain momentum in the United States and overseas. This includes efforts on annuals, perennials, woody shrubs and shade trees. A growing number of horticulturists and foresters at academic institutions, the U. S. Department of Agriculture, and commercial companies have a primary concern in ornamental plant breeding. Recently, Egolf (1) and Goldsmith (2) reviewed the present status of breeding efforts on woody ornamentals and hybrid annual flowers, respectively. The former report relates the plant species, including *Camellia, Chaenomeles, Hibiscus, Ilex, Lagerstroemia, Magnolia, Malus, Pyracantha, Rhododendron, Rosa, Syringa* and *Viburnum,* being studied by some 41 researchers. The latter report presents the current picture in F_1 hybrid annuals with special reference to petunia, snapdragon, marigold, zinnia, and geranium.

The purpose of this paper is to review three selected research areas of ornamental plant breeding which are undergoing change relative to the future task of developing improved types of ornamental plants.

1. Plant Improvement by Mutation Selection vs Employment of the Sexual Mode of Reproduction. To date the majority of ornamentals, particularly asexually propagated woody ornamentals and greenhouse crops such as poinsettias, chrysanthemums, geraniums and carnations have been introduced as a result of sport, chance seedling, selected ecotypic variants or planned crosses between parents which probably were derived from open-pollinated heterozygous wild relatives. This type of plant improvement, where asexual propagation of superior forms resulting from sports or chance seedlings, is of limited value in the development of superior type plants. The limiting condition is mainly that these singular changes in a plant characteristic, when compared to the standard form, result from mutations. The latter occur at a very low rate, approximately 10^{-6} and, furthermore, most mutations are of a deleterious nature. Mutant forms do have the advantage of giving a single change in what is genetically a heterozygous condition. Another advantage is that those ornamental plant species which are asexually propagated are uniform by virtue of clonal propagation from the original parent.

An example of an ornamental plant improvement program which has evolved from sport selection to hybridization is the greenhouse-

[1] Michigan Agricultural Experiment Station Journal Article No. 5267

grown poinsettia for Christmas sale. This plant, *Euphorbia pulcherrima* Willd. ex. Klotzsch, was introduced into the U. S. from Mexico about 1835. Until 1963, all cultivars which were introduced as being superior to older types were derived as sports or somatic variants on pre-existing clones. Advances were made by introducing redder forms, tetraploids, and types with increased bract size, but no improvement in keeping quality was found in red types similar to that observed in the best white keeping type, 'White Ecke'. The red-bracted cultivars, which make up about 85 to 90 percent of all plants sold at Christmas, had very poor leaf and bract retention when placed in the home environment following culture in the greenhouse. This created numerous problems for the grower; namely, his crop had to reach optimum bloom for a short, precise marketing period prior to Christmas, so that the customer would realize maximum enjoyment from a plant destined to last until New Year's at most. Jim Mikkelsen, at Ashtabula, Ohio, had the idea to hybridize red and white cultivars to incorporate the keeping quality of the latter into the former, and it resulted in the variety 'Paul Mikkelsen' in 1963.

An example where selection in self-pollinated lines derived from heterozygous varieties, which had previously been asexually propagated, has resulted in superior plant types is the seed-grown geranium for bedding plant purposes.

Prior to the introduction of the 'Nittany Lion Red' geranium, the plants grown for spring bedding plant sale were produced by stem and leaf-bud cuttings from stock plants during the spring. The seed-produced crop gives the grower a uniform, disease-free, shorter growing time product which can be readily programmed for specific marketing periods. The plant breeder can provide a better geranium by selecting lines for such traits as flower size, flower type, plant height, flower color and recombine these in a vigorous growing hybrid product. There is still a tremendous challenge in breeding geraniums for the future for earlier flowering and final plant height and, already there are improved varieties, the Morton and Carefree hybrids, when compared to the original seed types.

In woody ornamental breeding it would appear that the selection of sports, seedling and ecotypic variants as a means of plant improvement has been used almost to the point where further yield of unique plants will be negligible in relation to the efforts expended. Woody ornamental breeding is a complex task due to the long time interval between generations, seed dormancy factors, land area requirements and maintenance. However, it is encouraging to note that there are already a number of established genetics and breeding projects which hopefully will be carried forward and funded in succeeding generations of researchers which will be necessary to provide continuity for such programs.

2. **Plant Hardiness as a Factor in Breeding Programs.** Our current knowledge of the factor(s) responsible for winter survival of

plants and flower buds in perennial, ornamental shrubs and small trees is limited. Very few geneticists and breeders have identified the phenotypic characteristic(s) associated with hardiness and established their inheritance patterns. An example of this type of research is that presented by Kneckt and Orton (3). These researchers found that stomate density was related to plant hardiness in *Ilex*. A low stomate number was observed on hardier clones and it was proposed to employ this phenotypic character as a selection index to develop hardy breeding lines.

The hardiness of evergreen flower buds and stems has been studied by Glen Lumis, a graduate student in our Department. His observations during the past three winters showed that most of the flower buds of *Rhododendron yedoense* var. *poukhanense* (unnamed cultivar) were injured by low temperatures during December and January (See Fig. 1 for temperature data). Splitting of upper stems just below the flower bud was often observed outdoors and after artificial freezing tests. However, most of the buds of *R.* 'Maryann' were not injured. Bud survival data are shown in Table 1. During the months of December and January a significant difference in upper stem moisture content was observed between the 2 cultivars (See Fig. 1).

By sectioning the upper stems while they were frozen it was found that large ice masses had formed in the vascular tissue. These damaging splits occurred only in *R. yedoense* var. *poukhanense,* the less hardy cultivar with the higher water content. Artificial lowering of the water content of *R. yedoense* var. *poukhanense* twigs eliminated the splits and increased the hardiness to nearly that of *R.* 'Maryann'. Efforts to determine differences between the two cultivars, in addition to water content, were to no avail.

Browning is an obvious sign of low temperature injury in the flower bud. Although browning of floral tissues is symptomatic of low temperature, it provides neither any evidence of the location of initial injury, nor any differentiation between direct injury (caused by low temperatures) and indirect injury (caused by dead cells adversely affecting their living neighbors). In order to determine living from dead cells, whether of twigs from outdoors or from artificial freezing tests, the vital stain—neutral red—was used. This stain proved to be very useful. Initial injury to azalea twigs occurred in the upper stem. Exposure to slightly lower temperatures injured the upper stem pith and also the flower bud. There was no intermediate in flower bud injury; the flower was either dead or alive. In some cases only the ovary was injured directly by the low temperature. The rest of the flower soon became brown due to the deterioration of the ovary.

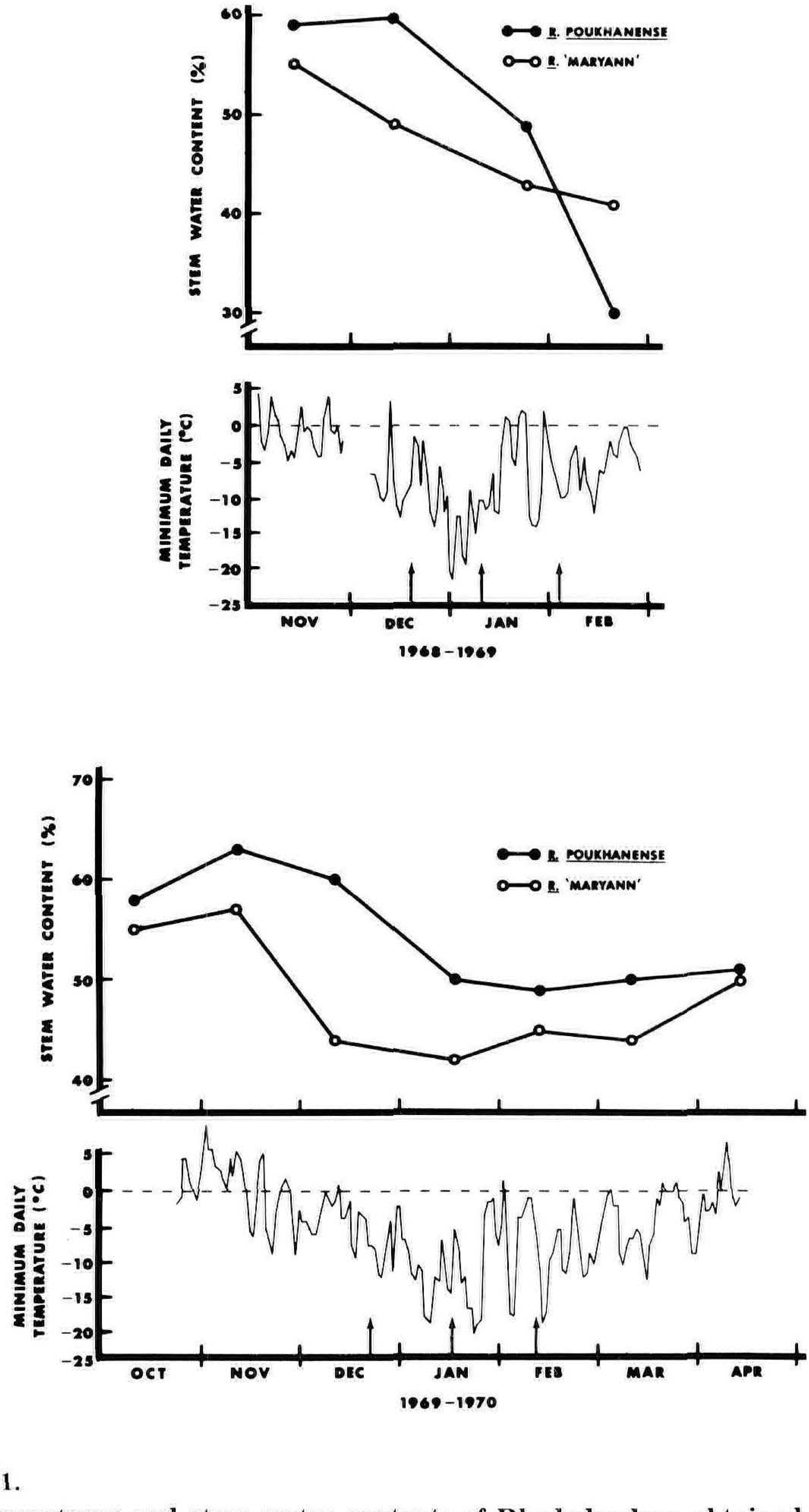

Fig. 1.

Temperatures and stem water contents of Rhododendron obtained from outdoor surveys in 1968-1969 and 1969-1970. Vertical arrows indicate flower bud injury sampling dates.

Table 1. Number of flower buds appearing normal or injured at various sampling dates prior to and after low temperature periods for three azalea cultivars.

Date	*R.* 'Maryann'		*R.* 'Mikado		*R. yedoense* var. *poukhanense*	
	injured*	uninjured*	injured	uninjured	injured	uninjured
12/18/68	2	58	2	58	3	57
1/10/69	9	51	33	27	48	12
2/3 69	12	48	39	21	54	6
12/21/69	2	46	2	46	3	45
1/16/70	9	39	6	42	39	9
2/11/70	8	40	9	39	44	4

*' Total for three replications

Further studies of the freezing process in azalea twigs revealed that freezing occurred in a nonequilibrium pattern where ice formation was not a function of decreasing temperature. Ice formed very rapidly. This is in sharp contrast to *Prunus* and *Malus* twigs under similar conditions in which ice formed much more slowly, as a function of decreasing temperature. Fig. 2 depicts the difference in freezing pattern between azalea, apple and cherry. When ice formation is rapid, the ice is directly involved in stress. Water content is a very important consideration during nonequilibrium freezing. A high water content, combined with the rapid ice formation, caused the large, splitting ice masses mentioned earlier. Even when the water content is moderate the strain of rapid ice formation can be damaging as tissues are contorted by their water loss and the formation of extracellular ice.

A screening technique based on stem and bud water content is planned for the future. We are also studying the possibility of using differences in the freezing process as screening procedure.

3. **Future Trends in Breeding Ornamental Plants.** There will be a continued effort to place on trial, evaluate and introduce worthy plant species which are discovered through ornamental plant explorations.

Cooperation between forest tree geneticists, breeders of ornamental plants, and ornamental horticulturists will increase in the evaluation of trees for landscape use, particularly pines, spruces, cedars and other evergreen types.

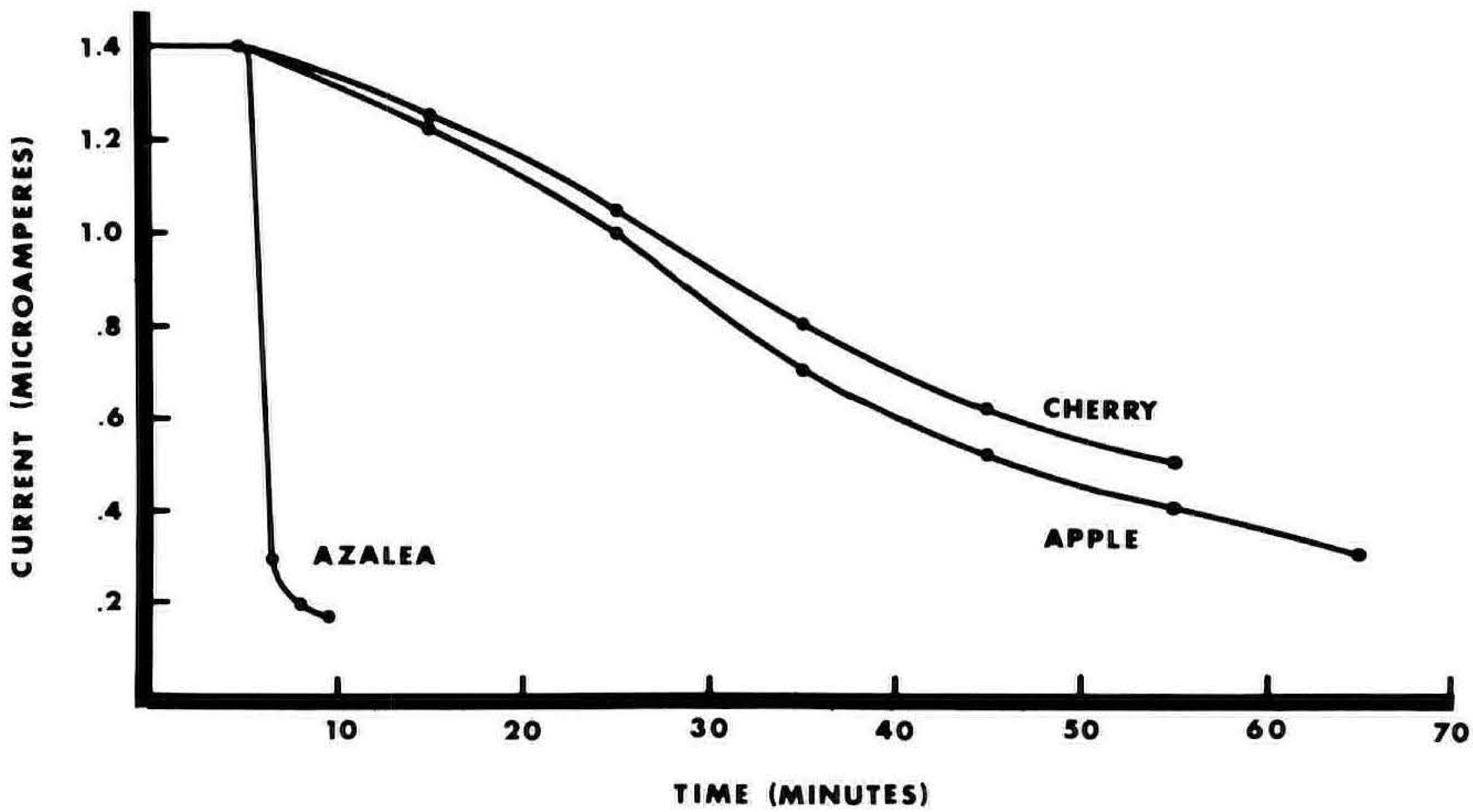

Fig. 2. Freezing pattern comparison among azalea, apple and cherry twigs.

New plant materials released should be a significant contribution to the diversity of types available and possess the ability to withstand such environmental stresses as air, water and soil pollution, cold and drought, and be adapted to the cultural practices used for growing plants to marketable size.

In annual flower crops there will be F_1 hybrids available in more species and refinements in the techniques used to produce seed crops will be made by the breeder.

Asexually propagated greenhouse crops will be tried as seed crops and breeders will continue to select and develop inbred lines, identify heritable characters and their genetics, and combine desirable traits in hybrid varieties.

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MODERATOR LEISER. I will now turn the microphone over to Al Fordham from the Arnold Arboretum, whom you all know. He will start the session on "New Plants". Al.

NEW PLANT INTRODUCTIONS AND THEIR IMPORTANCE

ALFRED J. FORDHAM
Arnold Arboretum of Harvard University
Jamaica Plain, Massachusetts

When raised from seeds, plants sometimes exhibit characteristics which differ greatly from those of other members of the same seedling lot. These variations create many new varieties which a more knowledgeable horticultural public has found increasingly interesting in recent years. Some examples of this are given below.[1]

Variation in Japanese Dogwood *(Cornus kousa)* **seedlings.** *Cornus kousa*, the Japanese dogwood, provides a striking example of the variation that can arise when plants are raised from seeds. An amateur horticulturist in the Boston area started a number of *C. kousa* plants from seeds in 1957. About 80 of these were lined out in a field where they have grown to flowering size. This year one inflorescence was collected from each of 24 trees and these were assembled and photographed. No two were alike. Some had good ornamental characteristics while others were obviously inferior.

Both *Cornus kousa* and *C. florida* have small globose clusters of insignificant flowers which are accompanied by four showy bracts. The combination comprises an inflorescence which is often loosely termed a flower. We will, for the sake of simplicity, use the term "flower". One tree had larger than normal flowers which measured from 6 to 6½ inches in diameter. Individual bracts were broad with a small neck. The bract tips, however, were recurved giving the flower a "floppy" look. One tree was double-flowered with the additional bracts varying from flower to flower in size, shape, and number. Some flowers had 6 bracts while others had 7 to 9.

The tree which presented the most pleasing appearance had flowers about 5 inches in diameter with wide, overlapping bracts which were slightly cupped. The color was a good white. Many Japanese dogwoods display their flowers in a manner so that they must be viewed from above to be seen at their best. Not so with this specimen; its flowers are borne so that they can be seen at eye-level.

In addition to variation in flower characteristics, there was also a diversity of growth habits. Some specimens were narrow in shape while others were broad and rounded.

Variation in Flowering Dogwood *(Cornus florida)* **seedlings.** Flowering dogwood *(Cornus florida)* also exhibits variation when grown from seed. From an ornamental point of view, some trees are far superior to others. Small, thin bracts characterize some flowers, while large, broad bracts are found in others.

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[1] Ed Note: Mr. Fordham showed slides illustrating these examples.

Variation in Sugar Maple *(Acer saccharum)* **seedlings.** Sugar maple *(Acer saccharum)* seedlings also vary widely. A good example of the variation that can occur in growth rate and tree shape is illustrated by a row of roadside trees at Rochester, New Hampshire. It is probable that they were collected in the nearby woods — once a common practice. The result of this kind of random selection is an unsightly hodge-podge. Some of the trees are tall and narrow while others are broad-spreading. Trees from selected clones of plants, on the other hand, would create a uniform row of trees and a more pleasant prospect.

Variations in shape of the sugar maple allow the landscaper to choose a form exactly suited to his design, location, or whim. Those broad and spreading would be best suited for school grounds, parks, home landscape or any situation where maximum shade was an objective. Clones characterized by tall, narrow, trees would be fitted for use as small street trees in lawns, or in locations where a narrow tree is desired. The large, narrow, oval, specimen is a shape which one frequently sees near homes in New Hampshire and Vermont. Its form must have been appealing to those who brought the trees from the woods to decorate their grounds.

MALUS 'DONALD WYMAN'

ALFRED J. FORDHAM

Arnold Arboretum of Harvard University

Jamaica Plain, Massachusetts

Malus 'Donald Wyman' came into being as a volunteer seedling in the crabapple collection of the Arnold Arboretum. It was first noticed in the late 1940s. Observational notes on the flowering and fruiting characteristics of *M.* 'Donald Wyman', kept since 1955, indicated that the seedling had attributes — particularly its fruit — which made it worthy of a cultivar name.

Each year in spring it produces a mass of small whitish blossoms which are followed in autumn by an exceptionally heavy crop of small bright red fruits which hold their color and remain on the tree into winter. While fruits of some crabapples become soft and ready to be eaten by birds by mid-September and on through autumn, others go into winter in a firm condition and are not suitable for birds until they have been modified by freezing. *Malus* 'Donald Wyman' is in the latter category and this trait is an outstanding feature.

During the cold winter months when snow covers the ground and there is a dearth of food for birds, crabapples of this type are important. They can make the difference between survival or death for many birds. In the Arboretum crabapple collection during the winter,

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During the cold winter months when snow covers the ground and there is a dearth of food for birds, crabapples of this type are important. They can make the difference between survival or death for many birds. In the Arboretum crabapple collection during the winter, flocks of robins—sometimes 40 or 50 birds—are not an uncommon sight. Some authorities have suggested that these robins nest further north and have migrated only that far south for the winter. Large flocks of cedar waxwings, purple finches, and starlings also take advantage of the winter crabapples. During some winters, pine and evening grosbeaks visit the region and they, too, go to the Arboretum crabapple collection.

When the merits of this tree were realized, it was decided to name it in honor of Dr. Donald Wyman who was about to retire from the staff of the Arnold Arboretum. Scions or budwood will be provided to those wishing to propagate *Malus* 'Donald Wyman'.

NEW PLANTS FROM MANITOBA

WILLIAM A. CUMMING

Research Station, The Canada Dept. of Agriculture
Morden, Manitoba, Canada

The Research Station of the Canada Department of Agriculture at Morden, Manitoba, is located 75 miles southwest of Winnipeg and 13 miles north of the 49th parallel. The following chart lists a few statistics on growing conditions:

Temperature extremes	−41° F to +111° F
Frost-free period	125 days average
Precipitation	21 inches average (15 as rain and 55 as snow)
Soil	highly calcareous with a high salt content
pH	6.1 to 7.9 in the A horizon; higher in the lower soil levels

Research in ornamentals at this institution consists of breeding and evaluating hardy ornamentals, as well as propagational and taxonomic research. The Arboretum contains over 1800 species and cultivars of trees and shrubs representing 120 genera.

[1] *Rosa* 'Cuthbert Grant' was introduced in 1967 by H. H. Marshall of the Brandon Research Station. It is a repeat bloomer with brilliant dark red, fully double flowers. The plant is a complex hybrid of the native prairie rose, *R. arkansana* X ('Donald Prior' X 'Crimson Glory') X *R.*'Assiniboine'. It won the Award of Merit from the Western Canadian Society for Horticulture in 1970.

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Malus 'Kelsey' was introduced in 1969 by the Morden Research Station. It is an upright tree to 20 feet which blooms annually. This cultivar is a Rosybloom hybrid between two Morden numbered selections. It was named for Henry Kelsey, an early explorer of Manitoba's northland, to commemorate Manitoba's Centennial year in 1970.

Syringa 'Miss Canada' was introduced by the Morden Research Station in 1967. It is a bright pink, late flowering lilac on a compact bush which resulted from crossing *S. josiflexa* 'Redwine' X *S. prestoniae* 'Donald Wyman'.

Weigela 'Centennial' was introduced by the Morden Research Station in 1967. It is a hardy bush attaining 9 feet in height which flowers to the tips of its branches most years at Morden. In contrast, *W.* 'Vanicek' only stays alive and flowers on the lower branches which are protected by snow. Flowers are erythrite red. The female parent is *W.* 'Dropmore Pink', which was selected by Dr. F. L. Skinner from seedlings grown from Manchurian seed. The pollen parent was *W.* 'Profusion'.

Juniperus horizontalis 'Prince of Wales' is a native clone collected in southern Alberta and named at the Morden Research Station in 1967. This cultivar forms a very thick, low ground-hugging carpet. It is very dense, colored medium green, and turns pale purple in the winter.

RALPH SHUGERT: At this time I would like Pete Vermuelen to explain our "Host Plan" for the visiting members of the G.B. & I. Region.

PETE VERMUELEN: It hardly seems possible that it was only a year ago that I was at Hadlow in England and talked with Dick Martyr after one of the sessions. Dick mentioned that it would be nice if we had some type of plan where some of their group could visit in America; later after we came back we conceived the "host plan" and wrote about it in "The Plant Propagator" and then talked to the Eastern Region about it last December. Lo and behold, a year later we have this very fine representation from the G.B. & I. Region with us. I just want to state publicly, for the record, that it has been amazing to me the cooperation that we had from all of the members on this host plan. Thirty-three of you indicated your interest to host the British guests. All of you have not had an opportunity to do so because of the vast distances that divide our country. Primarily those in the Eastern Region have had the opportunity and pleasure to be able to host our British members. We have arranged for the group to tour nurseries, arboreta, and college facilities, starting at D. Hill Nursery on Saturday evening, continuing into Sunday morning, Morton Arboretum in the afternoon, then going to Purdue, Cunningham Gardens, Siebenthaler Garden Center and Nurseries, Spring Hill Nurseries, Ohio Agriculture

Research and Development Center, Warner Nursery and other Lake County nurseries, Fairview Nurseries in Pennsylvania, J.C. Bakker, and Creekside Gardens in St. Catherines, Ontario, the Niagara Park system and back on home, stopping at Cornell Plantations. The last week of their stay here, September 20 to 26, is completely open; we haven't arranged any formal plans, but there will be nurserymen in the area — in the east — and any of you that have not signed up for the host programs but would like to, please see me. I am sure that some of these gentlemen from G.B. & I. would like to travel up and down the East Coast and we have them billeted, so to speak, for this last period only in our immediate area, all in New Jersey. They may like to go north or south and so anybody in New England, in Pennsylvania, Delaware, Maryland, or the Washington, D.C. area who would like to host one or two people for an evening or two and see that they get public transportation, would be most welcome.

I would like to see all the members of the G.B. & I. Region immediately prior to the Question Box this evening so that we can get the final details for our tour lined up. It is quite important and again, thank you everyone and all, for your cooperation in this host plan.

While I have this opportunity, there is another guest here today from Boskoop, Holland. He is a student of horticulture and presently working for 11 or 12 months in our nursery. He is here at this meeting and probably many of you have already met him, but please take this opportunity to talk with him and, of course, visit with all our British guests because they are only going to be here another day and a half; you may not have the opportunity again for some time. Here is Adriaan C. Boere. Adriaan would you stand up so that every one can see you?

RALPH SHUGERT: Thank you very much, Pete. We will now have a critique of the preceding session by Bill Curtis and Tom Pinney.

BILL CURTIS: This afternoon we heard about some of the plants in the past, the men who discovered these plants, who sent these plants back to us, and we heard about plants for the future; I think we find that all must have some of the same characteristics. They must have hardiness to be of value to us. They must have a desirable habit of growth. The plants must have ease of propagation, or we don't mess with them. They must have sales appeal; if they don't, the nursery is soon going to be filled up with plants that you like but you can't sell, so then you would go out of business. I think you all know of people who have been tremendous plantsmen, but sooner or later they have gone out of business because they were plantsmen and not businessmen. The successful nurseryman is a man who is both a businessman and a plantsman. The hybridizer in the future must look for all these qualities in the plants he produces. That is all I have to say. Tom?

TOM PINNEY: It was interesting to listen this afternoon to the various approaches the speakers had in helping to create new plants for the future. Certainly plant collection is something quite familiar to all of us — explorations and so on, but I guess the presentation that really fascinated me and, perhaps, finding a personal preference here, was the interesting talk concerning programming and planning genetically for the plants in the future. It seems as though we still have to depend upon genetic pools, as well as people who will go out and collect these various plants — explorations; certainly to put these together in some sort of planned formulation so that we can come up with the kind of plants we need seems exciting and fascinating to me. Personally, I can think of a lot of plants that I might foresee improved in various ways and perhaps, I will live long enough to see this. I guess we are ready for questions at this point.

JAMES WELLS: There is one thing we haven't talked about this afternoon and I realize that I am getting on dangerous ground here; that is the cost of putting plants on the market. Some years ago at the New Jersey meeting a few of us got together and talked about problems of putting a new plant on the market, and I was horrified that some people considered $20,000 as a minimum figure to put a new plant on the market. Now, the point of all this is not to bring out commercialism in the meeting, but the only way you really get a good plant on the market is for somebody to fight for it. One man has got to keep pushing, pushing and talking, and pushing. This is the only way you can get these plants spread around.

WILLIAM FLEMER: There is a great difference in the costs of putting a new plant on the market. What is included in the costs of putting a new rose on the market is the cost of the hybridizing program, of having geneticists on the staff, doing the color advertising in gardening magazines and that sort of thing; all of this is necessary to get a new rose into the trade and there is no question that $20,000 is a very modest expenditure where there is large national advertising. Our experience with new trees has been more modest than that but certainly by the time you are done, you have spent at least $10,000 and sometimes more in getting new trees across—the selection process, propagation, throwing away of that which is not suitable. It is a long, slow process; you have to do more than putting it in your catalog. The best short cut is to bring new plants to the attention of landscape architects and to their societies, and advertising in landscape architect journals, landscape horticulture journals, or other professional journals. So it is expensive, it does take time and it requires, I believe, a patent system in order to recover costs. I do think that we have an opportunity here, Jim; I know you and I talked about it many times that the Plant Propagators' Society could perform a very real service to the industry in general, and to the hybridizer, in particular in our publicly supported institutions, in getting some very good creations into the trade and replacing some of the inferior older varieties. I would like to see this taken on as a project for our Society and I would like to see, perhaps, a committee appointed to think it over this year and come up with a rational plan to be considered and adopted, perhaps, at next year's meeting.

JAMES WELLS: We used to have a Field Trials Testing Committee. It existed for a few years during the beginning of our organization and then just faded away. Why, I don't know; but here is a splendid proposal to reactivate our Field Trials and Testing Committee. I believe this is a fine idea, and as I may not be able to be here at the business meeting tomorrow, I will put my two cents worth in now and say that I urge bringing it before the meeting and getting some action.

RALPH SHUGERT: I would like to direct a question to Bill Curtis. On your *Pieris flamingo*, what testing to your knowledge has this plant or clone been exposed to here in the Midwest? Number 2 — in your opinion what hardiness does this clone have?

BILL CURTIS: I don't think it has been introduced in the Midwest. When you say Midwest, you mean the prairie states, don't you? I don't believe it has been sent to anybody in the Midwest, although I have sent this plant to the eastern United States — there are several large plants in that part of the country. Al Martin has one in his nursery that he bought last year for a garden show. We had such a mild winter and fall that before he could show it, the *Pieris flamingo* plant was all bloomed out. I believe that it would be an excellent parent for some hybridizers. Dr. Ticknor used this as a parent and he has the most beautiful pink plant that doesn't fade. Most of the pinks that I have seen do fade. *P. flamingo* sets buds early thus less danger from early frost damage, a desirable characteristic in our area. The Dutch last year gave *P. flamingo* a high award and it walked off with all of the first prizes in a show in Holland.

Going back to the question of putting new plants into the trade I would like to say this. There are shrubs and trees that have sufficient sale volume to warrant the expense of taking out a patent but the smaller propagator or nurseryman does not have sufficient capital to spend from $10,000 to $15,000 to introduce new plants to the trade. He has several choices; i.e. to sell outright to a large nursery, grow a large block of the new plant, selling it through modest advertising in the trade journals, or sell the liners to a large nursery with the privilege of selling this new plant in his own local area. I chose the latter method with the *Pyracantha* 'Red Elf'. For several years I furnished Monrovia Nursery with liners until they had a large stock block built up. Monrovia copyrighted the name 'Red Elf'. They have spent a great deal of money promoting this new plant yet they have permitted me to sell it with no restrictions.

Many of us have shrubs and trees that should be introduced to the trade. Why be selfish? Get your friend, the large nurseryman, to introduce and promote it; you can get your percentage of the sales and besides you are putting a new plant in the yards of your neighbors and friends.

TOM PINNEY: Thank you, Bill. There are numbers of ways to attack this problem. We are not going to solve it here in this room this afternoon. I think that our officers — I notice that Ralph is making a few scribbles — will take this back to the Executive Board for at least a review and perhaps get some action. I don't want to belabor the point but I have a feeling that we have gone far enough on the subject.

RALPH SHUGERT: Doug Weguelin, from the G.B. & I. Region, has asked for a few moments to give some personal comments and remarks on behalf of the G.B. & I. members who are attending this meeting. Doug, would you please come up at this time? This is not a paper, as such, but just some comments that Doug would like to make.

DOUG WEGUELIN: First of all, I would like to thank our hosts. We arrived out of the air about 3 hours after they expected us. They took us back to their homes after most of us had 20 to 24 hours traveling, terribly tired. We went to bed which was very, very welcome. We woke the next morning to find ourselves part of an American family. They just accepted us as if they had known us all their lives. I just can't thank you enough on behalf of everybody that came from the British Isles on how you allowed us to settle in. You not only accepted us into the family but you spent a lot of your valuable time taking us around — Sunday, Monday — and then to the airport on Tuesday; I would like to ask all of you who were our hosts, when you go back home, to thank your wives and families for the wonderful time you have given us.

It has been really great meeting everybody here. We are learners; we are just getting into the Plant Propagators' Society. You have given us a wonderful welcome. We have really appreciated coming here. There are two people from England I would particularly like to mention. These two people have helped the G.B. & I. Region of the Society terrifically; without their help, I don't think we could have gotten off the ground. One, who was unable to attend this meeting, is our Secretary, Bruce McDonald. I can't speak too highly of the work this young man has done in England. The other gentleman, who has just gone out to take some photographs, is Richard Martyr. He is our Editor. He has gone all the way to help us. He has just kept the whole thing going. It was through him that it started and I don't know how we could carry on without him. He really got the whole thing going well. I would like, in his absence, to say how grateful we are in England for the work he has done.

We are looking forward to seeing all of you in England, perhaps in 1973.

FRIDAY EVENING SESSION

September 11, 1970

QUESTION BOX

CHARLES HESS: Bob Garner, do you want to start the Question Box tonight, handling the question related to grafting?

BOB GARNER: Here is the first one directed to George Ryan. What is the concentration of glucose used to stimulate avocado grafts?

GEORGE RYAN: A 0.3 molar glucose solution was used in our experiments.

BOB GARNER: Next question. Why does Larry Carville place his grafts in the bench on an angle; why not upright? Well, I can say that it saves a lot of height in the frame, but what is the answer?

LARRY CARVILLE: It does save space and we find that the root development is at a better angle to the heat if you put them on a slant. Of course, this also means that two weeks after we put them in the bench, we have to turn the grafts. We give them a 180 degree turn.

BOB GARNER: Might I add, myself, that it is more convenient to bury the union and keep it equally warm; you have to pile up the covering when the grafts stand upright. By laying the graft on its side, you can more easily bury the union and keep it at an equal temperature so that you probably get more rapid callusing; callusing — the healing of wounds — is grafting. Grafting is the healing of wounds.

VOICE: Perhaps I will direct this to Charley. It is just a comment. If a plant is in a perpendicular position there is a different movement, translocation of rooting auxins, than when it is lying on its side; this reminds me of an article that Cathey published just recently about rooting cuttings. From the time the cuttings are taken he likes to keep them in an upright position. Never let them lie on their side. He finds a marked increase in rooting from cuttings that have never been allowed to lie on their side.

CHARLEY HESS: There are a couple of things involved. One is the auxins. As Dr. Thimann pointed out, they are the principal naturally-occuring root-promoting substance. Auxins travel in a polar direction, as he said. If you turn the cutting upside down, the auxin still moves cell by cell to the base. There is some gravitational effect, too. For example, in layering, the roots will coming at the lower side. This is believed due to auxins relayed to the lower side — so there could be some truth to it. I haven't had a chance to see the original paper to which Cathey was referring to see how critical is this uprightness. Some cuttings, as you all know from experience, form roots well if they are laid on their side.

BOB GARNER: The next question: Does the original position of the bud on the stock influence tree form after planting and subsequent growth to maturity? Question A, Hardwoods. Question B, Evergreens.

Now, I am going to have a go at the hardwoods. Many years ago we had a student from Canada; he studied the variation of trees in the nursery — apple trees and others. He took many, many records and in some of his experiments he inserted his buds on the north side of the stock, some on the south of the stock, some on the east, the west and all sorts of other peculiar things. When he came to carefully measure the trees, the only difference he found was that when he put the bud on the north side — that is, the shady side of the tree for us, because we are in the same hemisphere as you, he got a more erect growth immediately from the bud. It was though the bud wanted to peep over the top of the stock. It came in closer — whereas with a bud on the south side, you had to tie it in a little to get it to go upright. But that was the only difference he found in that study. Does anybody have anything else on deciduous plants before we close and ask questions about the evergreens?

CASE HOOGENDORN: While my boys are lining out plants in the field you know what I tell them? — slant them all to the north because the sun will draw them straight. If you do it the other way, you get an even more crooked plant. So here is your answer.

ROBERT GARNER: Another similar question. Does the bud position on the mother tree from which you take the bud affect quality of the tree for future shape and form of the tree?

Well, may I just take the hardwoods again and refer to the same man, Dr. Cameron, who did this work? He found no difference in the size of the resulting tree. He took his buds from the inside and outside, the south side, etc. of pear and apple trees. He went to all sorts of peculiar lengths but he found no significant differences. There were differences, but they were of no practical importance.

You can't tell, sometimes, whether some of these buds are fruit buds or leaf buds; they are multiple buds very often. They blossom nearly every year right on the inserted bud; a cluster of blooms comes out. Every year I get two or three phone calls from tree raisers not very experienced and they say what do I do, all my buds are blossom buds. I say, go away for a holiday if you like, or you can cut them out with your thumb if you have the time. The vegetation will come out of the side of the apple fruit bud, and everything will be pushed aside, and it will be all right. But now could somebody answer on the evergreens?

CASE HOOGENDORN: You asked about evergreens. When we are lining out evergreens, whether it is a 2-year graft or 2-year buddings, we all know that the growth of any graft, certainly after two years, will be full on the south side and down on the north side. Anyhow, I walk up and down the rows that these boys are planting and say, "Fellows, you put the weak side on the south." Now by doing this, putting the strong side on the north and the weak side facing south, we finally produce a uniform block of trees.

ROBERT GARNER: I think we all agree on this; if the plant is in a truly juvenile condition, the fact that you transfer the buds from one tree to another makes absolutely no difference as long as they are in the same environment. Charley is looking very serious here, but I have taken seedlings and waited until they flowered, being a very patient young man years ago. I also took buds from the seedling and dropped it into a glass or vase so that I wouldn't lose it and I nipped out into the orchard and I budded it on the tips of fruiting trees; then I grew these trees and I grew them in other ways, that I won't bother to describe, and they all flowered the same year eventually. I have gotten no different results in that way. I have seen it recorded otherwise in other places and it may be different, but in my experience when that seedling is determined to flower, then it flowers, and it flowers whereever you put the bud. I put it on dwarf stocks and I put it on strong stocks, I remember; trees grew up and they all flowered at the same time.

JAMES WELLS: The thought occurred to me as you were talking that if you take a cutting from a rhododendron, in particular from a mature plant, this is obviously flowering wood. If it was left on the plant it would flower, in all probability. You may even take it as a piece of flowering wood with a flower out on it and remove the flower. You root it and it loses this characteristic. Why? It takes two or three years for it to flower again. Now what happens?

ROBERT GARNER: I haven't got all these answers, but may I guess? The nutrition immediately is entirely different. If you bud it onto an established stock, a stock with a lot of stored food in it, then it can continue to flower to fulfillment probably, but if you separate it, as a cutting, the plant becomes enfeebled; it hasn't got that background of nutrition to carry it forward. It probably drops its buds or they fail to develop; is that right? Yes, because grafting is only an incident in the life of a tree. If it is properly grafted you haven't done anything to weaken the tree in any way. It is just as though you have pruned it; it is what I like to call an incident in the life of a tree. Just merely an incident. The other things — as cuttings — are catastrophes.

Shall we rush on. We have a lot of good questions here. Does the height of insertion of the variety bud on a dwarfing rootstock influence the size of the resulting tree? I mean if you put your bud in high — or low — does this influence the size of the resulting tree?

If it is a very dwarfing rootstock — say Malling IX, or something more dwarfing, then it does. It depends, apparently, on the proportion of the dwarf in the composite tree. Say you put a vigorous variety, as you generally do, onto a dwarf; well, if you have got all the root system and a considerable amount of the stem left as the dwarf, then the resulting tree, the composite tree, will be smaller, at least for a long time. It will have a bigger influence. If you bud it very low down — but I don't mean scion rooting — then you will have a more vigorous maiden tree. We used to think this was due to other things; for instance, if you put a pear on a quince — one of our members who is now dead, Amos — he said, "I don't like the sun to shine on the quince trunk". It incapacitates the tree a little bit. It doesn't like it, but I think it is true to say that if you put a vigorous apple on a dwarfing apple, they will compromise and they will compromise somewhat according to the quantity of each which is in the composite tree. If you work your dwarf very high, then you have a smaller proportion of the vigorous part in the tree, then the composite would be less big as a whole than it would if you had only a little piece of dwarf at the bottom and the rest of the tree vigorous. Do you see what I mean?

RALPH SHUGERT: If I could pursue this a little further. You are saying, in effect, if I understand you properly, that it is possible, depending on the techniques to dwarf apples, to influence dwarfing, to utilize the dwarfing effect of this rootstock by the height of the bud. This is very interesting, because what I have read is contrary to what you said. It was my understanding, from the little reading that I have done on this, that the dwarfing influence of the rootstock was in that stock, whether it was MM 972, 111, etc. You saying that, to a degree, the placement of the bud on the plant stock will have some effect on dwarfing of the tree. Am I right?

ROBERT GARNER: You are right, but I must emphasize that I meant only a trace of difference. Only a very small difference. Nothing like the effect of the genotype, as you call it, nothing like that. We are talking only in small degree in reference to the placement of the bud.

ROBERT GARNER: In cherries, the mazzard cherry stock, with the sweet cherry on it, are practically brothers. They are *Prunus avium*, both of them, and I can't see this dwarfing technique that we were discussing just now having much play. But what does have an effect is the actual form of the tree and the way it sets off. For instance, we often put sweet cherry on a *Prunus avium* stock such as 'F / 12-1', which is a clonal stock. I have a fairly large experiment at East Malling of trees that are now 15 or 16 years old, some of which I bushed off at 3 feet and some I headed off at 6 feet; we measured the heights, the sizes of the head of the tree, produced on the 3 feet trees and produced on the 6 feet trees, and the one on 3 feet trees were significantly larger in volume, and have always maintained that size — more than the other one. As we know, when we come to sell, say standard crab apples up on tall stems, you get a miserable head compared to what you get at the lower level. What causes all this, I don't know, but it is an actual fact.

BILL CURTIS: When we grew flowering cherries budded or grafted on mazzard seedlings, I found that those budded or grafted at

3½ to 4 feet developed a heavier head at digging time than those budded or grafted at 6 feet, the exception being the weeping *Prunus subhirtella* and the weeping form of *P. serrulata*, which were always budded or grafted at 6 to 6½ feet, developing good heads.

ROBERT GARNER: Thank you very much. Does anyone use *Magnolia grandiflora* as a stock for deciduous magnolia?

HANS HESS: We have used *Magnolia grandiflora* for deciduous magnolia and we have also used *Magnolia kobus* as understock for *Magnolia grandiflora*. Both will work. I would say that there are some varieties of *Magnolia grandiflora* which do not take well for some reason. There are others which are reasonably compatible. This is apparently due to the individual character of the plant, just like people. But they will work in both directions; *Magnolia grandiflora* for deciduous and *Magnolia koba* for *Magnolia grandiflora*.

ROBERT GARNER: When lining out grafts, should the ball be intact or broken or disturbed to any extent? What about the the soil root ball in larger containers?

BRUCE USREY: When you are planting something coming out of a container the root ball has to be broken up if it is bound; otherwise you get future twisting of the roots, even though you don't notice it.

JIM WELLS: This was mentioned the other day and I want to make the comment now that in moving plants from one size pot to the next you really have to break up the ball and tease the roots out. It isn't just a matter of scratching the surface of the roots. You really have to disturb the root ball — mash, mangle it; if you have this problem with containers my answer is just to work up the root ball vigorously.

ROBERT GARNER: Thank you very much. The last question on grafting. Why should *Pyrus calleryana* 'Bradford' not be grafted on any pear seedlings, but only on *Pyrus calleryana* seedlings? I am sure we have somebody to say something about this, but I can imagine it is connected with virus. May I give my thoughts on this. You would have the same situation if you had *P. calleryana*, tolerant to the virus, which is carried in the 'Bradford'. If this was always tolerant, whereas *P. communis* was more tender, then delayed incompatibility is due to the systemic spread of the virus through the plant to kill it.

CHARLEY HESS: The topic we will now take up is on rooting cuttings and we have some questions on specific plants. First, has anyone rooted *Taxodium distichum* — bald cypress?

VOICE: I have rooted a few but with a low percentage. It can be done.

RALPH MOORE: I have worked with this tree too. One spring I cut the tops off probably 100 or 150 different two- or three-year-old seedlings and I rooted them in sand or sand / peat, using cuttings from 4 or 6 inches long, with almost 100% success. But if I tried them with cuttings from a mature tree, I had almost 100% failure.

CHARLEY HESS: What is the best way to propagate crepe myrtle?

VOICE: We propagate crepe myrtle by hardwood cuttings.

VOICE: We root softwood cuttings of this under mist with no problem.

CHARLEY HESS: Do rooting hormones help on hardwood cuttings?

BILL FLEMER: We have never had any effect on our hardwood cuttings from root-promoting substances.

HUDSON HARTMANN: We have had just the opposite results from rooting hormones with hardwood cuttings of pears, peaches, peach-almond hybrids, olives, walnuts, and so forth. With many of these we do not get any rooting at all without the hormone treatments. We use IBA — quick-dip at 4,000 ppm or about 50 ppm with a 24-hour soak. We have used some of the techniques Bob Garner has been describing; the methods vary with different species. With some, such as Bartlett pear, apple, and walnut it was necessary to chill the top buds, while the base is kept warm. Other species, as peaches, the hardwood cuttings have to be set directly into the nursery without disturbing the roots. The same seems to be true for walnut; the cuttings have to be placed for rooting right where they are going to grow without disturbing the roots, or they don't make it. Different techniques vary with different species, but we do get a very strong response from the rooting hormones with many species.

CHARLEY HESS: What is wounding? Does wounding help rooting, a light wound, heavy wound, chemical wounding?

JAMES WELLS: I didn't put this question in. My answer is prejudiced because I am, of course, for wounding, but I would like to explore this subject. I still can't quite understand this chemical wounding. It seems strange to me and yet Brian Humphrey swears that it saves a lot of time. He can eliminate wounding techniques in making his cuttings; all he does is to put on a strong enough formula on the base of the cuttings that he destroys the basal tissue. He expects to do this and then, finally, he gets moderately higher rooting. This seems to me to be a very strange way to do wounding, and I would just like to know if anyone here supports this.

LESLIE HANCOCK: Don't you think that it is a fact that every plant is a law unto itself, and you can't say that because it works with a certain apple it must work, too, with a rhododendron. You know there is not one method that will give perfect results for a very large number of plants. Mr. Garner has done it with a given plant and has been very successful. I am not sure whether other people will find that they can do it with every plant or not. I would question whether they have gone far with it; this method may work well with some things and not with others.

BRUCE BRIGGS: Is it possible that wounding is only an injury to tissues and this is what we are talking about?

CHARLEY HESS: I think there is some truth to that; it is an injury effect you are getting. You stimulate cell division which is one of the first things that you have to get accomplished in starting root initiation.

We have talked about this before, the so-called traumatic acid which is synthesized in some plans in response to wounding; we have tried traumatic acid in stimulating rooting of cuttings, but it is not effective nor has it helped in grafting, which is another thought we had. There is evidence that, if you wound the inside of a pea pod, you get callus formation stimulated; traumatic acid can be isolated from this tissue, but apparently this is not a universal substance.

BILL CURTIS: I think all of us at some time or another have used hormones too strong and have burned the base of the particular cuttings, then they rooted well.

JAMES WELLS: In 1946, before I came to this country, I paid a good visit to Boskoop which is where I first heard of wounding, and immediately afterwards I came over here to Koster Nursery; I ran a series of tests with the *Juniperus* species and many other plants using hormones on cuttings made with a heel, without a heel, and with and without a wound. I have records on these treatments at home. These tests were also carried out with a control — with no hormone treatment. Therefore, we have non-heel cuttings, and heel cuttings with a wound and without a wound, and all of these with hormones. Now when you have the results laid out on a table, there is an absolute gradient of increased rooting in favor of the no heel plus wound treatment. The next best was a heal with a wound, and the next best was a heel without a wound; no heel and no wound gave the lowest rooting. But you notice a distinct increase of about 25% in rooting from wounding alone without any hormone added. Add hormone and you get higher rooting. Take away the heel and you get higher rooting still.

PETER VERMUELEN: What was the condition of the wood, the age of the plants, that you took the cuttings from in this experiment?

JAMES WELLS: This wood was all quite young, Pete. I mean the Pfitzers were strong, vigorous shoots — current season's growth. Of course, this was done in October and November. Yes, dormant plants. The Pfitzers were not particularly young plants, as I recall. The Thujas were three to four foot plants when we took the cuttings. Not really young, but not old. The wound that I gave at that time was a light wound. That is, drawing the tip of a knife blade down the stem. Later on we got to soldering together four Gem razor blades. These are the single-edge type blades. You can put four side by side, solder them together and with this you can make a very neat cut, drawing them down the stem making three or four parallel cuts at once. Now some plants don't respond to wounding at all — Taxus is one of them.

CHARLEY HESS: The next question: Does anyone have trouble over-wintering one and two-year *Acer palmatum* grafts in containers?

VOICE: We have had one-gallon can plants in beds in a lath house. No protection other than a grass material half way up the gallon cans; no other protection over the bed or over the lath house. No problem in Ohio.

PETE VERMUELEN: We haven't had any trouble with our one-year grafts in gallons generally; they are put in plastic covered houses. In the spring we use Saran or polypropylene cover so we do have some shade. After the first frost, first or second frost, they are covered with white poly. The plants are watered in very heavily; the houses are closed quite tight. We haven't had any problem with any *Acers* over-wintering.

CHARLEY HESS: The last question on cuttings. Is there a relationship between moisture content of the cuttings at the time they are taken and rooting? I would say this is getting back to the question of when should you take the cuttings — early in the morning, or late in the afternoon — and presumably it is in favor of the morning or a cloudy day.

At this point we will take a two-minute break, then Bruce Briggs will lead the discussion on "Seed Propagation".

BRUCE BRIGGS: Here is a question on weed killers. How much Dacthal should you use — in lbs. per acre?

RALPH SHUGERT: I will answer quickly. On the testing that I did in Nebraska and Ohio on germinating seedlings — those that have true leaves — on all the stock I worked with, we used it at 12 lbs. per acre. We have been very happy with it. Three years ago I tested it from 4 to 20 lbs. — 12 lbs. per acre was the most suitable rate.

BRUCE BRIGGS: Has anyone had any experience with injury from use of Casoron on Taxus or deciduous shrubs from repeated applications over a period of two or three years or more?

VOICE: We have used repeated applications on a number of things with Casoron; we have run into some trouble with Casoron. With Taxus we had some tip injury. We don't use it anymore.

BRUCE BRIGGS: Harold Clarke, you have used it at Long Beach, Washington; do you want to comment from the West Coast?

HAROLD CLARKE: We have used it on rhododendrons without any apparent damage. The cranberry people there have used Casoron regularly for several years now. They are very conscious of residues after the amino triazol incident. They find absolutely no trace of Casoron the second season. Of course there is 100 inches of rain and they flood the cranberry bogs with a foot of water, and so on. I suppose this might have something to do with it.

VOICE: I just want to say that we used Casoron in the south-western region. We put it on a lot of lining out stock. I began to get a little bit nervous when some of our Johnson Grass stools died out. As the summer progressed and the weather got hotter our plants slowly began to turn brown and died, I sent back about 50 bags of Casoron.

BRUCE BRIGGS: I am not surprised at your results in that hot weather; it should be used when the weather is cool because fumes do come out in the warm weather and then you are going to have problems.

DOUGLAS WEGUELIN: In England we put some of it on some spruce, *Abies*, and in a few days they looked like they were covered with gold dust. They all went yellow. The only thing we use it for is spot treatment on heavy weeds; if it is anywhere near poplars it is lethal.

VOICE: We have been using Casoron for the last couple of years on all our lining out stock 3 or 4 weeks after planting with no damage whatsoever at about 100 lbs. / acre.

BRUCE BRIGGS: It depends upon the area, the location; one area is moist and cool, another area is hot with a different soil. You are going to have to try it out and see how it responds under your conditions.

BILL CURTIS: I have used Casoron since it first came out and I have used it on everything that goes in the nursery. We grow rhododendrons, Taxus and many other plants. We don't use it during the summer. I never put Casoron on until December, January or February.

BRUCE BRIGGS: Do we have a nematologist in the room? Will nematodes survive in northern winters? Does cold weather kill nematodes?

ANDY LEISER: It depends on the species of the nematode and then how far north is north. Recently they have discovered some species of nematodes in Antartica.

BRUCE BRIGGS: This is about Off-Shoot-O. Do you get any effect on rooting with the application of Off-Shoot-O; does Off-Shoot-O affect rooting in any way?

BRUCE BRIGGS: Bob Ticknor, at the Oregon Willamette Valley Research Station, did some work on this and says that Off-Shoot-O did help rooting. Why, I am not sure.

CHARLEY HESS: We have a series of questions on hardwood cuttings. Bob Garner will moderate this group.

BOB GARNER: What is the best method of rooting named varieties of crab apple?

Well, we haven't had experience with crab apple at East Malling yet — I don't know if other people have tried rooting named varieties of crab apple. An experience we had with *Malus* in general — with the rootstocks and that sort of thing — we would take our shoots that were half grown, cut them right at the base, dip shallowly in IBA, but in the very severe winter-spring conditions here, I wonder if you shouldn't try it in the fall and then after having rooted your hardwood cuttings in bins, you then hold them — not to frosty — through the winter then plant them out in the spring. Something like that. I think that is how I would do it if I had to do the job.

RALPH MOORE: Last year we tried some *Malus floribunda*; not a large quantity but the rooting was about 90%, using softwood cuttings. I think it was in June. These were tip cuttings treated with Jiffy Grow and rooted under intermittent mist; they came along fine and over-wintered successfully.

BOB GARNER: Is there any value in placing hardwood cuttings upside down to callus? Well, I am sure somebody has comments on this, but I think some of us remember a considerable amount of research done by a Frenchman, I think it was Massot. He took his bundles of hardwood cuttings and put them in a corner of a walled garden, upside down; people wondered why they callused faster. I don't know if they rooted faster, but they callused faster in this way. We suggested that it was a matter of heat. He had turned them upside down and they were covered with the sandy soil, and they were in a sunny corner. You know the sun can heat the soil considerably provided it is exposed, even in the dead of winter. We thought this was not a positional effect because, as Charley told us, auxins will move regardless of position orientation. If the tissue is appreciably moist and the temperature is raised, the callusing is more rapid. Does anybody else have anything to add to that?

CURTIS ALLEY: We ran one year's experiment with grape cuttings in bundles; we placed them right side up, upside down, and horizontally. They were all below the surface. The take we got was the same regardless of position — between 90 and 95% takes — but the resulting rootings, that is the weight of the rootings, were heavier when they were callused upside down.

BOB GARNER: Have you used any other medium than sand and peat, such as a sawdust? I suppose that is for hardwood cuttings.

Some years ago we tried a range of different proportions of peat and sand. We went high peat, high sand, right through the range, sort of from left to right, and we still, I am glad to say, came out with the old 50-50. I should point out that when I talk about peat-sand, our sand is hardly true sand. It is more grit. It is a sort of ½ inch grade grit. It is coarse sand and coarse peat. It is not a fine sand, like silver sand, which packs. You really must have a magnificient drainage. I haven't myself tried these other things, except I do recall that some 40 years ago I put in spaghnum moss, live sphagnum moss below the sand, and pushed the cuttings in until they rested on top of the layer of sphagnum. I don't think we got much higher percentage rooting but, my word, they did grow beautifully, those that did. They had constant moisture from this sphaghum moss. I haven't heard it mentioned in America yet. Live sphagnum moss has special qualities. It prevents rotting of various kinds. It is able to control disease.

The next question — How much pre-treating of grafts from cold storage to the planting field should be done? Have you got to acclimatize them? From cold storage to the planting field. Comments, anybody?

We take plants from cold storage right to the field; in England from this jacketed cold store, I have been talking about, we gained experience in transferring stock late in the summer to the fields. We can take stocks straight from dormancy, held in cold store, and plant them out in May and June and get just as good results as though we had planted them earlier. We take them straight from the cold to the heat. Our cold storage temperature is about 32° F — the freezing point; outdoor temperatures vary not more than 70° to 80° F in the hottest days.

CURTIS ALLEY: By pre-treating, I believe, is meant callusing. For grapes I would recommend 4 to 6 weeks callusing after making the graft — prior to planting. With grape grafts we have to callus them before planting if the graft is going to be successful. This is not as necessary in the early season — in January or February. This callusing of cuttings or bench grafts prior to planting is strongly recommended for grapes. The best take we have obtained was when we planted cuttings in April. Not only were the cuttings well-callused but the top bud was out ½ to 1 inch and roots were evident at the base of the cuttings. If bundles of grape cuttings or bench grafts have been held in cold storage they should be moved out 4 to 6 weeks prior to planting and warmed to obtain callus and root development and to start bud activity.

BOB GARNER: Rooted Myrobalan B understocks do not seem to transplant well; that is, rooted under mist. Why?

LESLIE HANCOCK: We have had no problem with this.

BOB GARNER: No problem he says, but Myrobalan B is what we would call sensitive; it is a very sensitive stock. It is cheap and quick-growing in England and you would think it is common and easy to handle, but actually it doesn't handle at all well. It is almost herbaceous in a way, and transplanting it so it doesn't dessicate is difficult. It needs proper treatment. It is a sensitive, quick-acting thing, and we say it is almost perishable.

CHARLEY HESS: What is the length of supplementary light period for deciduous azaleas?

JOHN McGUIRE: As long as you break the light period — we use a 3 hour light break. We turn the lights on at 11 p.m. and turn them off at around 2:30 a.m. This is sufficient for any of the Exburys; any of the deciduous azaleas will tend to grow on in that situation.

CHARLEY HESS: We have a project at Rutgers; Dr. Norton there is working on controlled crosses between two dogwoods and he is getting a population of seedlings which look like red flowering plants from seed and, of course, we also should mention the Japanese maple, another colorful plant. He got a very high percentage of the plant population to be the desired type, if you know the parents.

CHARLEY HESS: Will Hugh Stevenson explain his technique of growing sassafras from seed?

HUGH STEVENSON: For one thing, we have trouble in getting good viable seed, locally. It germinates rather late in the spring and comes up after most other things are up, but it grows vigorously and you can get a 24-inch branched plant in a year. I think it is a matter of getting a good viable seed in the late summer or fall.

CHARLEY HESS: What are the merits of *Juniper horizontalis* 'Prince of Wales'?

BILL CUMMINGS: This is one of the closest ground-hugging junipers that we have in our collection. It is a solid mass and makes an excellent ground cover. It has a good green color in the summer months. I don't see how any plant could be more prostrate than this one.

CHARLEY HESS: What are the merits of *Tilia cordata* 'Morden' and is propagation wood available?

BILL CUMMINS: *Tilia cordata* 'Morden' is registered with the Canadian Ornamental Plant Foundation, which is a gentlemen's agreement among the murserymen in Canada, something like the Plant Patent Act in the U.S.A. and something like the British system. I don't think all the methods of introducing material into other countries has been ironed out yet; they will be but now we cannot release bud-wood of that or any other material which we are registering with the Canadian Ornamental Plant Foundation.

CHARLEY HESS: Thank you, Bill. What are the merits of *Tilia cordata* 'Morden'?

BILL CUMMINS: There is only a small percentage of seedlings of *Tilia cordata* that will stand our "banana belt" climate. We obtained a number of seedlings from Sheridan Nursery 30 years ago. There is one remaining. This is *Tilia cordata* 'Morden'.

CHARLEY HESS: Can we consider the question of continuous mist versus intermittent mist?

Well, I will begin with one aspect of it. We did start out with intermittent mist and when we got into larger water particle size, to use mist in outdoor conditions, we were putting on a large volume of water and so then problems developed — leaching, drainage, excessive cooling of the medium temperature and high use of water. So all these things suggested that it would be much more efficient to use an intermittent mist, 4 seconds every minute, or something like that. These are some of the reasons for switching from continuous method to intermittent mist. I do recall, however, that we had in some of our earlier experiments, I think, nozzles set up which would produce the type of mist that Jim was describing, that would seek out the cuttings and as it circulated around the chamber would land on the leaves. Under these conditions, we used mist continuously and we had good results. So I think it is not a complete yes or no situation. It depends on the type of nozzle you are using and if you have a nozzle system which gives a very fine mist you could, perhaps, go to the continuous situation, but if you are using a heavier mist, then an intermittent form is best.

JIM WELLS: Charley, this question is brought on by the excellent paper we heard earlier by Koslowski, in which he pointed out the violent changes that can take place in the plant structure in a very short time. I thought this was one of the most significant things that I have heard here at this meeting; it made me wonder if we had missed something in moving on, as you have described, to intermittent mist. We had something which would take care of these fluctuations in the very light, gentle mist with which we began; would there not be a virtue in going back to it, thus preventing these sudden changes in the plant yet not getting into leaching, cooling temperatures, and so on.

BILL CURTIS: Rudy Wagner, at Wenatchee, Washington — where they have lots of light and where it is real warm in summer — is doing an excellent job rooting outside under constant mist in a lathhouse. He has beds that are 3 feet off the ground so they have excellent drainage. He turns the mist on when he goes to work at 4 a.m. and shuts it off at night when he goes back home. That's no kidding; he puts in those kind of hours. You can check with Rudy tomorrow and he will tell you exactly what he is doing. I think he uses Monarch nozzles. I have seen his set-up; he is doing a tremendous job there outside under his conditions with the very high amount of light and warmth there in Wenatchee in the summers.

RALPH MOORE: Many of you have been to my place; those from the Western Region were there a few years ago when we had the meetings at Fresno and you saw us rooting miniature roses. We were also experimenting with other kinds of plants. We have high light intensities in summertime, too. We have raised tables or beds; we used to root in a medium of half peat and half perlite. Now we use a mixture of 1/3 soil, 1/3 perlite and 1/3 peat moss. We put this right in plastic pots and put the cuttings in the pots and turn on the mist. We use two types of misters, then we have lawn sprinklers — Perma-Rain, which are made in Lindsay, California, for orange groves. They turn slowly. We turn them on them at 7:30 or 8:00 a.m. and turn them off at about sundown.

BILL CURTIS: Many years ago, in fact 10 years ago it was, we had a meeting out at Asilomar, California; that was when the Western Region was formed. A gentleman who is up here in the front seat, named Wells, came out and I heard him make this remark, "You fellows in California are making a tremendous mistake. With the light you have here and this heat you should be rooting material outside in beds under constant mist."

JIM WELLS: Did anyone heed me?

DOUGLAS WEGUELIN: In intermittent mist, we do have to remember that what we are trying to do is to keep the cuttings cool rather than wet. We are keeping them cool by keeping them wet, but the basic thing is to get a temperature gradient with the tops cool and the bottoms hot. With mist you are trying to keep the cuttings cool with the least amount of water. You can either have, as Jim says, a very fine mist using so very little water that you can afford to be continuous or, in very hot climates, the bad effects of excess water is so slight that you can afford to be liberal with water, but in every other situation intermittent mist approaches more nearly what is desired.

CHARLEY HESS: I do feel as the water evaporates from the leaf you can get the leaf temperature below the air temperature and, under those conditions, you can reduce the vapor pressure and reduce transpiration.

BRUCE USREY: We use intermittent mist in California and we propagate in a hot, dry area, but there are some things that cannot take a constant mist; they have to have it dry. We propagate a lot of junipers out there — a lot of cotoneasters in full sun. With constant water they would rot. They have to be able to dry out.

CHARLEY HESS: We must be careful not to generalize. We all know different plants require different handling. With this we will wrap up the Question Box for tonight.

SATURDAY MORNING SESSION
September 12, 1970

The Saturday morning session began at 10:35 a.m. in the Minnesota East Ballroom of the St. Paul Hilton Hotel. Ralph Shugert served as moderator. The minutes of the three Regions' business meetings which were held before the presentation of the technical papers appears at the beginning of the "Business and Technical Sessions."

RALPH SHUGERT: This Twentieth Annual Meeting has certainly been an enjoyable session and, as announced previously, we have the Graduate Student Award winner with us and he will present his winning paper to us this morning. The winner, as you know, is Mr. Nazir Nahwali and the title of his paper is "The Effect of Dipping Depth and Duration of Auxin Treatment on the Rooting of Cuttings." Mr. Nahwali.

THE EFFECT OF DIPPING DEPTH AND DURATION OF AUXIN TREATMENT ON THE ROOTING OF CUTTINGS

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ABSTRACT

Factors hitherto not taken into account were shown to influence the rooting response of hardwood plum cuttings to treatment with IBA in 50% alcohol. The depth to which cuttings were dipped in the auxin solution and the duration of the dipping treatment were important, while rooting in cuttings dipped to 1 inch was improved by wounding.

REVIEW OF LITERATURE

Pre-treatment of cuttings with a root promoting substance is a singularly effective method of obtaining rooting in cuttings of many plants. Active substances and methods for their application, together with the responses of a wide range of plants, have been well documented (1, 2, 6).

Auxins are applied to cuttings either in a powder formulation, as a dilute aqueous solution requiring cutting treatment for up to 24 hours, or in solvents such as alcohol (8) in which the cuttings are dipped for a brief period of a few seconds (4). This "quick dip" method is favoured for hardwood cuttings because of the speed and uniformity of

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treatment (5). However, a number of factors which may contribute to treatment success have apparently been ignored. For example, authors often state that "cuttings were dipped to a depth of half to one inch", or treated "for a few seconds," suggesting that neither depth nor duration of dipping is considered critical.

From a study of rooting in plum hardwood cuttings it has become clear that insufficient attention has been given in the past to these and other conditions of auxin treatment. The influence of a number of factors upon cutting response to indolylbutyric acid (IBA) has been examined and the results of some of these experiments are given below.

MATERIALS AND METHODS

Vigorous annual shoots were collected from hard-pruned hedges of five plum rootstocks during autumn or spring 1968, 1969, and 1970, and reduced to 24-inch lengths to provide basal (proximal) cuttings (3).

They were treated with IBA dissolved in 50% ethanol in the manner stated in the appropriate experiment. After drying for about 30 minutes cuttings were placed in a rooting compost of equal parts coarse sphagnum peat (pH 3.9) and 3/16-inch grit with washed sand (pH 7.1), with a basal temperature of approximately 20° C (7). The aerial environment was not controlled, although extremes of weather were reduced by the open-sided building which housed the propagation bins. Percentage rooting (subsequently transformed to angular values) and number and position of roots were recorded after a period of usually four weeks. Least significant differences at the 5% level are shown at the top left-hand corner of the figures.

RESULTS AND DISCUSSION

Fig. 1 shows the response of four plum clones when treated to a depth of one inch for five seconds with a concentration range of IBA from 500 to 10,000 ppm. It is of interest in that it shows a fall-off in rooting at the highest IBA concentration. This was associated with the general absence of roots emerging from the basal 0.5 cm portion of the cutting, which suggested that this concentration was supra-optimal in tissues adjacent to the point of IBA entry. The possibility that further improved rooting could be obtained by applying a greater quantity of IBA to the cutting at a lower concentration was therefore examined by dipping to a greater depth.

Results are shown in Fig. 2 for 'Myrobalan B' cuttings dipped for 5 seconds at depths ranging from 0 (basal cut surface wetted) to 4 inches. An exponential response curve was unexpectedly obtained where percentage rooting rapidly decreased with increasing dipping depth ($P = 0.001$). Two other rootstocks showed a similar but non-significant trend.

The main difference between basal application and greater dipping depth is that almost no IBA is applied to the side of the cutting when only the basal cut surface is treated, compared with varying amounts of side application at greater depths. The importance of position of IBA application to the cutting was therefore examined. A 5 second application to only the basal cut surface was compared with application to the proximal 1 inch of the epidermis, together with the normal 1 inch dip to include both base and side.

Two methods were used to treat specific parts of the cuttings in this way. Areas not to be treated were sealed with a polyvinyl resin, which was subsequently removed where necessary to allow uptake of water, or the growth substance was applied by a small brush; similar results were obtained by both methods.

Fig. 3 shows that with 'Myrobalan B' and 'E 340 / 8.21' (a rootstock at present under test) inferior rooting was obtained ($P = 0.001$) when the side only was treated compared with a high rooting percentage when IBA was applied to the basal cut surface only. The traditional base and side treatment fell between these two extremes. These and later results suggest antagonism between base -and side- applied IBA. The effect due to position of IBA application increased with increasing concentration of the auxin ($P = 0.001$) as shown in Fig. 4.

Since the original optimum IBA concentration for plum cuttings was determined by dipping cuttings to a depth of 1 inch (Fig. 1), and with basal application subsequently shown to be more effective (Fig. 2), it was necessary to re-determine the concentration response with shallow dipping.

Cuttings of 'Myrobalan B' were treated either at the basal cut surface or for the basal 1 inch at a range of concentrations from 0 to 10,000 ppm. To integrate earlier experiments which suggested that the detrimental effect of deeper dipping was from side application, in a subsidiary study cuttings were also treated at their base with 5,000 ppm and for the adjacent 1 inch of epidermis with IBA ranging from 0 to 5,000. Thus, a range of treatments was produced linking with those of the main experiment in which 5,000 ppm IBA was applied to either the basal cut surface or 1 inch stem. Fig. 5 shows that shallow dipping was superior to dipping for 1 inch and that the optimum concentration was reduced from 5,000 to 2,500 ppm in the absence of side application.

The effect of increasing the concentration of side-applied IBA from 0 to 5,000 ppm was to gradually depress rooting from a level almost equivalent to that obtained by shallow dipping at 5,000 ppm, to one inferior to that obtained after dipping to 1 inch.

In contrasting basal IBA application with treatment to the epidermis, it was apparent that uptake was relatively rapid through the basal cut surface and either absent or impeded through the side of the cutting. The effect of possibly increasing uptake by wounding the side of the cutting was, therefore, examined with 'Myrobalan B'.

Two to three small scooping wounds to remove either the buds or equivalent internode tissue to the depth of the xylem were made over the basal 1 inch of the cuttings, which were then dipped to that depth in 5,000 ppm IBA. Cuttings that had internode wounds gave a higher response (Fig. 6) than those which had bud wounds, which in turn were superior to the control ($P = 0.001$). Roots arose from the cutting base and the wounds. A similar trend was obtained for a second clone which is not shown.

Another factor likely to influence IBA uptake and response of cuttings to auxin concentration is the duration of treatment.

'Myrobalan B' cuttings were treated for periods from 1 second to 18 minutes at 50, 500, and 5,000 ppm. A dipping depth of 1 inch was chosen to offset possible problems of changes in the solution level at shallow depth over the longer dipping times and also to depress the general response in order to detect treatment differences. Fig. 7 shows a correlation ($P = 0.001$) between duration and concentration, with the higher concentration most effective at 5 seconds, the medium at 30 seconds, and the lowest concentration requiring an 18 minute period of uptake. In relation to the "quick dip" method, the different response at 1 and 5 seconds is of particular interest.

Throughout these experiments consistent trends were obtained for the effect of treatments on the number of roots produced. Although differences were often significant they were not sufficiently large to affect the establishment of the cuttings. Generally, root production increased with increasing concentration of IBA and with wounding, but decreased slightly with decreasing dipping depth. Within the proximal inch, however, treatment to only the basal cut surface was superior.

These results are important in the development of methods for the practical application of auxin treatments and may have wide application in the propagation of plants by cuttings.

It is also hoped that the demonstration of the need for effective IBA uptake through either the cutting base or a wound, and the apparent antagonism of laterally applied IBA will lead to a clearer understanding of the mechanism of auxin stimulation of rooting in cuttings.

ACKNOWLEDGEMENT

This work is part of a study for the Ph.D. degree carried out at East Malling Research Station, Kent, England. The assistance of members of the Pomology Section and, in particular, the encouragement and advice of my superior, Dr. B. H. Howard, is gratefully acknowledged.

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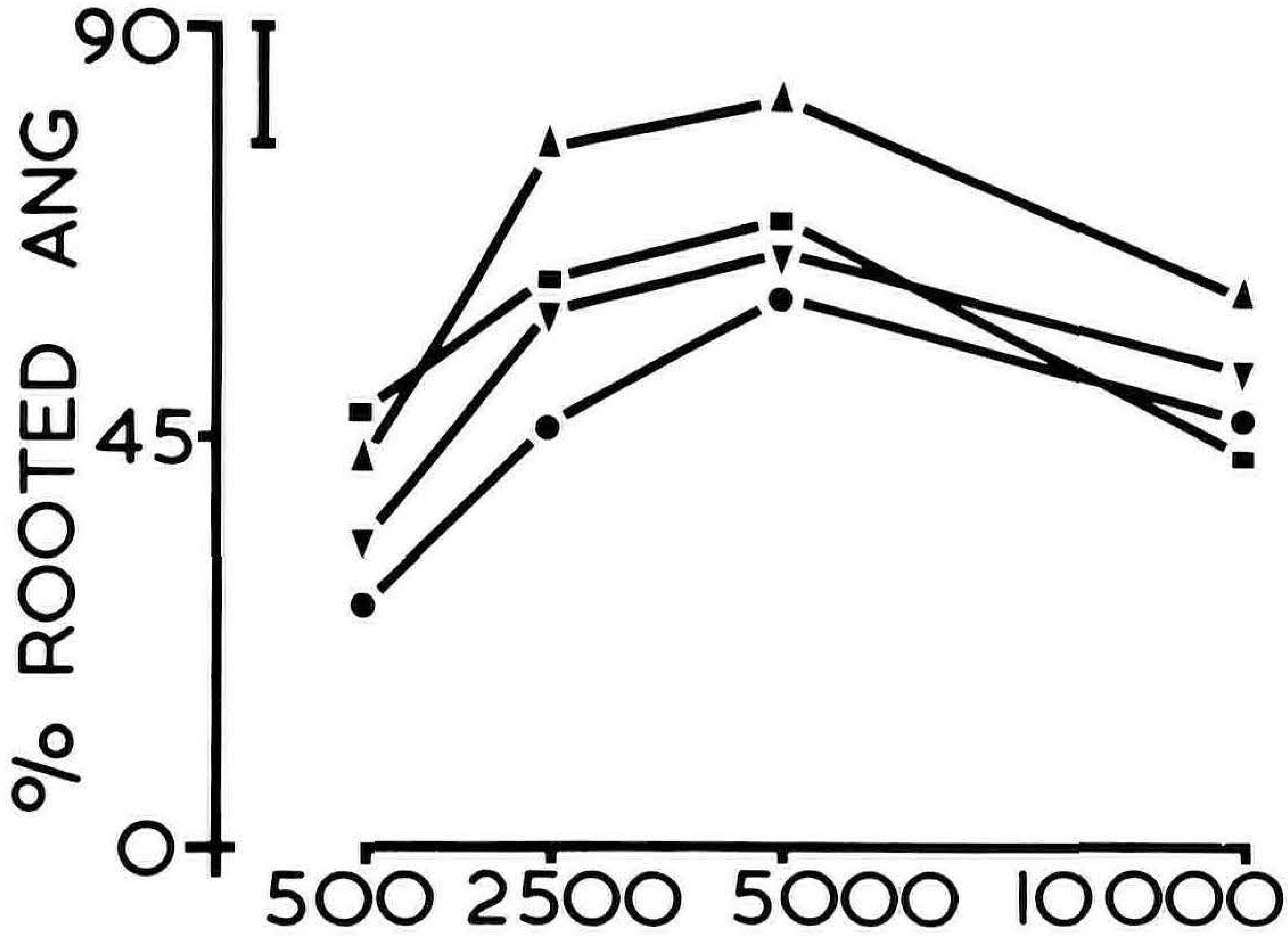

Fig 1. **Response of four rootstocks to IBA concentration**

▲ 'Myrobalan B' *(P. cerasifera)*
■ 'St. Julien A' *(P. insititia)*
▼ 'EA 16' ('Pershore' x 'Brussels'; *P. domestica)*
● 'Brompton' *(P. domestica)*

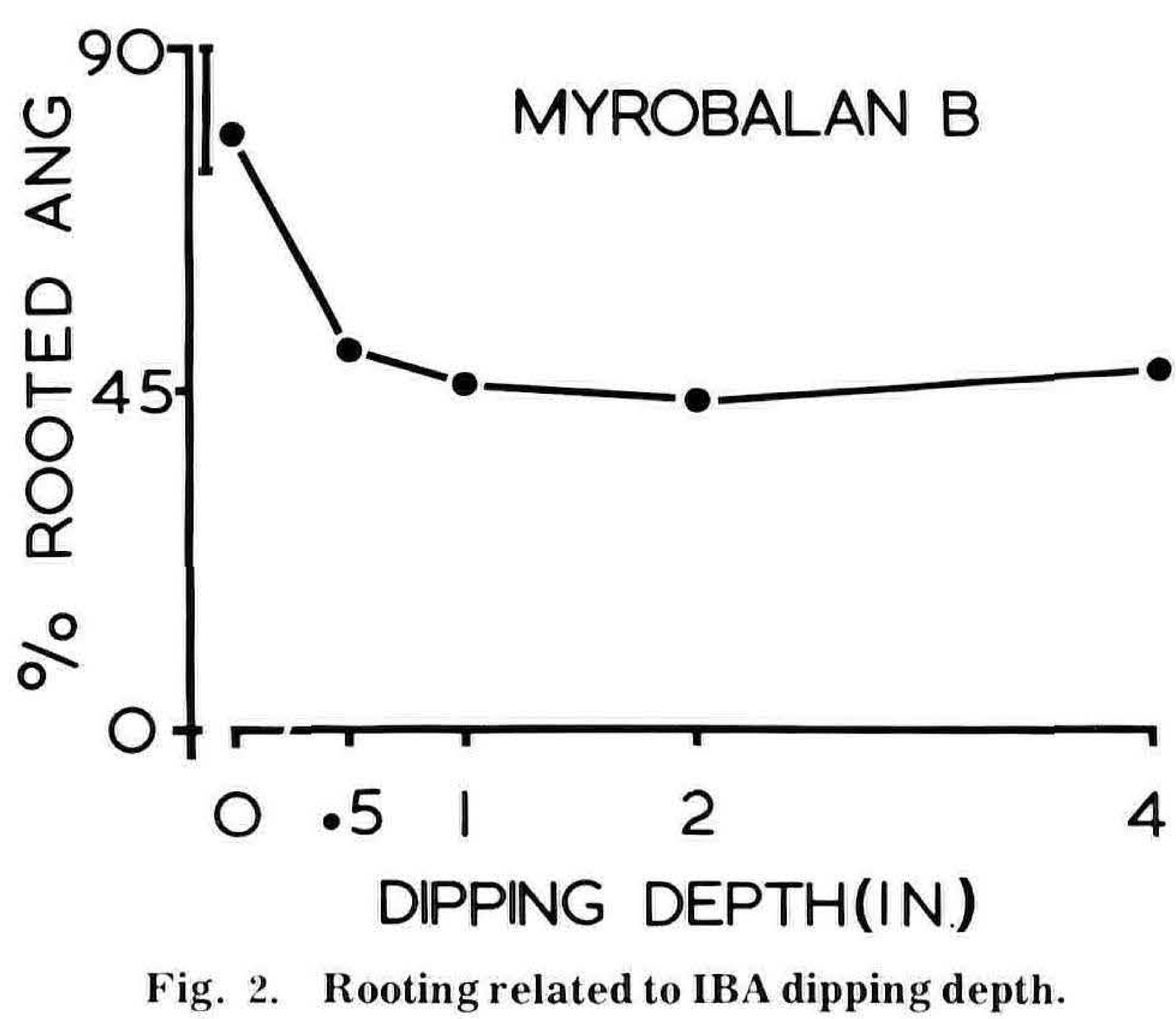

Fig. 2. **Rooting related to IBA dipping depth.**

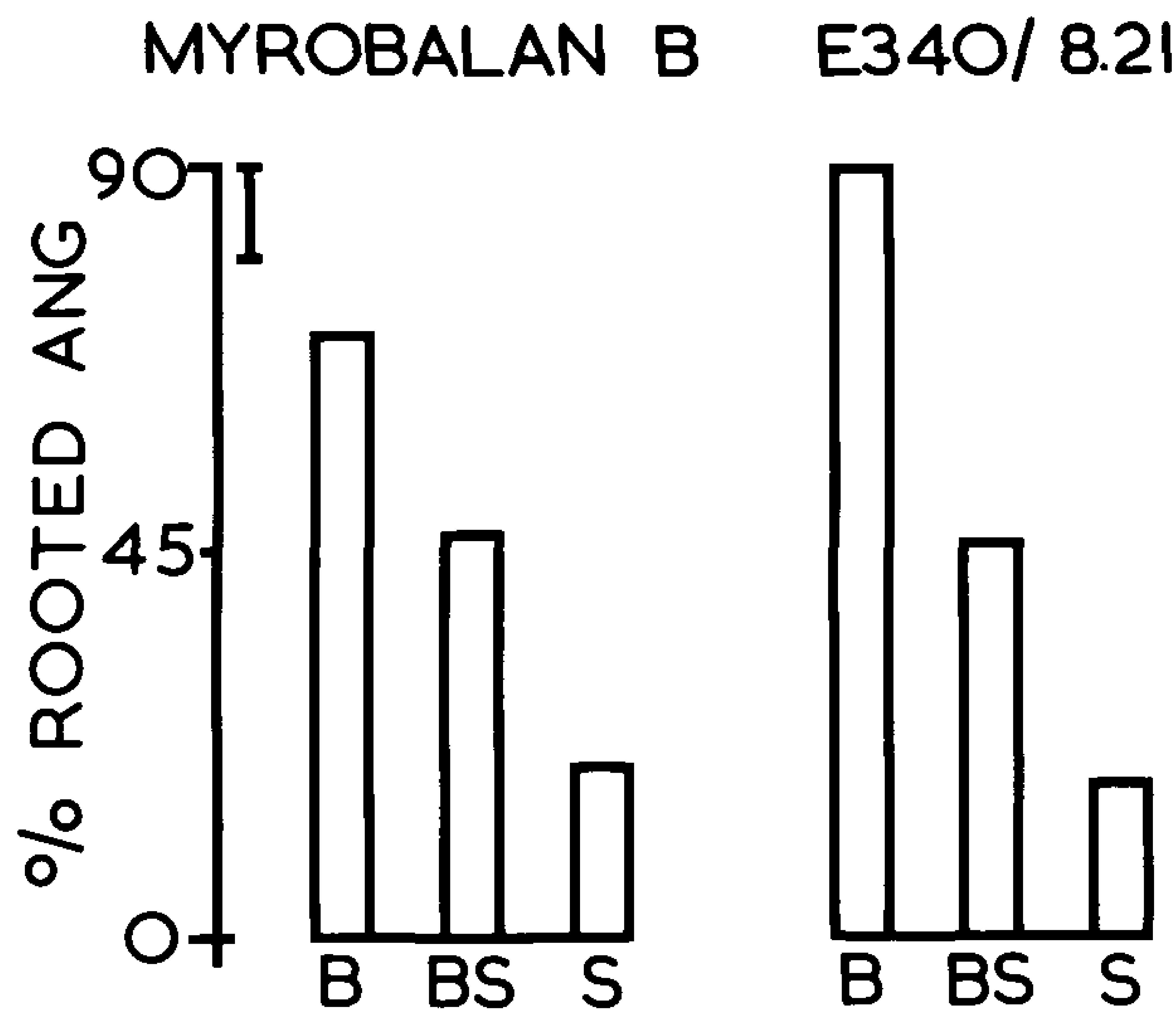

Fig. 3. **Rooting of two clones related to position of IBA application.**

B = Basal application
BS = Base and side application (1 inch dipping depth)
S = Side application for 1 inch

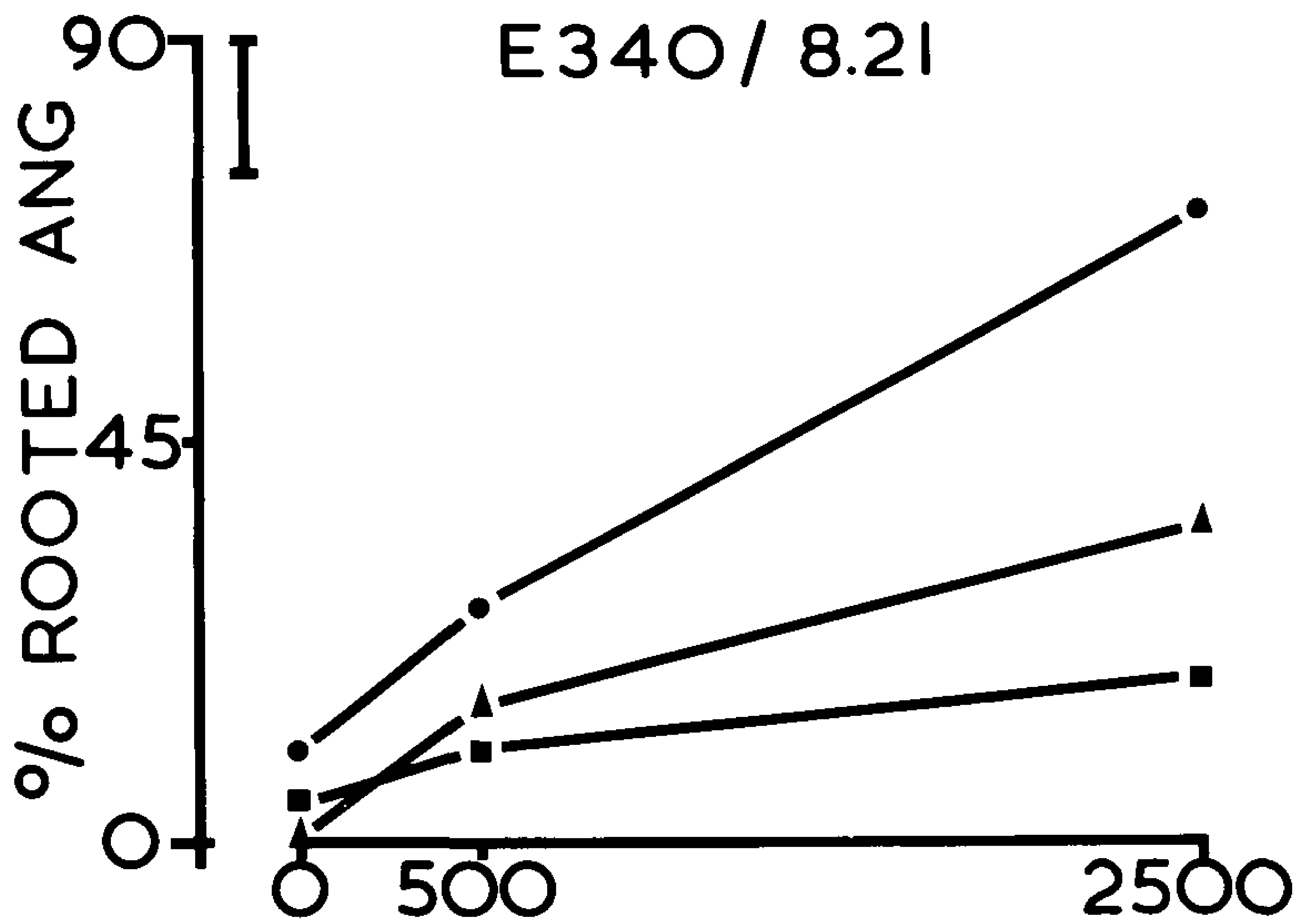

Fig. 4. **Rooting related to position of IBA application and concentration**

● Basal application
▲ Base and side application (1 inch dipping depth)
■ Side application for 1 inch

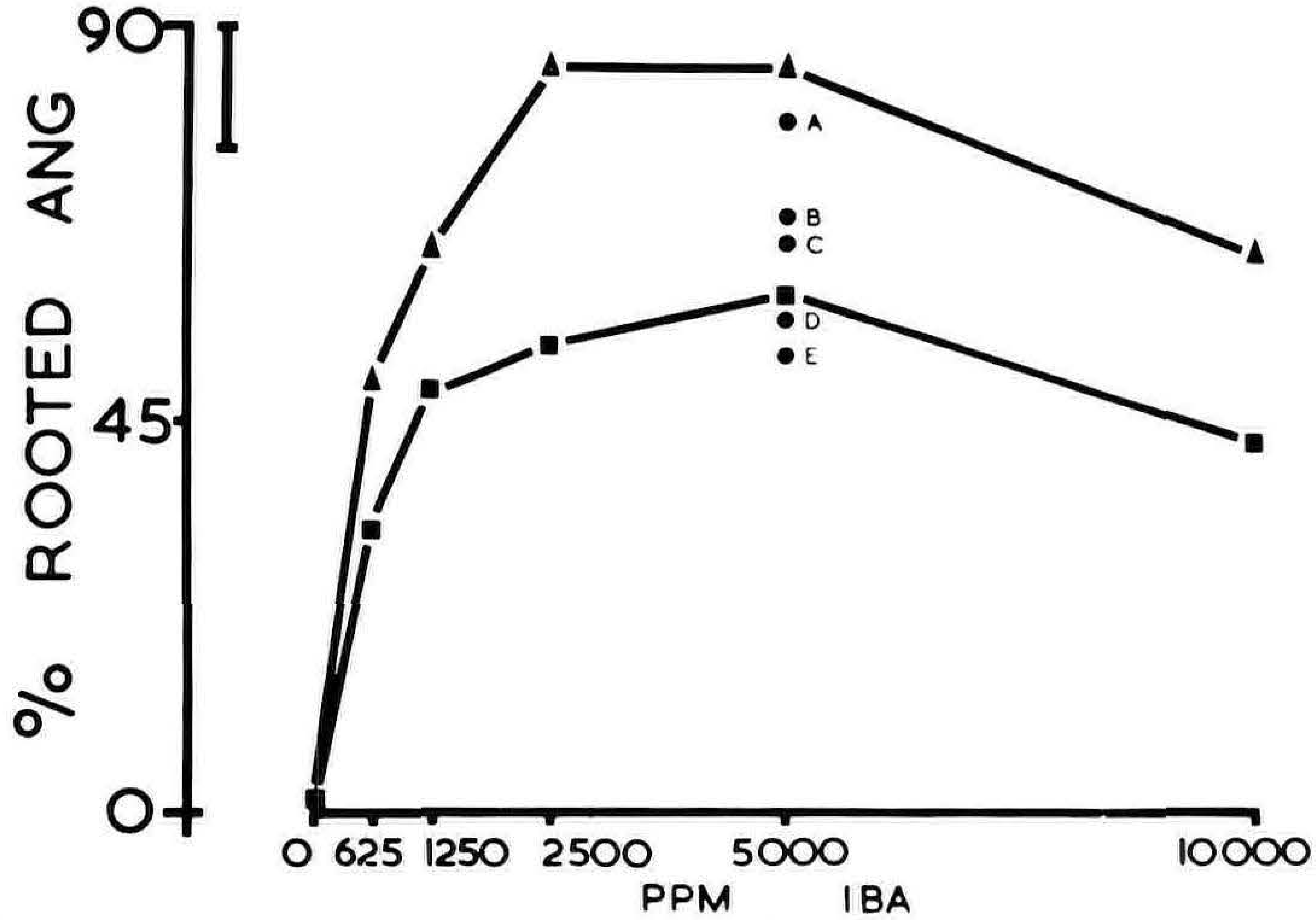

Fig. 5. Response of 'Myrobalan B' cuttings when treated with IBA at different depths and concentrations.

▲ Basal IBA application

■ One-inch dipping depth

A to E, 5,000 ppm basal application with 1 inch side applied IBA at 0, 625, 1,250, 2,500 and 5,000 ppm respectively

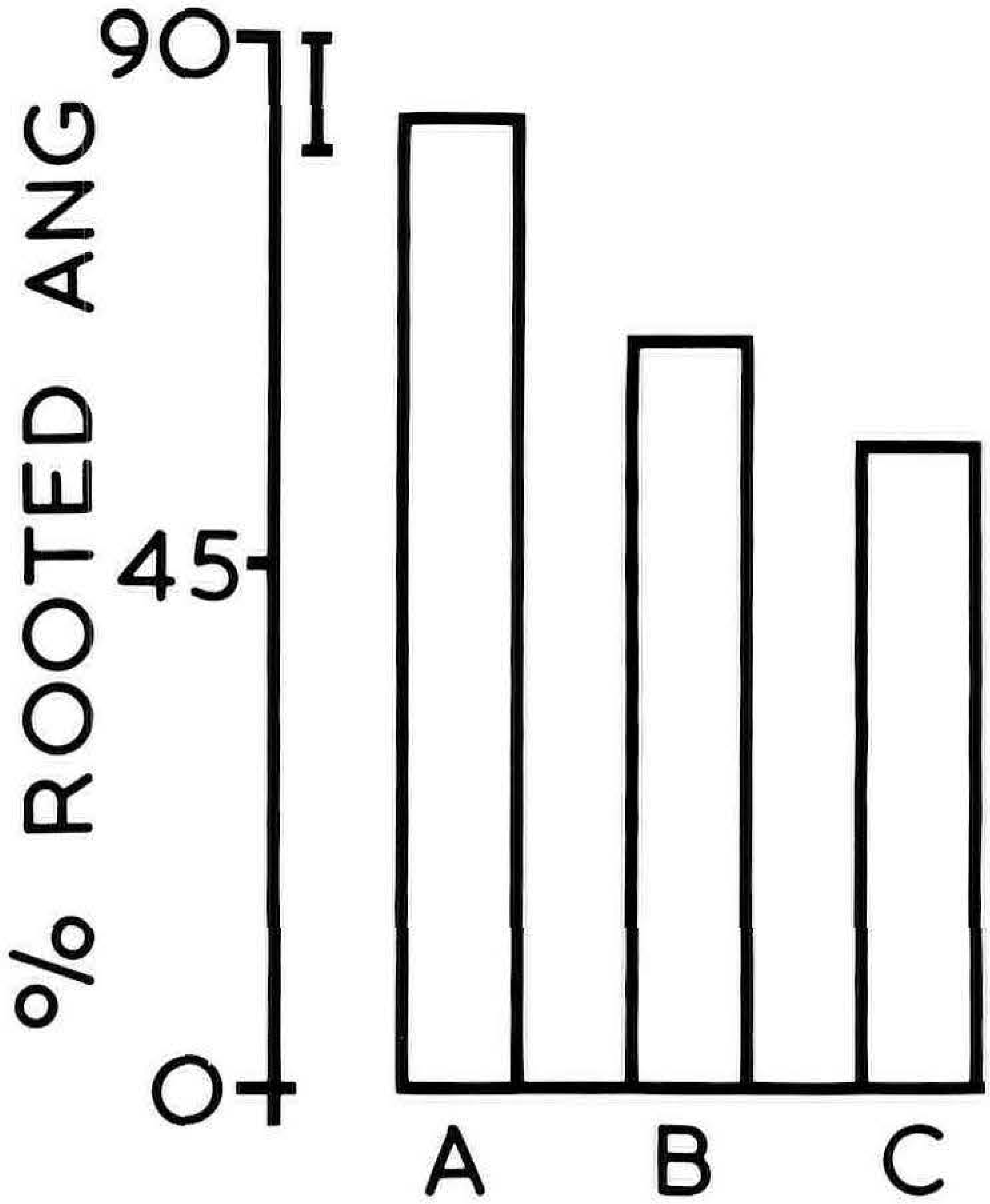

Fig. 6. The effect of wounding upon 'Myrobalan B' cuttings dipped to 1 inch at 5,000 ppm IBA

A Two to three internode wounds

B Two to three buds removed

C Normal control

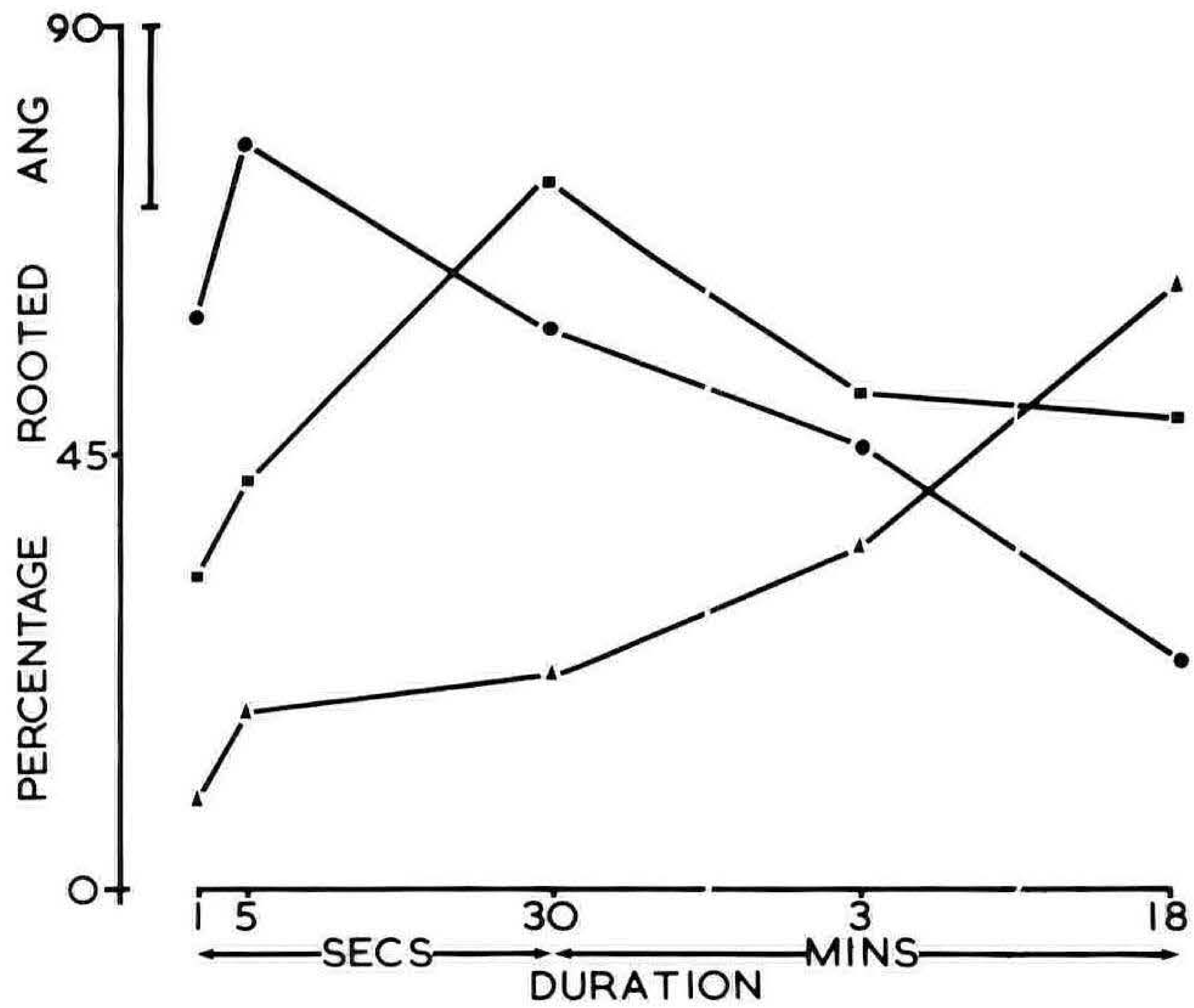

Fig. 7. **Relationship between duration of IBA treatment and concentration for 'Myrobalan B'**

● 5,000 ppm IBA
■ 500 ppm IBA
▲ 50 ppm IBA

RALPH SHUGERT: That is certainly a marvelous piece of work; thank you very much for presenting it to us.

The next speaker is a gentleman that I have known for several years; this past July I visited his nursery and found that everything I had heard about it was true. It is certainly a well-run operation — much advanced in techniques. The title of his paper is "Plant Propagation and Systems Analysis" in which he will summate some of his ideas and philosophies of a successful nursery operation. It is with a great deal of honor I present to you George Oki.

PLANT PROPAGATION AND SYSTEM ANALYSIS

GEORGE OKI

Oki Nursery, Inc.

Sacramento, California

I would like to take a little different approach to this problem in order to get down to the "brass tacks" of how to get the most out of these Plant Propagators' Society meetings.

One of the first requisites is that you must stay awake; that is you must be attentive and, of course, your physical presence is necessary. Not only is the presence of your body needed but also your mind in a clear, open manner. A wealth of information is given out but then what are we to do about it, how do we digest it, how do we take it home and put it to profitable use?

I think one of the most important things to be considered is how we identify ourselves. You may describe yourself as the manager of a nursery, a hard-driving Simon Legree with a good educational background in horticulture, with a complete staff, a fair amount of facilities, and a liberal boss who gives you some latitude in how you run the operation. What is the company philosophy? How does it fit with your identification of this company? You might say you're a diversified company producing general ornamentals, bedding plants, pot mums, etc. What are the company's aspirations and outlooks? What do they project for the future — a year from now, 5 years from now, 10 years from now, 20 years from now? How do these align with your own personal aspirations? Where do you want to be in 5, 10, or 20 years?

We might next ask several questions about ourselves. How do we stack up in knowledge? What are your personal traits, such as judgment, imagination, leadership, loyalty, adaptability, integrity, and profit-mindedness? We must first define ourself because what we are will determine how we do things regardless of where we're working. Most of us come to these meetings, as I like to express it, "big, dumb and happy." I use the term "dumb" because we come with an open mind ready to receive this wealth of information.

Now let's look at our Society. It is a completely integrated group composed of growers, propagators, educators, researchers, extension people, and people from arboreta.

Last night, I sat down in an attempt to define the term "plant propagation". I don't know how you define it but this is my definition: "a secondary event in the programmed process of placing a desirable plant or plants in the hands of a consumer with a reasonable profit", and I like to define "program" as "a predetermined sequence of events". I call this a secondary event because I think the primary event is "writing the program." In attending these meetings over a period of many years, we have all heard of the five basics or essentials many times. Many of us, when we think or speak of these five basics, look at the detail and forget the principle. When we look at light we might ask how can we use it, where does it come from, how do we eliminate it? On our tour Thursday, we saw an excellent use of light in the production of a chrysanthemum crop. I don't know how many of you grow chrysanthemums on a year-round basis but this is a crop which normally blooms in the autumn, but with the proper use of lights we can grow and flower chrysanthemums 52 weeks of the year. This is all because of the proper use of lights; the use of light to induce vegetative growth in the propagation stage and the elimination of light when necessary to induce the flowering stage. We also saw the partial elimination of light by the use of greenhouse shading, lath, and other structures. Thus we make proper use of the light to assist us in our production.

Next, let us consider heat. Most of us as propagators will think immediately of bottom heat. We use bottom heat routinely to aid in rooting plants and it is important to consider the location of the thermostat; is it up in the air, down on the ground, in the rooting medium? I think one should be in the medium and one in the air — one to control the temperature of the atmosphere inside the greenhouse and one to control the temperature in the medium. At my own nursery I have observed heat going to the medium area and the exhaust fans and water cooling system going on at the same time. I think it is important that you give consideration on how you apply heat and how you eliminate it.

We also saw the use of cold storage the other day, but the use of cold storage in California is almost nil. We use cold storage but not in the sense that we are going to store plants but rather in the sense that we are going to control their growth or their maturity, as with Easter lilies or the blooming of azaleas. Three years ago we built two refrigeration units 25 ft x 12 ft x 50 ft and we were attempting to build a rack and logistics system within this area. We tried one system, but later by analyzing the system and redesigning it we were able to get 600 bins as opposed to 400 bins previously. This increased our handling capacity one-third without any expansion or investment of extra dollars. This is only one example of a systems analysis.

We have heard a lot about water at these meetings and I like to think of water as an antidesiccant. We use it for mist, we use it to wash, the plant uses it as a vehicle to move nutrients, but we seldom consider the elimination of all of this water we use in our greenhouses. Several years ago I visited a greenhouse range of over 750,000 square feet. The houses were all brand new and one crop, carnations, was being grown. I was appalled to see the drainage system being used in this new range. It consisted of a drainage tile down each bench which drained to a central collection area and then the water was pumped out into a back field. Their back field was the best patch of tulle grass I ever saw. A simple example of poor planning.

Another area I visited had one of the most sophisticated greenhouses I've ever seen — their mist system was outstanding. It produced a mist so fine that it reminded me of a San Francisco fog. There were sophisticated controls for bottom heat for each bench, concrete walkways, and the logistics problem of getting materials in and out of the greenhouses appeared to have been well-planned. However, I questioned their judgment in building such a sophisticated greenhouse, even though they boasted they could root a juniper in less than 90 days days and certain broadleafed evergreens in less than two weeks, because when I walked out of the back of the greenhouse I found that these cuttings which were rooted in such a short time were taken out of the greenhouse and placed under a lath house and left for one year. Was this really a good investment?

We've also heard a lot about plant nutrition — slow release fertilizers versus rapidly available types and nitrate versus ammonium nitrogen. I've always had the philosophy that my plants don't have taste buds. Nitrogen is nitrogen as far as I am concerned but I wanted control of that nitrogen. One of the first sophisticated fertilizer injector systems was born at Oki Nurseries. The system uses water as the vehicle to carry the nutrients and employs chemical feed pumps with a venturi tube to measure the flow of water. The system would operate from 25 to 300 gallons per minute with a minimum of error. Initially, however, we sent out a boy to do a man's work. The principle was correct, but we had to redesign and get a larger size pump to get the maximum out of the system. Fortunately, we were working with a company which had a systems guarantee.

When speaking of nutrition I like to tie it back to the growing medium. We hear a lot about the U. C. system and how it doesn't work. I said the "U. C. SYSTEM". In most instances the grower has applied only the medium and has forgotten the system. It is a system and if it is to work all aspects of it must be employed.

I would also comment here about the use of substitute organics. I have seen many different types of organic materials used in media with the idea of making a more economical mix. But I ask in all sincerity, is it really a more economical mix? We had used some of these materials but eventually went back to our "more expensive mix" of peat, sand and perlite for our bedding plants, and over the past three years we have had practically no problems as far as production is concerned. We have also gone back to pure peat for our azalea plants and have eliminated many of our problems there. So I ask again, do these other organic additives really give you a more economical soil medium?

Another area with which we're all concerned is sanitation. Several years ago at Oki Nurseries, we had been using various methods of sterilizing or pasteurizing our media and equipment but our disease problems kept increasing. So we sat down and evaluated our procedures to determine if everyone was following the sanitation practices as closely as possible within human tolerances. We could find nothing wrong but as we sat in the greenhouse one day the wind came up and the glass panes began to rattle and it immediately dawned on us that here was the culprit. Now it is a standard practice with us to go into our greenhouses once a year and empty them out, go through the preventative maintenance and, before we go back in, we pickle the house with formaldehyde. After this we go through our sanitation procedures on a routine daily basis. We must occasionally sit down and determine where the neglect is occurring. In this case it was our greenhouses. Perhaps you should go home and take a look at your greenhouses. How proud are you of them?

After you have visited several nurseries you're bound to come to the conclusion that there is a lot of money in the nursery industry — at least in the area of facilities and equipment. It seems to me that the nursery industry ought to attempt to standardize equipment. For instance, there are as many different types of tree diggers as there are of tree farms throughout the nation. I often wonder how many dollars went into what I call "cut and fit" and how many dollars are spent in materials handling. Two years ago at the California Nursery Growers' Association meeting we had a speaker in logistics, or material handling, and I believe he was one of the most informative speakers we have ever had. At one point in his talk he stated that the fork-lift is only to move an object vertically, not horizontally. This statement must have struck home because in the last two years there has been a tremendous increase in pull-carts in California. Along these same lines I think that each one of us should sit down and chart our logistics of the flow of supplies and plants through our operation. I'm sure you'll find that it can be improved.

Another area which needs consideration is standardizing procedures, especially in the use of some of the new growth regulators. This past year we had the opportunity of using a chemical "pinching" agent, Off-Shoot-O, and we were the consistent failures in the university trials in California. We failed consistently for two years. In an attempt to determine why we failed we sat down and made up a procedure to be followed which was: water all plants to be treated, then on the following day apply the correct concentration of Off-Shoot-O. The Off-Shoot-O was never to be applied later than 10:00 a.m. One day the men were running out of time but they decided to go ahead and spray the remaining area anyway, but I wish they hadn't. They saved me 15 minutes of labor for the next day, but they burned out 15,000 azaleas. Standardized procedures and adherance to them is important; many of these new chemicals are tricky but they will work if applied correctly.

How many of you go out and visit other nursery or greenhouse operations on your own? How many of you have taken time to visit a nursery operation different from your own? Plant growers in the cut-flower and floricultural industry are specialists in their own right. In many instances they grow only one or two crops; they have many innovations and practices which can be observed and adapted possibly to your own operation.

We have been hearing more and more of meristem or tissue culture; it is not something that is going to come, it is already here. I recently visited a commercial orchid operation in South San Francisco which had a propagation room about 10 x 15 ft. Under a bank of lights were a series of test tubes going around in an endless chain and others were on a shaker; it was here that they propagated all of the orchids for their operation — it was truly amazing. Dr. Toshio Murashige, of the University of California at Riverside is currently working under a grant from the California Association of Nurserymen to develop techniques so that this system can also be used to produce woody ornamental plants. I am confident that one of these days these procedures will be used for propagating woody plants.

As an example of planning procedures I would like to read a paper which my 19-year-old son was assigned to prepare in order to project our bedding plant production for 1971. He developed the following outline of the things he wanted to do.

I. Project goals.
  A. Determination of the quantity of bedding plants sold this current year.
  B. Calculation of proposed bedding plant production.
  C. Calculation of next year's flat, seed, label, and other supply requirements.

II. Methodology to be used in attaining project goals.
  A. Collection of data.
    1. Tally of each bedding plant variety ordered for the current year whether the order was filled or not.
    2. Inventory of flats, seeds, labels and other supplies in stock.
    3. Percentage increase or decrease of current year's production to match next year's goals.
  B. Intermediate summarization of data.
    1. Increase or decrease each individual bedding plant variety by a percentage of the current year's demand projected production of each variety.
    2. Calculation of weight of each bedding plant variety

from the individual variety production (assume there is 100% germination).

C. Final summation of data.

1. Comparison of seed weights of each variety of the current year's order and adjustment of any irregularities.
2. Addition of new varieties and deletion of varieties with no consumer demand.
3. Interpretation of data.
   a. Graphic comparison of all previous year's bedding plant sales to current year's sales.
   b. Draw hypotheses about bedding plant sales from graphs and other data in regards to plant and material handling, plant schedules and associated logistics.
4. Project conclusion.
   a. Schedule production.
   b. Logistics program.
   c. Purchase supplies.

I thought this was rather good and so I asked him to write it out as a short paper and this is what he wrote:

> "Oki Nursery has been engaged in the production of the rapidly expanding bedding plant line since 1968. In order to satisfy the consumer demand for bedding plants and yet to avoid excessive production of bedding plant varieties a format to predetermine and project bedding plant production in all phases involved with the profitable production of these lines was devised. The goals of this project being the determination of the quantity of the bedding plants ordered for the current year, calculation of the ensuing year's bedding plant production estimates, and the projection of the ensuing year's supply and demand. The methodology used in obtaining these goals can be categorized into three steps; (1) collection of all pertinent data, (2) intermediate summarization of data, and (3) final summarization of the data. Initiation of this project began by establishing a tally of all bedding plant varieties ordered. This tally included all orders whether they were filled or not. To define the current year's demand atmosphere a percentage multiple is delimited by matching the current bedding plant production to the projected production plan. Also at this time the inventories of supplies are made. With the necessary preliminary data at hand the intermediate summarization of data takes place. The per-

centage multiple is factored into the demand tally of each individual bedding plant variety. This projected production for each variety is then changed from a number quantity into a weight. The final summarization involves a rigorous double-checking of all figures. Adjustments of irregularities and the addition of new varieties and the deletion of varieties without consumer demand. Bids are placed for supplies and upon receipt of the bids the order is placed. With the question of which varieties and in what quantities to produce them solved, there still remains the situation of improved logistics and production techniques. Graphic analysis of all previous year's bedding plant demand in comparison to current year's demand and an analysis of other pertinent data are the keys to helping the production staff to find the hypothesis leading to the improvement of plant and material handling, planting schedules, facility capabilities and associated logistics. Computers will undoubtedly do all of these computations some day, but for now this project requires 100 man hours of tedious work. A format such as this, however, must be done for the profitable production of any large crop."

I would like to conclude by considering what we should look for in a top propagator, grower, executive or the top nurseryman that each and every one of us should be. I found this in a 1965 issue of VIP-PLAYBOY and it's entitled "What I Look for in a Top Executive".

(1) Integrity. Obviously any executive must be honest in the conventional sense of the word, but top executives must also possess a very high degree of intellectual honesty and integrity. He must support, rather than sacrifice his subordinates and stand ready to fight for what he thinks is right. Under no circumstances can he be a responsibility-dodger or a buck-passer.

(2) Soundness of judgment. Top executives must be endowed with a large measure of common sense. It is essential that he be realistic, down to earth — a man who is both reasoned and seasoned — and whose mind can recognize and take into consideration all the realities of a situation no matter how harsh or untolerable they might be.

(3) Imagination. The man at the top must possess the ability to see and seize an opportunity, to build and create, innovate and when necessary improvise. He must have the imagination to foresee possible consequences or results.

(4) Decisiveness. Much of leadership is decision. The best executives are those who make strong courageous

decisions, calmly and cooly; they do not hedge or vacillate. The top executive must be a man whose decisions are firm, crisp, clear-cut and who is willing to make his decision and implement them regardless of personal risk.

(5) Breadth of outlook and perspective. The man at the top of any executive pyramid cannot be a narrow specialist. He must be able to view the whole and understand it. Understanding also the action and interaction of the parts which constitute the whole. He cannot allow himself to be preoccupied with any of these parts to the exclusion or detriment of the whole.

(6) Initiative and leadership. The top executive has to think and act on his own or he is not a top executive. It is essential that he have the intelligence and the ability to generate ideas, originate plans and programs, handle situations and solve problems and to lead and direct others in their work.

(7) Dependability and stability. The upper echelon manager must be built for rugged, long-term wear. He must be dependable, capable, and willing to do his job day in and day out. He must be entirely reliable in the sense that he will be thorough in his work and will follow through. He must be a consistent performer, one who remains stable and unruffled even under the heaviest of pressures.

(8) Loyalty. There is no implication here of any blind loyalty to an individual, rather the upper-bracket manager must show a basic and constructive loyalty to stock holders, employees, associates, superiors, and to the company and its customers. The best interest and welfare of all should be considered — the best interest and welfare of all should always be one of his main concerns and the primary consideration in whatever he does.

(9) Adaptability. We live in an era of constant change and nowhere is there more of it than in the business world. The top executive can not be hide-bound, hewling to preconceived ideas or obsolete methods. He must be flexible, able to adapt himself and his thinking to new and unprecedented situations. He must think and move with the times, taking full advantage of all opportunities presented by changes and developments be they social, commercial, technological, or whatever.

(10) Profit-mindedness. Surprisingly enough, there are many men who would otherwise qualify for a top executive position but for one reason or another are simply not profit-

minded. The upper bracket manager must always bear in mind the need to make reasonable profits, for without them no business can long survive in our economy. Profit mindedness is an absolute necessity for success and the good executive is constantly aware of the need to keep costs down and production and sales up. He thinks, decides, and acts to the end that the company will earn a fair profit — a fair return on the capital that has been invested in it so that the company can continue to operate, grow and expand.

How do YOU size up?

RALPH SHUGERT: George, I thank you for a very excellent presentation. I think your 19-year-old son is an outstanding young man and I am sure you are proud of him.

PLANT PROPAGATION AND ECOLOGY

F. O. LANPHEAR

Department of Horticulture

Purdue University

Lafayette, Indiana

The term "ecology" has become a household word with many connotations. Ecology in the strict sense is the science that deals with the interrelationships of living organisms and their environment. Frequently this is construed to mean how the environment, particularly the polluted environment, affects plants and animals. However, if one considers the strict definition, the effect of the plant and animal on the environment should also be considered.

What is the relationship of plant propagation and ecology? In a very limited sense this has already been considered in the session dealing with environmental factors. Yet, in the broad sense of the term, ecology goes much beyond this. Every time a new plant is propagated from seed, cutting, or graft the propagator has participated in the modification of the environment, even though the effect of a single plant may be small. If we consider man and his immediate landscaped environment it is interesting to note the many ways in which plants modify the local environment and reduce certain human stresses that exist in cities and suburbs.

The role of plants in modifying the microclimate is recognized by many. The use of trees for windbreaks and in providing shade has been practiced for centuries. This principle is applied regularly in residential and other small scale landscapes. An important question minded. The upper bracket manager must always bear in mind the need to make reasonable profits, for without them no business can long survive in our economy. Profit mindedness is an absolute necessity for success and the good executive is constantly aware of the need to keep costs down and production and sales up. He thinks, decides, and acts to the end that the company will earn a fair profit — a fair return on the capital that has been invested in it so that the company can continue to operate, grow and expand.

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What is the relationship of plant propagation and ecology? In a very limited sense this has already been considered in the session dealing with environmental factors. Yet, in the broad sense of the term, ecology goes much beyond this. Every time a new plant is propagated from seed, cutting, or graft the propagator has participated in the modification of the environment, even though the effect of a single plant may be small. If we consider man and his immediate landscaped environment it is interesting to note the many ways in which plants modify the local environment and reduce certain human stresses that exist in cities and suburbs.

The role of plants in modifying the microclimate is recognized by many. The use of trees for windbreaks and in providing shade has been practiced for centuries. This principle is applied regularly in residential and other small scale landscapes. An important question is to what extent can vegetation in the larger landscape be effective in modifying microclimate as well as alleviating other human stresses such as air pollution, noise pollution, glare and others?

One type of pollution that is characteristic in cities is thermal pollution, producing what is known as the "heat island" effect. This is increased air temperature due to the high absorption of solar energy by concrete and asphalt that covers so much of our cities, as well as the heat from auto exhausts, air conditioning units, etc. Temperature differences of 10° F or more are quite common between the city and surrounding countryside, particularly during the night.

This can be modified in localized areas by the type of ground cover that is used. For example, air temperature over artificial turf has been measured to be 8 to 12° F higher than over natural turf. Landscape plantings are also effective in reducing temperature. Whereas building and pavement absorb 90 to 95% of the incoming solar energy, foliage only absorbs 50 to 60%. In addition, evaporative cooling from vegetation further reduces the air temperature.

In a recent St. Louis study, the air temperature was 92°F in a city park and 102° F in the downtown business district. This 10 degree difference points out the effectiveness of grass and trees in reflecting the sun's radiation contrasted to the heat absorption and storage of asphalt and concrete. Also noted in the study were differences of 2 to 4 degrees between open and tree-lined streets.

Another influence that has been investigated is the effect of plantings on noise reduction. Generally, vegetation is most effective in reducing irritating high frequencies as much as 10 to 20 decibels, which is more than half, while the lower frequencies were less effectively reduced. Large pine and spruce plantings, 50 to 100 feet wide, are also capable of reducing some of the lower frequency noise, characteristic of traffic, as much as 10 decibels.

The lowest frequencies, which are the most difficult to eliminate but fortunately the least annoying, are not affected by plantings. Plantings of a single species usually exhibit a non-reducing zone about midway between the low and high frequencies.

Effective evergreens for year around noise reduction are arborvitae, Douglas-fir, spruce and pine, all of which have foliage to the ground. Other evergreens, such as hemlock, holly, and juniper, are not as effective. Some good deciduous plants are thickets of sassafras and pawpaw, as well as mixed species. Size and density of the plantings is critical in noise control, with hedges and other narrow plantings being relatively ineffective. Proper selection and spacing of plants, along with proper land grading, could contribute significantly to the alleviation of noise along highways and other problem areas.

We all learned in elementary school that human beings and animals inhale oxygen and exhale carbon dioxide. Plants in contrast absorb the caxon dioxide in the process of photosyntheus and give off oxygen to the atmosphere. Thus man and plants must depend on each other for life-giving materials. While absorbing carbon dioxide, plants also absorb other gases in the air, including pollutants.

The effects of vegetation on reducing air pollution was also considered in a recent study. It has been suggested that trees and green belts remove various types of air pollutants, both gases and solid particles. Based on sulfur dioxide (SO_2) uptake studies of Douglas-fir, it was calculated that a 15'' DBH tree has the potential of removing 43.5 lbs. of SO_2 per year if the concentration of SO_2 was 0.25 ppm. If the SO_2 level gets much higher the plants would be injured but they can tolerate this lower level indefinitely. Putting this into perspective, greater St. Louis pumps 455,000 tons of SO_2 into the air annually. Theoretically, 50 million trees or 5 percent of the land space could absorb this much, assuming the SO_2 content remained constant at 0.25 ppm. Although these exact conditions do not exist the significance of vegetation as a potential secondary filter or control is apparent. However, without primary pollutant controls the pollution may reach levels that injure the plants making them useless for any purpose.

The most effective way to control air pollution is at the source, such as reducing the amount of pollutants from autos. However, to further combat this air pollution, green belts of trees and shrubs should be placed along highways to remove various pollutants, both gaseous and solid particles. Although trees, shrubs, vines and turf remove a vast array of harmful impurities from the air we must breathe, plants, like people, can only tolerate so much. It is imperative that we find ways of combatting pollution at the source before it is too late.

Plants may also clean air by just allowing pollutant particles to precipitate out on their leaves, stems and branches. Many plants also have very fine hairs or pubescence on their parts which tend to trap dust and other particles. Also moisture on the leaves may trap dust particles. These particles are usually washed away by rains or heavy sprinklings.

This same trapping effect can be useful in removing ragweed pollen and other allergy irritants from the air. Studies have revealed that 110 yards inside a dense coniferous forest more than 80% of the pollen is removed from the air.

In addition to the effect of plants on these physical discomforts landscape plantings can also be used to alleviate other forms of pollution, such as visual pollution. A well planned planting screen can conceal an ugly junkyard or even a parking lot. Also how often have you been disturbed by the glare of bright lights, either from oncoming traffic or streetlights. Plantings can be very effective in reducing glare.

As we consider the many ways in which landscape plantings enhance the environment, the task of the plant propagator takes on added significance. Yet, the task of the propagator is not just to propagate more of the same plants. As one considers the many environmental stresses imposed on man, it is quite apparent that plants are exposed to these same stresses. In fact, unlike man who is mobile and able to temporarily escape the contaminated environment, plants are stationary and must endure the hostile conditions continuously. Consequently, plants are needed that will endure the hostile conditions of the city and surrounding areas. Air pollution, high temperatures, moisture stress and salt toxicity are just a few of the problems that threaten the survival of existing plants as well as future plantings. The propagator must be just as aware of these environmental factors as he is about the adaptability of plants to a particular natural climate. The following discussion will attempt to describe the nature of the various problems that are characteristic of the urban landscape in the 20th century.

Air pollution is not new, but it has changed and become more critical. In the earlier part of this century industrial smoke and sulfur dioxide (SO_2) were serious problems in many of our cities. Many plantings were unable to survive these conditions, particularly the evergreens. Fortunately, this problem was greatly reduced with stricter controls on the quality of coal that could be used by industry. Now, in addition to industrial emissions, some of the more serious air pollutants to plants are due to the proliferating traffic situation and the photochemical pollutants generally called smog. This type of air pollution is not restricted to Los Angeles, but exists wherever there is a heavy concentration of traffic, typical of cities on the east coast as well as in our midwestern cities. Some of the specific pollutants that occur in areas of heavy traffic that are known to be toxic to plants at rather low concentrations are ozone and peroxyacetylnitrate (PAN).

This changing pattern of air pollution requires a re-evaluation of plants that are to be recommended for city plantings. For example, lilac has frequently been recommended, but we now know that lilac is one of the most sensitive woody plants to ozone and becomes badly disfigured upon exposure to 0.2 to 0.3 ppm of ozone. Others that are relatively sensitive to ozone include black locust, sycamore, white ash, white and Scotch pine. The ginkgo, one of our most durable and generally recommended city trees is showing noticeable injury in a number of cities, particularly when located close to highways. The cause of this particular problem has not been defined but is suspected of being related to one of the photochemical pollutants.

Air pollution is just one of the problems we face in growing plants in cities. Yet, I believe it is the most serious problem because of the difficulty of control and the inevitable increase in air pollution with increasing population, industrialization and the mushrooming transportation problem. If something isn't done to alleviate this situation, and all indications are dismal, we should anticipate severe damage in the future to many forms of vegetation in the city and surrounding areas. Rural areas will not completely escape this problem. We must begin selecting and propagating pollution-resistant plants.

The situation in the city becomes even more foreboding when we look at some of the other environmental stresses imposed on plants. Less and less space is allocated to plantings, forcing them into restricted root environments of raised planters or sidewalk tree wells. Moisture frequently becomes limited in restricted soil areas. Although water can be added, provisions for this type of landscape maintenance are usually lacking. Another problem is the abnormally high or low temperatures that the roots of trees are exposed to in raised planters. Unfortunately, plants have generally not evolved root systems that can tolerate these extremes. Plants that can tolerate these conditions must be propagated and made available for the future.

Even if the root environment is adequately cared for we still have the problem of excessive heat in the ambient air. The causes of the abnormally higher temperatures in urban areas include high absorption of radiant energy by asphalt and concrete, heat output of air conditioning and industrial activities, and the reduced air movement that frequently occurs. The effects of these high temperatures on urban trees can only be surmised at this point as we do not have adequate information on this or most of the other problem areas I have mentioned.

In addition to the problems encountered in urban situations, there is a demand to use plants in other locations and situations that are unsuitable for plant growth or survival. Trees and shrubs are planted along our new highways which are void of topsoil and frequently will not support this type of vegetation. Even if the soil is improved for planting, so much salt is placed on some highways that plantings 20 to 30 feet away soon become victims of this serious stress. We need to consider propagating plants that are adaptable, not only to the salt, but to the sterile soil conditions that exist. We can learn much about this by observing those plants in nature which will grow in gravel soils or along railroad tracks, such as sumac. The usual selection of plants for landscaping are not satisfactory for these hostile conditions.

The challenge to the plant propagator is great. The problems are many but the possibilities are even greater. The possibilities can only become a reality if the technology and mechanism for implementation are available. Our primary job is to define these problems more critically and then explore ways of overcoming them.

This will require selection and breeding for resistance to such stresses as air pollution. Greater emphasis is needed in solving some of these pressing problems. We cannot ignore our role in enhancing man's environment.

CLOSING REMARKS

RALPH SHUGERT

Spring Hill Nursery

Tipp City, Ohio

Ladies and Gentlemen and Guests: For the past several days we have been exposed to a multitude of words of wisdom, have enjoyed a delightful tour of the St. Paul area and, in addition, have enjoyed the camaraderie of fellow propagators and dear friends. In 1953 I had the pleasure of attending my first meeting as a guest of Hugh Steavenson. I recall Hugh's explanation of the International Plant Propagators' Society as being an extremely unique organization, wherein exchange of ideas were freely expressed. This general theme and philosophy is still with us today. We heard on the first day of the meeting the expression of the International Plant Propagators' philosophy as expressed by Jim Wells, and I think it goes without saying that all of us in this room have a bit of this inner feeling, if you will, to plant propagation and its role in the nursery community. Without a doubt, the plant propagator today is a man respected and certainly appreciated by his fellow nurserymen.

Just one week ago tonight, I spent a pleasant hour in rereading the Proceedings of our first meeting and it was fascinating to reread the words of the gentleman who founded this Society. I would place it in my library bookshelves with Hemingway, perhaps, on one side and Robert Frost on the other. We have all witnessed the excitement of change in the 20 years of this Society and I think probably today the challenges are certainly as great, or perhaps even greater, than they were a score of years ago. Today's present market and plant challenges are quite different than they were during the first years of this Society. This morning you heard George Oki give an outstanding talk in summing up and putting together the words and the ideas that were expressed during this meeting. He told us what it means for the nurseryman and the nursery community to take from this meeting the ideas engendered and return to implement them. The language was certainly well expressed and it would behoove all of us to utilize the knowledge that we have been exposed to this week, and fit it into our own specific organization. So today, the present, we are witnessing new thoughts and a new standard, if you will, for 1970. In the next score of years it would be fascinating to gaze into a crystal ball

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I would be remiss if I didn't once again acknowledge the tremendous help and assistance in formulating this very important Society meeting. I am not going to make the mistake of trying to name names because inevitably when one does this someone is overlooked, unintentionally. But I will say now and for the record for all of the members who first of all helped plan and formulate this program, and secondly for all of the members who attended the program, particularly our members from the Great Britain and Ireland region, my deep, sincere appreciation. It was a fascinating experience and certainly an exhilarating one. To all of you, once again, my deep thanks. May you all go in peace and walk at the right hand of God today and tomorrow. I now pronounce this twentieth meeting of the International Plant Propagators' Society adjourned — *sine die!*

a piece of stem and one leaf with its axillary bud. It is clear that whereas some varieties do quite well, others lack vigor. Experimental work on the vegetative propagation of rhubarb has shown that it may be readily propagated from cuttings obtained by cutting out — discarding — the largest buds to destroy apical dominance and so stimulate a number of small shoots. Various physical manipulative treatments have been given to the English red raspberry, *Rubus idaeus*, during "summer" conditions in growth rooms and — this summer — to plants in the field, with the objective of obtaining regeneration from root cuttings in the so-called "off" season, a period roughly corresponding to summer in England.

At present, sterile culture work is confined to asparagus and is concentrated on anatomical work to follow the sequence of events which take place when pieces of stem are grown *in vitro* to produce plants.

Supplementary light and high temperatures given during the propagation stage of winter lettuce and an extension of the normal daylength in the growing house have resulted in an advance of five weeks to maturity, lettuces forming heads in February instead of the end of March.

In a quick walk round the Department, the Conference participants saw some of this work in progress and, in addition, several interesting projects of the final year horticultural students. Reprints of published papers were available for those who wished to delve more deeply into certain aspects.

The Society was honored to have as its Guest of Honor at the *Inaugural Dinner, Professor J. D. Ivins, Deputy Vice Chancellor of the* University of Nottingham, who warmly welcomed members of the Conference.

THE PRESIDENT AND HIS KNIFE

ROBERT J. GARNER

East Malling Research Station

Maidstone, Kent, England

It is old-fashioned to speak about knifemanship today because the whole trend is to do away with it, to make it obsolete. And another thing, it is a bold man who will stand up among his fellow propagators and talk about it. So I want to make a few friends, to take you into my confidence and to discuss our problems together. In that way we may each learn something or at least catch a bit of stimulation to encourage some down-to-earth enquiries and vital reassessment of our practices.

A while ago I was listening to one of those morning talks, "Farming Today", and a large-scale rose grower was saying that today they try to eliminate every hand operation, and they are succeeding.

Herbicides have replaced the hoe, machines plant, cut over and lift, and pallets convey the material into and through the sheds and storage. Wrapping, labelling and packing is done by machine and the final distribution is palletised in collaboration with forwarding agents. Orders are sorted, advices and invoices mailed and reminders allotted by computer. Output has doubled and the staff is half what it was.

In all this there is one thing not covered — the bud-grafting operation. Beyond providing some improved materials for tying or otherwise anchoring the new bud, we are still using the unaided intimate human skill of the trained knifesman. These skills are in short supply and we must make them go as far as possible. I suggest we should now concentrate on easing the work of the skilled operators. To do this effectively we must change our attitude to work evaluation. We must use the extra capacity of the skilled man's hands, eyes and brain to the maximum, and prevent him from getting tired. Examples from other trades are seen in packing sheds where flow patterns prevail, in milking parlors where the operator is placed on a special floor level to adjust the machine, and in fruit picking, where one's hand moves but an inch or so and all preliminary and further work is mechanical. Some modern plant nurseries are using ground level mobile platforms, for hydraulic cutters and pulverisers to cause trimmings to disappear. These things and others are already on the way. Our attitude must now be to regard the skilled hands as of the highest value and to place these in their best position for maximum efficiency.

Essentials for grafting success. To be really skilled and efficient we must know the material (the plant) we are handling. We can learn much from teachers but we must ourselves be good observers. We know that the parts to be grafted must not only be alive, they must stay alive till grown together. The chief cause of death is drying, and detached leafy material dries very quickly and needs special care. Leafless woody material also needs good protection to prolong its life. A modern jacketed cold-store is excellent for holding scions but many old-fashion horticultural tricks are also quite satisfactory. Polyethylene bags are a tremendous aid provided they are partially ventilated and shaded from the sun.

Compatibility is essential for a permanent graft and this may be destroyed between stock and scion by a virus carried in one component not tolerated by the other. Remember, too, that grafting is due to the healing together of wounds and that well-matched wounds hasten union formation. Firm anchorage is vital, and correct alignment helps. Over all, there is the need for good horticultural practice, choice of variety, timing and culture. Grafting is but an incident in the life of the plant and the number of unions formed over a period or at one time is not limiting. Growth and form of the composite plant is more related to the disturbance of the root shoot ratio by pruning, than by the actual grafting. Massive well-established rootstocks certainly give quick results but may not be acceptable.

Knives I have known. There are knives of many shapes and sizes, some highly manufactured, others simple if not crude, yet each quite adequate for its purpose. The essentials are strength, a good comfortable grip for control and a lasting edge. Grafters generally have favorite knives to which they have grown accustomed, thus you will find pet knives which with use and sharpening have become quite unrecognizable. Speaking of sharpening I like having a straight blade that can be sharpened on a flat stone. I hold the blade at about a 25 degree angle to the stone and push it forward against the stone as in sharpening a chisel; I personally prefer blades sharpened on both sides. This 25 degree angle provides adequate strength and such blades sharpened so last well and do not roll up their edges. For shield-budding I favor the curved-back blade for flicking open the stock as I finish the cut. However, knives are almost infinite in pattern and the dozen or so I have here are merely a few examples. Some grafting knives are used more like chisels or gouges, or even needles, but mostly we like to use them to make slicing cuts. This means that the cutting edge travels across the path of forward progression and makes cuts with great smoothness and efficiency and with least damage to both blade and plant tissue.

Mechanization and grafting. The mechanization in bench-grafting is well-established and is used on a vast scale, especially for vines where the material is so readily graded to fit. Simple, self-holding, grafts are efficient and good graft anchorage is achieved by callusing them in temporary warm storage. While complete mechanization generally may be the aim, much can be done to speed grafting even today. For example, scions may be prepared in advance of field work. The scions are cut into short lengths, tied in bundles and dipped in anti-dessicants, or other seals, and when dried are cut to wedge or tongue, as necessary, and stored moist and cold in containers ready for use during the next few weeks. Grafting is then possible at high speed during selected weather. Incidentally, no further scion-sealing is required. Furthermore, scions pre-sealed succeed later in the season than non-sealed.

The art and science of knifemanship. It is an art based on observation of scientific facts. The exploitation of the facts is the art itself. Each operator will develop his technique in his own way but he will only become really efficient if he observes the essential needs of his materials and has the knowledge, acquired by study, to make full use of the basic physical facts.

FIRST SESSION

NURSERY STOCK PRODUCTION IN DENMARK

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Nursery stock production in Denmark covers a large field which I cannot cover completely in 15 minutes, but I shall try to give a general picture of the Danish nursery industry today. There are 932 nurseries in Denmark, from quite small nurseries covering less than ½ ha, to the largest one which covers approximately 120 ha.

Everyone who either grows plants or offers them for sale has to report to the Government Plant Protection Service for inspection; thus there are a great number of nurseries registered, though most of them are, more strictly, garden centres. This also includes some who just produce a few perennials, roses, evergreens, etc. in their garden as a part-time occupation. I should say that 120 nurseries covers 95% of the total plant production. The plant inspectors are rather strict in their judgment of the general health condition of the plants and are especially checking for virus; thus "outsiders" who do not care about quality etc. soon learn either to become better growers or to quit.

We have quite a number of forestry nurseries because the different forest owners have wanted to grow their own plants for various reasons; today, however, the trend is towards a few big nurseries, and these nurseries are the most highly mechanized in the business. They sow, plant, weed, dig the plants, pick them up, drive them home to the cold storage without much labour cost; then during the winter they are graded by hand and, if already sold, they are packed ready for delivery in the spring.

Quite a few nurseries have become specialized. For example, two nurseries cover 65% of the fruit tree market, four nurseries wholesale 80% of the perennials, six nurseries supply about 85% of the rose understocks both for home production and for export. Other nurseries grow evergreens, shrub and/or roses. Only very few nurseries, however, have become completely specialized and most nurseries do have more than one line. In our own nursery we have specialized in the wholesale production of *Juniperus*, *Taxus*, *Picea*, *Abies* and *Pinus*, with some other plants which do well in containers. Additionally we grow 60,000 roses, some *Malus*, *Prunus* and some shrubs for our own garden centre. Quite a few nurseries carry different lines like us but it is really too mixed an affair.

The Danish Nurserymen's Association have had their own Adviser, Jorgen Mosegaard, for several years; he keeps the nurseries informed of what is going on in nurseries and research stations in other countries and also keeps us abreast of any relevant developments in other branches of industry. He has done a lot to promote container growing and I think we are doing quite well in this line of the business.

Danish nurseries have also had a great help from the "Egedal Machine Factory" where teamwork between Adviser, Jorgen Mosegaard, a practical machine-minded nurseryman, Mr. Grave and other technicians has resulted in the development of several very fine and labour-saving machines which have also been exported to a great number of countries. The State Experimental Station, Hornum, is mainly doing research on three subjects: "Nursery Crops, Softfruit, and Production and Maintenance of Nuclear Stock".

Research into nursery problems can be summarized as follows:

Container production of plants.

Nutrition.

Propagation of understocks for fruit, roses and for difficult evergreens. This was started a few years ago.

Replant problems of apples, pears, etc. This work is being investigated in the laboratory and chemical treatments are being tested in the field.

During the last years the work on variety trials of ornamental woody plants, including roses, have been intensified and Poul Brander, who took his Master's degree at Wye College, has done a very great job on this.

The production and maintenance of nuclear stock primarily concerns fruit trees and shrubs; when it comes to research on-propagation of evergreens and many of the ornamental plants we have to use English, American, German and Dutch literature. A large group of growers and retailers got together some years ago and formed "Planteskolernes Propagandacentral" which makes colored pictures, catalogues and pamphlets telling people how to grow rhododendrons, etc. All this is to help the nurseryman encourage people to buy plants and nice gardens instead of color TV, Hi-Fi, or mink coats!

We, in our nursery, co-operate with another nurseryman to produce our own colored catalogues with our own pictures. These catalogues we sell to different Danish, Swedish, Norwegian and Finnish nurseries in order to keep the price fairly low and, in this way, we have also gathered a large collection of colored plant pictures. The catalogues are sold to only one nursery in any particular area.

In the last years quite a few garden centres have turned up, which only sell and do not grow plants. Two of them keep most of their plants inside during most of the season; this looks rather nice in some ways, but not all the plants appreciate it and it is rather cold for the customers in the fall and early spring. Supermarkets have started to sell roses and small evergreens and, this fall, the first low-priced warehouse is opening a small garden centre. Still some of the old-time nurseries, which not only propagate, but also sell both wholesale and retail are doing quite well.

A few of the larger nurseries have their own export businesses. We have also an organization called "Danplanex" which consists of a group of growers sharing common sales management and a common sales office. To some degree, therefore, the growers in this organization will be told what to grow as the salesman will know best what their customers in the various countries want. The export trade has been helped considerably by the extensive use of cold storage which has lengthened the season and evened out labor peaks.

CLEMATIS ARMANDII GRAFTING

CHARLES E. SALTER

Bransford Nurseries (John Tooby & Co. Ltd.)

Bransford, Nr. Worcester, England

We find that the most economical way of propagating this plant is by grafting.

Preparing scion material. We first planted a stock plant on an east wall, with some protection from the north side. When this plant had established itself after the first year, we waited for young growth to commence, which normally is about late April or the beginning of May; when growth has reached about 18 — 30 inches (45 — 80 cm) and just before the main terminal bud ceases to grow, we cut back to about half its length. If this is not done, it will go on to produce excellent flowering wood for the next season; by cutting back we encourage more young growth to come from the remainder of the stem which will produce the right size and type of material for which we are looking, i.e. about 5 — 8 mm in thickness and with no "flowering wood" which normally will not produce a plant after grafting.

Stocks. Stock required for clematis grafting is *Clematis vitalba* — commonly known as old man's beard or travellers' joy which is raised from seed, sown in February to March in a light sandy loam, and lifted in December. We, however, buy our stocks from a nursery which specializes in growing stocks for the trade. The best size for grafting *C. armandii* is 5 — 8 mm; the smaller sized stocks (3 — 4 mm) are normally used for grafting clematis hybrids.

Propagation pit space. Any propagating pit in which one can obtain a temperature of 65° to 70° F (17° to 21° C) and cover with a polythene sheet or frame will be adequate for grafting *C. armandii*. Plenty of good daylight is essential, so make sure the glass is washed nurseries, which not only propagate, but also sell both wholesale and retail are doing quite well.

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Scion material. The choice of material is determined at the beginning of December when grafting commences. We select all material to be about 5 to 8 mm in size with no flower buds and, on returning to the house where grafting takes place, we pick up a bundle of 50 stocks to start grafting.

Grafting. This is carried out in the glasshouse. We first cut the clematis bine up into pieces by cutting about ¼ in. (6 mm) horizontally above the node. An average clematis bine will give up to 16 — 20 scions. The top pair are not used unless material is short. After cutting the bine, we select some suitable stocks ¼ in. (5 to 8 mm) thick and clean around the collar. We now proceed to cut the head of stock just above the collar, leaving the root and a collar of about 1 inch (25 mm) in length. Then cut about 1/16 in. (2 mm) off the side of the collar starting from the bottom and exposing the cambium layer. After placing the stock back on the bench in a clean area (we use newspaper laid out on a bench) we proceed to cut the scion vertically down through the middle of the stem to about ¾ to 1 in. (20 — 25 mm) below node (remembering we have previously cut the scion ¼ in. (6 mm) above the node); this gives us two scions at each leaf joint.

Tying in of grafts. We place scion on top of stock, pairing the two together by starting at the bottom of the stock and holding the two with the left hand. We start to tie with a cotton twine or similar material (not raffia) from the top of the graft working in a downward direction, making sure the eye of the scion is left exposed, and finish up with a double half hitch or a reef knot, keeping the twine taut while tying. Finally trim the top of the graft to give a neat union and replace on the bench for potting.

Potting of grafts. We use John Innes compost No. 1. Pots used are 2½ in. (60 mm) diameter which, though rather small for the size of the stock, are very pliable. If a circular movement is made when inserting the stock into the pot, it will wind itself around the inside of the pot. The top of the union is kept just level with the top of the pot and the pot filled to about ½ in. (12 mm) from the top, making sure the "eye" of the graft is above the soil level. After potting, some water is applied using a small watering can with a narrow spout to avoid flooding the graft; an ideal can is one that is used in most houses for watering house plants. Then the pot is placed into the propagating pit with a bottom temperature of 65° to 70° F (17° to 21° C).

Attention required. For the next 3 to 4 weeks check the temperature and guard against drying out; if watering is required spray lightly with a fine rose and turn the polythene or frames about three times a week because too much condensation may cause rotting between the unions. Callusing takes place after 2 or 3 weeks and the plants will begin to unite. At about 4 to 6 weeks, young growth will start from the "eye" in the middle of the scion (similar to roses after they have been headed back); once this commences remove the plant to an open bench with a temperature of about 50° to 55° F (10° to 13° C). When it has produced two sets of leaves, pinch out to harden and encourage fresh roots to form on the stock and, finally, pot on into a 4½ in. (11 cm) pot and stake with a 4 foot (120 cm) cane. We much prefer to use clay pots for this purpose. Place in a cold greenhouse or polythene house and within 6 to 9 months of grafting one will have saleable stocks.

PROPAGATION BY ROOT CUTTINGS

F. H. ELEY

Notcutts Nurseries

Woodbridge, Suffolk, England

The root cutting method of propagation is one of the least used methods of vegetative propagation. It is certainly one we hear little about. The primary reason for this may be the inconvenience in obtaining the propagating material. In most cases the stock plants have to be dug up or else the soil round the roots of the plants must be excavated to expose the roots prior to their removal; at best a rather tedious procedure. As this has to be done in mid-winter, it is is not surprising that propagators find other ways of increasing their stock.

Despite the difficulties involved, the root cutting method is by far the best way to increase certain plants which do not easily grow from stem cuttings. The Californian poppy, *Romneya hybrida*, is very readily increased by root cuttings. At Woodbridge, we find this operation is best done in late December or early January.

Stock plants are grown in large pots and planted in our display borders where the flowers are very useful during the summer for Flower Shows. The stock plants are carefully dug up, and the roots which grow over the top of the pot and through the hole at the bottom are ideal for our purposes; only a very small amount of this fleshy type of root is produced on plants dug up from the open ground. These are cut off and carefully put into a box, making sure all pieces of root are the right way up; they are taken into the greenhouse and cut into lengths of about one inch. To avoid confusion when potting, it is best to cut horizontally across the top of the root and slanting at the bottom. The cutting is then potted vertically into 1½ in. peat pots, covering the top with 1 in. of compost. For ease of handling, these small pots are put into plastic seed trays and placed in a warm greenhouse at 55° F. When the roots begin to show through the wall of the peat pot, usually in March, they are ready to pot on into 5 in. pots. Great care is needed with romneyas at this stage, because the roots must not be disturbed. This is why we use the peat pot as it can be planted "pot and all".

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Before the peat pot came onto the market, clay pots were used, making sure to wash them very clean to stop roots sticking to the side of the pot. Before the War, when propagating houses were kept locked, this propagation technique for romneyas was one of the best kept secrets of our nursery.

In May or June, the romneyas are planted into nursery beds and by autumn have reached a height of two to three feet.

Rhus typhina and *Rhus typhina* 'Laciniata' are also increased by root cuttings, which is easier than stem cuttings or by seed, in the case of the type itself. The roots of these are readily obtained. Sometimes the roots run as far as 4 ft. from the plant, just under the soil. The cuttings are made about 2 in. long, slightly longer than *Romneya* cuttings. These are potted into 5 in. pots, about 20 to a pot and given the same treatment. In the spring they are potted into 3 in. peat pots and planted out in nursery rows in June. The percentage obtained is not as high as with romneyas but high enough to make it worthwhile.

Chaenomeles will, of course, root from stem cuttings but they also grow well from root cuttings. The only precaution is that one must be sure that the stock plants are on their own roots.

We find the best plants for roots are two-year plants. We wait until the saleable plants have been undercut, then lift them carefully, cut off what roots the plant can spare and lay the plant back. These are then treated the same as the *Rhus* — 20 in a 5-in. pot, with very good results.

Clerodendron trichotomum is perhaps the easiest of all to propagate by root cuttings. We pot these as for *Chaenomeles*, 20 to a 5-in. pot do not repot into 3-in. peat pots. They are simply planted into a cold frame in April and will reach 1½ to 2 ft. by autumn.

I should think *Clerodendron* would propagate very readily in a cold frame, or even in nursery beds but I have not tried this method.

I do not claim for one moment that there is anything new in this method of propagating. I have been involved in this for 40 years and find it is the best way to increase the stock of certain plants which do not root well from stem cuttings. Another point is that the work can be done at a slack time in the propagator's calendar — if any propagator ever admits to having a slack period!

The whole operation can be carried out by junior members of the propagating staff, leaving the senior members free for more skilled jobs, such as grafting.

Root cuttings, although admittedly of limited usefulness in the whole field of propagating, are of great value in the production of a few special plants. The technique should not be forgotten as it is sometimes an inexpensive substitute for more costly grafting or very poor results often obtained with softwood cutting propagating.

TRIALS ON PROPAGATION OF CHAMAECYPARIS AT KINSEALY

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In recent years the demand in Ireland for trees and shrubs for amenity planting has increased more rapidly than home production, resulting in a sharp rise in imports. With the increasing interest by nurserymen in modern techniques of production we have initiated at Kinsealy a programme of research into plant propagation to encourage our nurserymen to expand their production of subjects well suited to propagation at home. The trials on the vegetative propagation of *Chamaecyparis* cultivars summarized in this paper are part of this programme of trials and demonstrations. All cuttings were treated with 0.4% proprietary IBA powder after immersion in a solution of Captan before insertion in a mist bench with bottom heat at 21° to 24° C.

Effect of time of insertion on rooting and development. Twenty cuttings of each of 20 cultivars were inserted at fortnightly intervals from the beginning of February to the end of March, 1969. The percentage rooted was generally higher from the earlier insertions, especially in the more difficult-to-root cultivars. Table 1 shows the results obtained with four easy-to-root and four difficult-to-root cultivars.

The rooted cuttings were hardened off and planted into a cold frame containing a standard growing medium of peat and fertilizers. This substrate, based on experimental work at Kinsealy and now marketed by a commercial firm has given very satisfactory results with a wide range of food and flower crops under glass. Rooted cuttings of trees and shrubs have also developed very satisfactorily in this compost. Table 2 shows the height attained by the rooted cuttings of *Chamaecyparis* in November of the same year, the figures being an estimate based on the measurement of three typical plants of each cultivar.

All cultivars in the trial showed a similar trend in development in relation to date of insertion of the cuttings, but the later insertions of the more difficult-to-root cultivars gave too few rooted cuttings. Apart from 'Ellwoodii' the easy-to-root cultivars showed no pronounced effect until the early March propagation. The results of this observational trial suggest, therefore, that cuttings of the more difficult to root cultivars should be taken earlier, the easy-to-root kinds can be left until later without reduction in numbers rooted and without marked effect on subsequent development.

Table 1. Effect of date of insertion on percentage rooting of eight cultivars of *Chamaecyparis lawsoniana*

Cultivar	Date of insertion of cuttings				
	4/2	18/2	4/3	18/3	31/3
'Glauca'	100%	95%	95%	90%	90%
'Ellwoodii'	95%	95%	95%	80%	70%
'Brilliantissima'	90%	90%	65%	55%	70%
'Pottenii'	90%	80%	100%	95%	80%
'Stewartii'	15%	30%	40%	0%	5%
'Lutea Smithii'	45%	20%	30%	0%	0%
'Versicolor'	15%	0%	5%	5%	10%
'Darleyensis'	5%	15%	50%	30%	15%

Table 2. ***Chamaecyparis lawsoniana.*** **Height (cm) in November in relation to date of propagation**

Cultivar	Date of propagation				
	4/2	18/2	4/3	18/3	31/3
'Glauca'	34cm	35cm	37cm	22cm	22cm
'Ellwoodii'	30	26	18	19	16
'Brilliantissima'	28	30	28	20	20
'Pottenii'	35	35	36	30	32

Effect of substrate. Cuttings of four cultivars were inserted in four substrates, peatmoss (P), sand (S), 2 peatmoss 1 sand (2P1S) and 2 sand 1 peatmoss (2S1P) on April 4. Table 3 shows the numbers rooted when lifted on June 11. The numbers in parenthesis are ball-rooted cuttings, i.e. with so much compost adhering that the individual roots could not be separated readily.

Sand alone gave results significantly poorer at the 1% level than peat and sand composts. The results from peatmoss alone were in-

Table 3. Effect of substrate on rooting of four cultivars of *Chamaecyparis lawsoniana*[1] (Inserted 4/ 4/ '68)

Cultivar	No. rooted in each substrate				
	S	P	2P1S	2S1P	Mean
'Fraseri'	2.5 (0.0)	6.0 (1.8)	6.7 (1.3)	6.2 (0.2)	5.4 (0.8)
'Stewartii'	2.8 (0.2)	2.5 (0.0)	4.7 (0.2)	3.5 (0.0)	3.4 (0.1)
'Milfordiensis'	5.0 (1.0)	6.2 (2.8)	7.5 (2.8)	8.7 (2.8)	6.9 (2.3)
'Pottenii'	6.5 (1.3)	7.7 (4.5)	8.7 (2.5)	9.0 (1.5)	8.0 (2.4)
Mean	4.2 (0.6)	5.6 (2.3)	6.9 (1.7)	6.9 (1.1)	
	F-test[2]	Substrate	**	(***)	
		Cultivar	***	(***)	
		Interaction	NS	(NS)	

[1] Means of 4 replicates of 10 cuttings
[2] On arc-sine transformed data

termediate and not significantly different from the other media, but the roots in this medium were brittle. At Kinsealy we are currently using 2P1S as our standard medium for rooting *Chamaecyparis* since peatmoss is obtainable in more uniform grade and composition than the washed river sand of granitic origin used in our trials.

Cuttings with and without heels. Cuttings of four cultivars with and without heels were rooted by four different methods (Table 4). The cuttings consisted of the growth of the current year stripped from the parent branch. In the heeled cuttings the heel of older wood was trimmed with a sharp knife according to the generally accepted practice. In the remainder the heel was removed by cutting through the stem of the cutting at a position circa 5 cm above the base. Forty cuttings of each cultivar were included in each treatment. All were immersed in a Captan solution before being treated with a proprietary 0.8% IBA powder.

In each cultivar the cuttings without the heel of older wood gave as high or higher percentage rooted as cuttings prepared with a heel. Cuttings of the same cultivars in a trial in a mist unit in February (three replicates of 20 cuttings) gave as good (*C. l* 'Erecta viridis') or better percentages rooted from the cuttings without heels.

The effect of taking cuttings without heels was demonstrated on a range of conifers by Wyman in the U.S.A. as long ago as 1930. At Kinsealy similar results have been obtained with *Juniperus spp*, both in a mist bench and in a cold frame.

Table 4. Rooting of cuttings of *C. lawsoniana* cultivars with and without heels (Inserted 19/9/'69)

Method	Treatment	Date lifted	Percent rooted and cultivar			
			'Pottenii'	'Allumii'	'E. Viridis'	'T. van Boskoop'
Mist	Heeled	11/11/'69	37%	57%	30%	25%
	No heels	11/11/'69	85%	65%	65%	30%
Single Frame	Heeled	30/4/'70	25%	7%	20%	5%
	No heels	30/4/'70	25%	30%	2%	0%
Double Glass	Heeled	30/4/'70	35%	57%	22%	25%
	No heels	30/4/'70	55%	57%	52%	0%
Glass + plastic	Heeled	30/4/'70	42%	60%	30%	2%
	No heels	30/4/'70	80%	85%	30%	2%

Effect of spacing. Two cultivars were included in a spacing trial, comparing 20 with 60 cuttings per 69 sq. in. (*C. l.* 'Pottenii') and 20 with 40 cuttings per 69 sq. in. (*C. l.* 'Fraseri') (Table 5).

In the relatively harder to root 'Fraseri', the wider spacing gave a higher percentage of rooted cuttings after 11 weeks. In the easier to root 'Pottenii' the trend was similar, as also with 'Argentea Nana' used in guard rows. These results suggest that under the conditions of this trial cuttings of less easily rooted cultivars should not be crowded. When material is plentiful and the cultivar easy to root it may be better to insert cuttings closely to obtain greater yield per unit area of propagating bench.

Table 5. Effect of spacing on rooting of two *Chamaecyparis lawsoniana* cultivars[1] (Inserted 15/1/'69. Lifted 10/4/'69)

Cultivar	Spacing	Mean percentage rooted	"t" (df = 3)
'Fraseri'	Wide	64	
	Narrow	25	
			5.51
'Pottenii'	Wide	89	
	Narrow	68	
			0.188

[1] 4 replications of each spacing treatment

While most of the results presented in this paper have been obtained during trials carried out on a mist bench, other methods may be more economic since conifers take up bench space for a long period (8 to 11 weeks) compared with many other subjects. The cold frame with a sheet of plastic over the cuttings is an example of an alternative method adopted by some nurserymen. An efficient propagation schedule implies the integration of two or more methods, based on thorough knowledge of the response of each of the species and cultivar and the provision of the appropriate environment for rapid rooting.

SELECTION OF MATERIAL WHEN PROPAGATING LEYLAND CYPRESS

BRIAN HALLIWELL

Royal Botanic Gardens
Kew, Richmond, Surrey, England

X Cupressocyparis leylandii, the "Leyland Cypress", is a bigeneric hybrid having as its parents, *Chamaecyparis nootkatensis* and *Cupressus macrocarpa*. It was first noticed as seedlings amongst a batch raised from seed taken from *C. nootkatensis* in 1888 but since that time it has arisen on a number of occasions, sometimes with *Cupressus macrocarpa* as seed parent. Stock has been maintained by vegetative propagation and today a number of clones exist to which names or numbers have been given. For a long time this tree was considered as little more than a botanical curiosity. Its true worth came to be realized when its fast growth, hardiness and ability to

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I have had experience in the propagation of this tree over a period of about 10 years with moderate success. At about the time of these reports of difficulties in propagation, I was having trouble in rooting one batch of cuttings. These had been taken from an old tree at least 50 years old which had acquired a reputation for being very difficult to propagate, yet other people who in the past had material from this tree did not have these difficulties. Why was there a difference? Methods of propagation were similar and it seemed that there was only age which was basically different. I decided to carry out experiments to see if there was anything in this supposition. Besides this old tree which was probably clone 2 I had access to other trees of about 20 years of age and others of about 5 years, also of clone 2. Cuttings were taken during November and December prepared about 6 inches in length, their bases wounded and dipped into Seradix 3 and inserted into a rooting medium of equal parts peat and sand. Propagation was carried out in a glasshouse where the propagation beds had bottom heat and where the air temperature varied between 60° and 65° F; the experiments were carried out over a three-year period.

The results obtained were:

50 year old tree gave .... 5% success,
20 year old tree gave ....34% success,
5 year old tree gave ....94% success.

After rooting, these cuttings were potted; when the pots had filled with roots these plants were moved into larger pots. When 2 years old further cuttings were taken from these plants and these rooted with 100% success. I was able to repeat the experiments with other trees of differing ages and from different sources and always there was a similar pattern of percentages.

It is well known that conifers are easiest to propagate when in their juvenile state and this has been borne out in these experiments. This selection of juvenile material for propagation is extremely important in a very wide range of trees and shrubs and with many difficult subjects this is often the only means by which success can be achieved. On a commercial scale it is obviously impractical to use stock plants that are two years old but the juvenile state can be retained on stock plants by growing them on the hedge system with these hedges clipped annually. Tests carried out using material from these hedges have given very good results, comparing very favorably with young stock plants.

The experiments recorded are obviously incomplete and roughly carried out. Although I have tested a number of clones, these have been unnamed and the entire range of named clones need to be tried before any definite results can be achieved. It does seem, however, that my work indicates that when selecting material of "Leyland Cypress" for propagating, it is important to ensure that it be in the juvenile state.

RESEARCH AND THE PRACTICAL PROPAGATOR [1]

B. H. HOWARD

Pomology Section

East Malling Research Station

Maidstone, Kent, England

Experience and skill are prerequisites for successful propagation, but nurserymen are becoming more aware of the opportunity offered by research for improving existing techniques and developing new propagation methods against a background of decreasing availability of skilled labor and increasing production costs.

A most important discovery by research workers was the role played by hormones in controlling various responses in plants, including root initiation in cuttings, leading to the manufacture and use of synthetic auxins which have become an essential and singularly effective tool in the nursery.

There is evidence, however, that auxins are not necessarily used in the most effective way by propagators, underlining the need for applied research of the type done at the East Malling Research Station by N. Nahlawi, whose paper entitled, "The effect of dipping depth and duration of auxin treatment on the rooting of cuttings", won the 1970 Graduate Student Award of the Society.

He has discovered relationships between the rooting response of hardwood cuttings of plum rootstocks at a range of IBA (4 (indolyl-3) butyric acid) concentration and their dipping depth in the hormone solution and its site and duration of application. This work demonstrated that in propagation research, as in other biological fields, account must be taken of the fact that plants, or cuttings, rarely respond to one influence, such as auxin treatment, in exactly the same way under different conditions of treatment and environment. For this reason it is essential that techniques are based, wherever possible, on a sound understanding of the mechanism operating within the plant, so that the technique can be exploited with species or in conditions not previously experienced.

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[1]An abstract of a paper in which examples were drawn from the postgraduate studies of N. Nahlawi, which is given in full on page 292

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Such an understanding has led to the successful widespread development of the mist technique for rooting softwood cuttings, the main feature of which is that leafy cuttings with minimal energy reserves can be kept in an environment which allows the accumulation of essential carbohydrates from photosynthesis (1, 2).

It has been demonstrated that the leaf area of cuttings and light intensity under mist influences rooting (3), but in cuttings comprising leaves, petioles and stem it is usually only the leaf which significantly contributes photosynthates, while the petiole and stem utilize them in survival and growth. Therefore carbohydrates available for rooting are the balance between photosynthetic input and respirational losses, termed net-photosynthesis.

The ratio of leaf to stem was not found to be important under the favorable conditions of the mist bench, but in the unfavorably warm and shaded conditions of a traditional closed case, cuttings with relatively large leaf area to stem survived and rooted best. (Table 1).

Table 1. Response of various types of hop cuttings to unfavourable propagating conditions in a closed case.

Cuttings[1]		Net photosynthate *(dry wt)*	Rooting *(potential under mist = 100)*
Two-node	low leaf to stem ratio	loss	6.3
Trimmed leaf bud	low leaf to stem ratio	loss	4.6
Leaf bud	high leaf to stem ratio	gain	28.6

[1] For description and diagram of cuttings see Howard and Sykes (2).

It is important for research workers to establish, and for nurserymen to appreciate, these complex interactions between the plant, its environment, and applied treatments. With this objective forty-two nurserymen have agreed to participate in a number of experiments carried out on their own nurseries and co-ordinated from East Malling Research Station, aimed in the first instance at establishing to what extent techniques such as wounding cuttings, and inserting buds by various methods are soundly based and of general value.

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SECOND SESSION

ASPECTS OF PROPAGATION IN FORESTRY

JOHN JOBLING

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Forest Research Station, Farnham, Surrey

England

SUMMARY

Comparatively few forest trees are raised vegetatively but poplars and willows are grown in the open nursery from hardwood cuttings and several horticultural cultivars, including Leyland cypress and selected clones of elm, are produced under mist indoors. The methods of propagating these are discussed and brief reference is made to recent research on the subject.

INTRODUCTION

Every year some 100 million plants are raised from seed in Forestry Commission nurseries. Most of them are conifers, principally the spruces, pines and larches, and only about 1 percent are broadleaved trees, mainly oak and beech. Normally the seeds are sown broadcast on to raised beds; the subsequent seedlings take one or two seasons before they are large enough for lifting and transplanting, then the transplants need a further one or two years to reach a size suitable for forest use. In the south of the country, plants large enough for planting out can be raised in two years, but in the north three years are normally needed. The techniques of raising forest trees from seed are well known and are amply reported in forest literature.

In contrast, comparatively little vegetative propagation is undertaken by the Forestry Commission; probably fewer than 100,000 plants are produced annually, and only small quantities of stock raised vegetatively are actually planted in forest conditions. In the

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In contrast, comparatively little vegetative propagation is undertaken by the Forestry Commission; probably fewer than 100,000 plants are produced annually, and only small quantities of stock raised vegetatively are actually planted in forest conditions. In the production nurseries of the Forestry Commission propagation is limited to selected poplar cultivars grown for timber at wide spacing on low-lying fertile ground, to Leyland cypress, x *Cupressocyparis leylandii*, a valuable ornamental tree but whose future in forestry is still uncertain, and to a small number of poplars and willows raised especially for amenity. In practice much of the vegetative propagation undertaken by the Forestry Commission takes place in the Commission's Research Division nurseries, where different methods of clonal reproduction are being tested and clones are being raised for various types of experimental work. Methods of raising trees that are unable to produce fertile seed are also being examined. Though the number of plants grown is not large, work is conducted on a wide range of species including most of the common conifers and the main species and hybrids of elm. Methods of raising London plane, *Platanus acerifolia* are also being looked at.

In the private forest sector and in the horticultural trade the situation is quite different due to the sustained demand for trees for screening, shelter and ornament, and large numbers of cultivars are raised each year by vegetative means. Many different techniques are used, some of them peculiar to horticulture.

This paper discusses the methods of vegetative propagation commonly practiced in forest tree nurseries and briefly reviews the related research presently being conducted.

PROPAGATION IN THE OPEN NURSERY

Virtually all species and hybrids of willow and poplar, whether grown for timber or for amenity, are raised vegetatively. Dioecious flowering and the low viability of seed limit opportunities for sexual reproduction, and successful methods of vegetative plant production have inevitably evolved. But propagation from cuttings is seldom difficult and as successful cultivation in the field depends on the availability of tested selections, often derived from artificial breeding, the adoption of vegetative methods has been logical. Though scores of cultivars of poplar and willow are raised of widely differing performance, the nursery methods are reasonably standard and lead to uniformly good results. For convenience the genera are considered separately. London plane, the only other broadleaved tree commonly raised in the open from cuttings requires a different technique. This leads to variable and sometimes disappointing production although it is generally practiced.

Poplar. Cuttings may be collected and prepared for insertion at any time after leaf-fall, provided the shoots from which they are taken are well ripened. In practice there is no advantage in early insertion, and if cuttings are made ready in advance they may be safely stored in plastic bags in a cold chamber at a temperature of about +3°C. If cold storage facilities are not available they may be kept for short periods in plastic bags in a cool, darkened room. Warm conditions promote root and shoot growth, and should be avoided. Though cuttings made from two-year old and even three-year old wood root adequately in most soils, root production is slow and the resulting plants are correspondingly small. Root initiation and development on one-year old wood is generally rapid, on the other hand, and unless propagation material of this age is in short supply older wood should not be used. The cuttings can be prepared from shoots from stumped nursery plants, from stools cut annually, or from shoots from standing or felled trees using vigorous epicormic growth or upright branches in the upper crown.

Poplar cuttings are mostly 23 to 25 cm long, and there is no advantage in using longer material. Shorter cuttings than this will root, but when less than about 15 cm long the quality of the plants grown from them is poor. Thin cuttings from the upper parts of shoots should not be used as they also produce weak plants and may even fail to root, but thick cuttings from the basal parts of shoots are acceptable provided they can be easily inserted in the soil. Cuttings without leaf buds will usually throw out shoots from adventitious buds but as there is a delay before growth starts, the resulting plants tend to be small. The top cut end of the cutting should be just above a leaf bud.

Though insertion of cuttings of late flushing cultivars can be delayed until mid-April, insertions should usually be completed by the end of March as poplars generally are early leafers.

Poplars respond to fertile nursery conditions and well-grown stock suitable for field planting can be raised in a single season from cuttings in a soil which is base rich, moist and well-drained. Fertility must be maintained by regular manuring, for example by application of compost or hop waste at 50 metric tons per hectare, and by dressing with a phosphatic-potassic fertilizer such as potassic superphosphate at 750 to 1000 kilos per hectare, at least every other year. Annual top dressings in mid-season of a nitrogenous fertilizer, at about 380 kilos per hectare, are also desirable. Acid conditions hinder growth of poplar and may lead to failure and liming should be carried out periodically to maintain the soil pH value at or above 6.0. When the pH value falls below about 5.0, conditions are becoming marginal.

Cuttings should be inserted vertically until the top cut end is level with the general soil surface. As the soil settles the upper 2 to 4 cm of the cutting will protrude from the bed.

As poplars are capable of developing a wide spread root system in the nursery, the plants are commonly lifted at the end of the first year whether large enough for field planting or not. Thus comparatively close spacings may be used in cutting beds, though for sustained vigor and to allow access to different parts of the bed the cuttings should not be closer together than 40 cm in rows or closer than 45 cm between rows. Heights in excess of 2 m are usually achieved in the first season in a well-manured nursery, and the selection of stock for field planting should not ordinarily be difficult. Not all cultivars are so vigorous though, and in a cool, wet summer even normally vigorous poplars may grow slowly.

A rooting percentage in excess of 90 can usually be obtained for all the common cultivars except Grey poplar, *Populus canescens*, and if only selected, high quality cuttings are used the rooting percentage may reach 100. Grey poplar varies from clone to clone, but even in favorable circumstances the rooting percentage is seldom greater than 60. In practice most clones of this tree are very difficult to root from hardwood cuttings, and only the aspens, the *Leucoides* poplars, and *Populus deltoidea angulata*, a North American Cottonwood, present the propagator with greater problems.

One-year rooted cuttings too small for field planting, and any other stock to be retained in the nursery for a further season, should be lined out at a comparatively wide spacing to allow ample room for crown and root development. The transplants, as well as cuttings to be left in position for two or more years, should be 60 to 90 cm apart.

In some Forestry Commission and trade nurseries the plants are cut back immediately after transplanting, that is when they are still only one year old. Growth from the cut stump is invariably vigorous and sturdy, well-branched plants, larger than those grown in the first year, are obtained at the end of the second season. Cutting back ensures a regular supply of cutting material, and three-fold increases in plant production can be achieved annually with the method. But for a sustained supply of large numbers of cuttings, stools which are cut back annually are required.

Two-year and older plants that have not been cut back may be expected to have heights in excess of 3 m at lifting. If plants much taller than this are grown special planting techniques may be needed to keep them upright.

Willow. Traditionally, most willows including cricket bat willow, *Salix alba* var. *coerulea*, are generally planted out as sets. But rooted plants are raised at many nurseries and their use for ornamental planting is increasing. Their use in bat willow planting is recommended since the method ensures the production of good quality stock free from defects in that part of the stem destined to produce bat timber, that is the lower 2.3 to 3 m of the bole. Rooted plants are raised from both cuttings and sets. The method of raising plants from cuttings is similar to that described for poplar, using cuttings 18 to 25 cm long and 13 to 25 mm thick, and inserting them in January and February. Initially at close spacing, 15 to 23 cm within rows and 60 cm between rows, the cuttings are usually lifted after one year and transplanted to a wider spacing comparable to that used for poplar. The plants may be cut back at this stage. In both cutting and transplant beds only one shoot is allowed to develop, and it is relatively easy to raise a plant with 2 to 3 m of clean stem and a well-developed head of branches.

When plants are raised from sets, usually grown on nursery stools, though occasionally taken from the crowns of standing or felled trees, the sets are 2.5 to 3m long and are inserted 30 to 60 cm apart in rows and 60 to 90 cm apart between rows. If one-year old sets are used the plants usually remain in the nursery for two years, but if two-year's old, the plants can be lifted after only one year if growth has been good. Stools especially established for set production are rarely more than 90 cm apart, and are usually cut back to within 25 cm of ground level. The shoots growing from stools are sometimes thinned to ensure that only strong and straight sets are produced.

For direct planting in the field, sets should be stout enough to stand upright without staking. For bat willow the stem must be at least 3 m long to allow the basal 60 cm to be placed in the ground, leaving 2 to 3 m of the clean stem above ground. When a mature bole of 3 m is required a clean set over 3 to 6 m long has to be produced. As such long clean sets are difficult to grow, rooted plants are to be preferred.

Other tree willows are raised in the same way, but as none is cultivated to produce bat timber free of defects, the techniques are less demanding. Only weeping willows require specialist treatment. Most willows may be expected to have a rooting percentage of 90 to 100 and, as with poplar, the numbers of cuttings that root are not significantly influenced by application of a root promoting growth substance.

London plane. This tree, assumed to be a hybrid between *Platanus occidentalis* and *P. orientalis*, the American and Oriental (European) planes, is traditionally raised from hardwood cuttings in the open nursery. Vegetatively raised stocks may also be obtained by layering but the technique is not common. Fertile seed is produced and mixed seedling populations may be raised. But to retain desirable bark, foliage, fruit and stem shape characteristics propagation must be asexual.

Cuttings are taken from well-ripened one-year old wood and are usually 17 to 23 cm long. Trials suggest that cuttings with only two or three buds from rapidly grown shoots do not root well and should be discarded. Cuttings with at least four buds should be chosen if possible. Terminal growth, which is too thin, should be avoided altogether. Stools cut back annually produce a sustained yield of suitable material, though pollarded trees pruned every year are a useful source of cuttings. But cuttings taken from trees more than about 20 years old appear to root less readily. The cut at the top of the cutting should be just above a bud and the basal cut just below a bud.

To ensure satisfactory results cuttings should be inserted shortly after leaf-fall and not later than early November. Insertion should be vertical and so long as the bark at the base is not stripped the cuttings may be pushed in. If damage is likely to occur the cuttings should be rested against the vertical side of a narrow V-shaped trench, firming and leveling after the trench has been filled in. Not more than about 25 mm of the cutting should be above the soil surface. The spacing may be as close as 10 cm within rows and 25 cm between rows.

One month after insertion or as soon as it is reasonably dry the soil should be refirmed. In early spring the soil should again be refirmed and any cuttings lifted by frost pushed in to their original depth. At time of leafing and until first growth has hardened off in late July beds should be shaded with lath shelters placed about 45 cm above the soil surface.

Heights vary considerably in the first year from a few centimetres to 60 to 70 cm, but very few plants are vigorous enough for planting-out, and the rooted cuttings should be lifted and transplanted for one year. The rooting percentage is seldom higher than 70 and in some years it is likely to be a good deal less than this. Trials to improve the rooting of London plane are briefly discussed below.

PROPAGATION INDOORS

The range of tree species and the number of plants raised vegetatively in houses and other structures for forestry is comparatively insignificant. Apart from specialist production of the main species for various studies, only Leyland cypress and two or three elms, which cannot be raised from seed, are presently being grown for planting out. Some propagation is still undertaken in cold frames equipped with soil warming and overhead mist watering but there is an increasing trend towards propagation on benches in plastic and glass houses, as these provide greater opportunities for environmental control.

Elm. Though there is a large and varied elm population in this country, the only species that regularly produces fertile seed and can be raised in large numbers by conventional forest nursery techniques is Wych elm, *Ulmus glabra*. Smooth-leaved elm, *U. carpinifolia*, together with its varieties, also produces fertile seed, but production is seldom large and supplies are usually difficult to come by, so vegetative propagation is necessary. Fortunately most elms are able to reproduce themselves from sucker growth, and in both hedgerows and woodlands, continuity of stocking is obtained by this type of regeneration. Suckers may also be lifted and lined out in the nursery for a year or two to promote vigorous shoot and root growth, and then planted out at another site. Planting stock of English elm, *U. procera*, and of Dutch elm, *U. hollandica* var *hollandica*, is sometimes raised in this way. But the method is unreliable, since many apparently vigorous suckers lack adequate root development and fail after being detached from the parent tree; for a sustained program of plant production improved techniques are required.

The breeding and selection of elms for resistance to elm disease in the Netherlands, and trials of elms of potential forest value in this country have led to greatly increased work on vegetative propagation. So far, the rooting of softwood cuttings in mist during the growing season has proved to be the best method and the rooting of hardwood cuttings in the open nursery the worst, but no method has yet been adopted or tested for large scale plant production.

Softwood cuttings root three to five weeks after insertion in a heated rooting medium provided wilting is prevented by copious watering; two or three separate insertions may be made during the growing season. Experimentation has shown that cuttings should be about 15 cm long and, after removal of lower leaves and treatment with a growth substance, inserted to a depth of 5 to 6 cm. A rooting medium of 50% sphagnum peat, 25% coarse sand and 25% horticultural grit has given satisfactory service in trials but recent work suggests that the sand may be eliminated. Soil temperatures of 21° to 24° C appear to be required to promote early callus development and rooting, but cutting survival depends on adequate watering, especially during the critical period immediately after insertion when recovery from handling is often in the balance. Shading and ventilation to prevent air temperatures rising above about 20° C are also necessary.

Though cuttings may be taken from trimmed hedges and standing trees, stock plants established in the nursery close to the propagating beds ensure minimal handling and delay between collection and insertion. Elm cuttings travel reasonably well for short periods in plastic bags, but storage in a heated room quickly leads to wilting. The cuttings must be prepared in a cool shed. Cuttings may be stored in a cold chamber at + 3° C for some days provided they are lightly packed in plastic bags. The effects of prolonged storage at this temperature have not been properly tested.

The application of indolyl-butyric acid (IBA) dust in talc to the cutting base immediately prior to insertion improves root initiation. Recent trials suggest that treatment with napthylacetic acid (NAA) dust in talc may be even more beneficial, and work to test the effects of different concentrations of this chemical has been started. Treatment with IBA in solution, using a wide range of solvents, has not so far improved root initiation in elm cuttings. The effects, if any, of application of a fungicide with the growth substance are being examined.

The rooting percentage of softwood elm cuttings varies considerably and sharp fluctuations are common from one cultivar to another. The success rate is usually greater at the beginning of the summer than at the end. Commelin elm, *U. hollandica* cv Commelin, a product of Dutch breeding with high resistance to Elm disease, and currently being recommended for general planting, is among the easiest to raise, while English elm, *U. procera*, the most common British elm, is one of the most difficult. A rooting percentage of 60 to 80 may be expected with the easiest rooting clones.

After weaning, rooted softwood cuttings may be lined out in the open nursery, shading and watering as required in the first few days to prevent wilting. By the end of the season the plants raised from the earliest inserted cuttings should be 40 cm tall, and those grown from the last insertions 20 cm tall. In contrast, hardwood cuttings of elm are difficult to root and even in a heated medium the rooting percentage is usually low. Applications of a growth substance in dust form have not produced significant benefits, though the use of solutions may be advantageous and different formulations of IBA and NAA are presently being tested.

Poplar. Species and hybrids of poplar that are difficult to propagate from hardwood cuttings in the open nursery may be readily rooted in mist units equipped with bottom heat. Cuttings from the apical parts of vigorous stock plants root within three weeks of insertion and weaning can usually start after four or five weeks. After transference to the open nursery, when watering and shading may be needed for a short while, the rooted cuttings may reach heights in excess of 60 cm before seasonal growth terminates.

The cultural techniques for poplar are similar to those described for elm, though root promoting growth substances tend to be more beneficial in terms of both speed of rooting and number of cuttings rooted, and wilting is less likely prior to and after insertion. The aspens and the *Leucoides* poplars root least readily from softwood cuttings, while the black (*Aigeiros*) and balsam (*Tacamahaca*) poplars are easiest to root.

London plane (*Platanus acerifolia*). Experiments are currently being conducted to see if London plane can be raised in commercial quantities from softwood cuttings. There is no experience of the treatments required to initiate root growth, and during the preliminary phases of the study the tests on London plane have been similar to those conducted on elm. Early trials show that although cuttings quickly wilt after removal from the stock plants, recovery is rapid in mist, and the presence of large leaves is not a hindrance. Treating cuttings with growth substances in solution has not, so far, greatly improved rooting, but application of NAA dust in talc to the cutting base has been beneficial. Defoliation prior to insertion causes a decrease in the number of cuttings rooted.

Hairs which are easily detached from the leaf under-surface during cutting collection and preparation have proved to be a serious problem. They affect workers in much the same way as pollen and other irritants, and cause symptoms of hay fever.

The rooting of hardwood cuttings of London plane in heated beds is also being examined; there is already evidence that material prepared in March and inserted after treatment with a growth substance in a medium maintained at a temperature of 21° to 24° C may produce roots after only three weeks. Notably after dipping in an IBA solution, roots are formed on the lower 4 cm of the cuttings, in contrast to the formation of roots on elm only at the base of the cutting. Different types of cutting and different formulations of IBA and NAA are being compared.

Both the softwood and hardwood cutting techniques with London plane are likely to lead to higher rooting percentages than are obtained with conventional methods in the open nursery and further trials in heated beds seem justified. But the handling of rooted cuttings of London plane raised indoors has not been studied and problems may arise as more intensive production methods are tried. Experience with elm suggests that losses due to death of roots may occur on lining out

Leyland cypress. Overhead misting with hard water is believed to be responsible for depressed rooting and survival figures in nurseries in eastern and southern England. Recent trials in Forestry Commission nurseries in these regions have shown that when cuttings in heated beds are watered by hand with rain water, higher rooting percentages are obtained than when watering is done only from mains supplies with a high lime content. It is not clear from the work if the benefits are partly related to reduced irrigation rates due to hand watering, but this seems likely. There is evidence to suggest, however, that automatic mist, whether from the mains supply or not, need only be resorted to in prolonged spells of clear, warm weather. The effects of the accumulation of sodium and calcium ions in the rooting media are being studied.

Variations in root initiation among different clones are being examined in the hope of improving the production of little used, though apparently desirable, clones. It seems likely that clones which are not widely grown may have been overlooked only because of their poor rooting and survival rates in cutting and transplant beds. Attempts are being made to improve the survival of these by using better propagation techniques. Clone 'Leighton Hall No. 11', a vigorous type suitable for hedging, is receiving special attention. The commonly grown, easily rooted, clone is 'Haggerston No. 2'.

The relationship between soil temperature and root initiation is also being studied. So far, it has been seen that by increasing soil temperature from the range 21° — 24° C to 28° — 30° C, improvements have been obtained in rooting percentage, while reductions in temperature to 15° — 19° C have been found to depress the rooting percentage. The implication of this information, especially in commercial nurseries, is being reviewed. Speed of rooting is already known to be influenced by soil temperature, but there is less experience of the effects of temperature on cutting survival and plant production.

PROPAGATION FOR SPECIALIST USE

The Forestry Commission tree improvement program depends on the successful vegetative propagation of selected plus trees chosen for future seed orchards. The methods vary from species to species, but in practice Western red cedar, (*Thuja plicata*), Lawson cypress (*Chamaecyparis lawsoniana*), Western hemlock (*Tsuga heterophylla*) and Sitka and Norway spruce (*Picea sitchensis* and *P. abies*) are raised from cuttings, while Scots pine (*Pinus sylvestris*), Douglas-fir (*Pseudotsuga menziesii*), and European and Japanese larch (*Larix decidua, L. leptolepis*) are raised by grafting. The different techniques required have been discussed in recent forestry literature.

RECENT DEVELOPMENTS IN COLD STORAGE AT TILHILL

HENRY JACKSON

Tilhill Forestry (Nurseries) Limited
Greenhills, Tilford, Farnham, Surrey
England

The cold stores at Tilhill are of Danish design, that is an indirect cooled house, or jacket cooled. The stores, one of 10,000 cubic feet capacity and one of 22,000 cubic feet, were both constructed by our own labor working to plans sent from Denmark. The advantage in having such facilities, as many members know, is that nursery stock can be stored bare-root for many months, which means that a greater bulk of stock can be stored; also it is much easier to control humidity than in a direct-cooled house.

Mr. Dufresne, who is a refrigeration expert from Denmark, will be giving a separate paper on technical questions on jacket cooled stores, and I am sure he will answer any questions that members put to him. The first question to which we wanted an answer was, "How long could stock be stored and still remain viable?" For our trial we used 2-year seedlings *Picea abies (P. excelsa)*; these were tied in bundles, bare-root, and put horizontally in slotted crates. Seedlings were put in the store in December, 1968. We transplanted 200,000 of the stock on 25th August, 1969 and achieved a 90% take. The plants were not damaged by autumn frost and made 3 to 5 inches of growth.

As it was too expensive to run our large stores, the balance of the stock, approximately 20,000, was transferred to a mobile refrigerated

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Ed 's note. Mr. Jackson then showed slides of his cold store, his methods of stacking and of transplanted cold stored plants including *Larix europea, Fagus sylvatica, Acer platanoides* and *Picea abies (P. excelsa).*

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Storage was another question about which we needed to know more. We had been storing conifers in racks in an upright position, as this was recognized practice. The drawback to this method is that a lot of storage space is lost. As we had large numbers of *Picea sitchensis* we decided to use crates to store the plants. The bare-root plants were tied in bundles of 50 and stacked horizontally in the crates. Size of crates was 2 ft. x 2 ft. x 3 ft. 10 inches, in order to fit our lorries. The crates were stacked 5 high on 5 in. floor pallets so as to permit a hand stacker to handle the crates. The stacks of crates were three deep with a gangway wide enough to handle the stacker. The plants were stored quite safely for five months. Using this method plants can be brought out of the store on the stacker 2 to 3 crates high and taken straight to the lorries where they are transferred to rollers fitted to bed of lorry. The crates are then pushed to front of the lorry and stacked.

We have had no major trouble with stock stored in this manner. It is important to ensure that stock is brought into the store with the foliage as dry as possible, and that plants with damage caused by lifting should be watched as mould can form on damaged parts. Thiram dust is blown through the store by hand blower to control mould.

I have with me several plants which have been in cold store for up to eight months for members to see.

GENERAL INFORMATION ON COLD STORAGE OF NURSERY PLANTS IN JACKET-COOLED STORES

P. DUFRESNE

Ove Hinrichsen,

6100 Haderslev, Denmark

In 1956 the first jacket-cooled store room for nursery plants was erected for the nursery exporting company, Danplanex, of Rødekro, Denmark, and today cold storage of nursery plants has become indispensable for the modern European nurseries. During the past lorry, also jacket cooled. These plants were then held until the main stores were restarted in November and were then transferred. We transplanted this stock in January, 1970 and achieved a 70% take. We then potted 25 of the remaining plants on the 19th May, 1970 and of these 24 have survived. I have a sample of these plants for members to see, also a sample of the original plants as first stored in December, 1968. The temperature of the store was held at 32° F. and humidity at 94 to 96%. Although this trial only covered one species we were quite pleased with the results. Obviously much more information is needed on other species before any large storage of plants can be carried out.

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Before the jacket cooling system was developed, some very primitive experiments were made in storing plants in normal direct-cooled cold stores, but to avoid drying up the plants it was necessary to pack the plants into airtight bags or boxes because of the very low humidity and the air circulation in these stores. The demand today is storing lifted (and well-ripened) plants from autumn until the normal (or extended) time of next year's planting or lining out with complete preservation of growing abilities without the necessity of wrapping up the plants.

A suitable low temperature (0° C or 32° F) is required to keep the plants dormant without any risk of frost damage to the fine root fibers, and a suitable high relative humidity (95 — 98%) causes the plants not to dry up, and it keeps the loss of weight down to a minimum. To fulfil these demands a completely uniform temperature all over the cold store has to be established, the relative humidity must constantly be kept close to the saturation point, and at the same time there must be no movement in the room air inside the store.

The cooling down of a room is normally achieved by mounting a cooling coil in the insulated room in connection with a compressor (condensing) unit outside the room, which evaporates and condenses respectively, one in the pipe system circulating refrigerant. The bigger the cooling surface of the coil the less the difference becomes between the coil temperature and the room temperature, and the less the air is dehydrated. With traditional direct cooling it is difficult to bring this temperature difference below 6° C (10° F); this is to say that the air that leaves the cooling coil is —6° C (22° F) when the room air is 0° C (32° F). The cold air must be prevented from blowing directly on the plants, therefore it is necessary to establish a safety zone with no plants, which means a heavy loss of storage room. To avoid this low temperature airstream in the store, jacket-cooling is preferred.

A jacket-cooled store is an insulated room with a built-in box made of asbestos plates, which have a high heat transmission. The cold air from the coil circulates between the asbestos jacket and the insulated walls, ceiling and floor. This airstream must not be so cold that condense drops or ice is formed on the inside of the jacket. Therefore a constant air circulation is established over the jacket and, in the mixing chamber, the refrigeration system provides for the adding of a suitable quantity of cooled air to the constantly circulating air, by which the temperature difference between the jacket surface and the room air is decreased to about 1½° C (3° F), and internal condensation ice is avoided. The refrigeration unit is automatically working and does not need daily inspection.

At the end of the sorting time and when the quantity of stored plants is reduced, it may be necessary to add moisture to the air. At a temperature of about the freezing point very little added water is enough to saturate the air. The most simple way to do this is to sprinkle water on the floor (never on the plants!). The best indication for need of sprinkling is when the concrete floor becomes white dry.

When the plants are to be stored it is very important that they are well ripened and that growth has ceased; deciduous plants should have lost their leaves. If the plants are stored in the early spring they need to be brought in before they start growing. A healthy plant is not damaged from direct cooling, but an unripened or bad plant will not become any better from cold storage.

The plants must be surface dry when they are brought in as wet plants might contribute to the possibility of fungal attack.

When the plants are being brought in the room temperature must fall at an even rate (as in nature!). Once 0° C (32° F) is achieved this temperature is maintained until the plants are taken out again.

It is possible to grade, cut back and pack during the storage time, which is important to nurseries where lifting machines are used and great numbers of plants accumulate in a short time. The consignment of plants for bigger orders can be packed and kept in the cold store until dispatch without any risk of disease.

When the cold store is empty it should be thoroughly cleaned out and ventilated, including the shelves, pallets, boxes and anything else used in the store.

The use of a cold store is of great importance to practically all nurseries. It is possible to extend the grafting season until there is a convenient time for it, because the cutting material can be held back in the cold store. Seedlings can be held back to be lined out when the conditions are good. Orders can be sent off when the customers (and the plants) are ready. Bigger orders can be collected in the cold store for later dispatch. In other words, the work load can be spread more evenly over the year, thus reducing wasted labor to a minimum.

When the cold store is to be erected, it is necessary to establish a close co-operation between the architect, the building contractors and the supplier of the cooling system, because the cooling unit has to be exactly proportioned to the building.

THIRD SESSION

VEGETATIVE PROPAGATION OF TEA

L. BATES

African Highlands Produce Company
Kericho, Kenya

Methods of vegetatively propagating tea

Camellia sinensis X *assamica* vars. differ in all tea producing countries of the world, each of which has developed techniques which are influenced by local conditions which may not occur elsewhere. Individual concerns within these countries have further developed their nursery techniques to suit their particular requirements. The following is a brief outline of one such method which was developed from the general recommendations of the Tea Research Institute of East Africa.

Nursery beds. These consist of 150 gauge polythene sleeves, stapled or spot sealed at the base and perforated in the lower half to assist drainage, stacked upright in beds of 2 to 4000, 10 cm lay-flat tubing being used for plants required for new extensions and 15 cm lay-flat tubing for the larger plants needed for infilling vacancies in mature fields. Sleeve length is 25 cm in the former case and 30 cm in the latter. Over each bed a tent or hoop shaped framework is constructed on which polythene sheeting is stretched following planting of the cuttings. The whole nursery is covered with a high shade of bracken supported by poles, wire stretchers and chicken wire.

Rooting medium. The sleeves are filled to approximately 7 cm from the top with forest soil of high humic content to which is added 600g of single superphosphate per cubic metre of soil. The sleeves are then topped up with sterile, grit free subsoil. Both the forest soil and the subsoil are checked to confirm an acidity of pH 4.8 to 5.3.

Cuttings. Internodal cuttings with a single whole leaf are taken from the regrowth made by bushes pruned about six months previously. Material is removed from the mother bush when soft and green and during a period of vigorous growth. Cuttings are 3.5 cm in length below the node, being trimmed off immediately above the node. Following preparation, the cuttings are immersed in water for 30 minutes before being planted in the sleeves. It is standard practice to add a copper fungicide to this water as a prophylactic against damping-off (*Pythium* sp.) The cuttings are pushed into the sleeves at a slight angle from the vertical so that the leaf does not touch the soil and the node is immediately above soil level. Following a final watering the beds are covered with polythene sheeting which is sealed around the sides with earth from the paths between beds. Shade density is checked by taking temperatures at soil level in sample beds daily, at noon, for a week when they should average 27° C. Under normal conditions the beds may then be left for about three months by which time roots averaging 7 cm in length will have formed and the polythene sheeting can be removed. This is done by opening the ends of the beds for two hours per day in the early morning for a week, followed by a complete removal for two hours per day for a further week after which the polythene is removed completely. Polythene sheeting is used only once. Attempts to use it for a second time have led to poor results possibly due to the rapid oxidation of polythene in the intense solar radiation at high altitudes on the Equator.

As soon as the polythene is removed the young plants are fed with a weekly application of NPK 25 / 5 / 5 at the rate of 120g in 120 litres of water per 30 metres of bed.

Shade. Once the plants have made about 20 cm of top growth the shade is gradually thinned over a period of two months and the plants are then hardened off for a further period of two months before being planted out in the field. The whole operation takes from 9 to 15 months depending upon the size of plant required.

Conclusion. Bearing in mind the lack of skilled nurserymen this simple method produces cheap and acceptable results in the range of 80 to 90% utilizable plants. The cuttings are handled only once and the presence of fertile soil in the lower part of the sleeve enables the plants to be grown on without the need for transplanting or other operations requiring even a modicum of skill. The nursery manager would need to inspect the beds once per week for aphis or damping-off during the time the plants are under polythene and check that the watering and shade are correct once the plants lose the protection of the polythene. The comparatively expensive costs of transporting plants to the field can be offset to a certain extent by siting nurseries as close to the area of development as possible.

THE VEGETATIVE PROPAGATION OF CORYLUS

P.D.A. McMILLAN BROWSE

Hadlow College

Nr. Tonbridge, Kent

England

This subject was chosen for a short talk to this meeting because it is an extremely good example of a group of plants which, although fairly easily propagated by traditional means, can nowadays be produced more intensively by sophisticated, modern techniques.

Layering. This system of propagation is a particularly useful method of propagating small numbers of plants but it is extensive in its use of land and stock material. The parent plants should be planted in noon, for a week when they should average 27° C. Under normal conditions the beds may then be left for about three months by which time roots averaging 7 cm in length will have formed and the polythene sheeting can be removed. This is done by opening the ends of the beds for two hours per day in the early morning for a week, followed by a complete removal for two hours per day for a further week after which the polythene is removed completely. Polythene sheeting is used only once. Attempts to use it for a second time have led to poor results possibly due to the rapid oxidation of polythene in the intense solar radiation at high altitudes on the Equator.

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Layering. This system of propagation is a particularly useful method of propagating small numbers of plants but it is extensive in its use of land and stock material. The parent plants should be planted in well-prepared land at a spacing of at least 2 m square, and allowed one year to establish. The stock is then cut down to a low crown or stool so that in the following year vigorous, strong growing shoots are produced; these will, depending on the species in question, be about 1 m in length. This sort of material has a number of advantages in that the crown of the plant is low, the shoots are flexible and the shoots have a high capacity to root. Simple layering is carried out in spring just prior to bud break; the only important treatment is to ensure that the stem is bent as nearly to a right angle as possible in order to restrict the stem and encourage root production. Layer well away from the stock plant so that the layer lead is low, thus forcing new shoots to develop from the stool.

Under these circumstances well-rooted layer can be lifted in the autumn, the layer leads are trimmed back to the crown and the following spring the process is repeated, using the new shoots which arose from the crown in the previous year.

Grafting. Although this system of production is a reasonably intensive system, it has the disadvantage of producing plants which are not on their own roots and which are liable to sucker. One year old seedlings of *Corylus avellana* are used as rootstocks. These are brought into a warm glasshouse and bedded, bare root, into peat during early March and the tap root is stopped to encourage laterals; once root activity has commenced they are grafted with 3 or 4 bus scions of the previous season's material. Use a based whip graft, i.e. head the stock back into the hypocotyl and use a graft about 3 cm in length.

Tie in with rubber strip or suitable material and bed into a peat and grit compost in a grafting case, maintained at 60 to 70° F. Treat regularly with 5% DDT dust against weevils and with a Captan solution to prevent decay due to *Botrytis*. The union develops quickly and as soon as it is well-callused the ties can be removed and the case gradually aired to harden the shoots off. After 5 to 6 weeks the new plants can be bedded out into a frame for the ensuing growing season.

Division. This type of production is a very extensive system requiring much stock, usually a certain proportion of saleable stock is used to maintain enough liners. The process can be carried out in the autumn or spring and is usually limited to those types developing a thicket-like habit, e.g. *C. maxima* 'Purpurea'.

Summer cuttings. All this group of plants (*Corylus spp*) will regenerate from softish cuttings inserted under mist. Very soft cuttings do not seem to survive well and it is advisable to wait until June when the tip growth is slower and thus somewhat "harder". *C. maxima* types, however, seem to provide problems because of the nature of the buds which are open (i.e. partially developed) and hairy, causing them to deteriorate relatively easily. *C. avellana* types do not present problems as the buds are tight and waxy. Winter survival is the chief problem as, unless the rooted cuttings can be flushed into growth to produce an integrated new plant, losses can be severe.

Hardwood cuttings. Perhaps the most valuable contribution to the propagation of this group of plants has come from Howard's work at East Malling (1, 2) and it is merely a question of adapting his published report on Hazel propagation from hardwoods.

The most significant feature of this technique is the production of stem material of high capacity to regenerate, which is obtained by growing 'stooled'' stock plants on a hedge system — thus providing the vigorous growth of correct nutritional status. As the technique, as far as nurserymen are concerned, is new and requires some attention, a start should be made by using only the "basal" cuttings, i.e. that piece including the basal swelling of the stem, as this has the highest capacity to root. Cuttings should be made some 15 cm in length and the base dipped in a 1% solution of IBA in alcohol; this is allowed to dry on and then the cuttings are placed in a "Garner" bin with a bottom heat of 70° F. The operation is conducted at the end of February and the cuttings will require 4 to 5 weeks heat treatment; the heat is then reduced and as soon as conditions are reasonable, the cuttings are bedded into a cold frame. This is an exceedingly easy technique as *Corylus* appear to be very tolerant of "poor" conditions in the bin as they will withstand the wetter and cooler conditions which are often associated with inexperienced management.

The following plants will respond to this technique:

C. *avellana* 'Aurea'
C. *a*. 'Contorta'
C. *a*. 'Heterophylla' ('Laciniata')
C. *chinensis*
C. *colurna*
C. *axima*

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PLANT PROPAGATION USING IN VITRO CULTURE TECHNIQUES

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INTRODUCTION

The emphasis of this paper is on the production of plants under aseptic conditions. As the principles of *in vitro* culture have been revieved by Murashige (7) in an earlier volume of the IPPS Proceedings and as technological aspects have recently been discussed by Marston (4, 5), this introduction merely serves as a reminder of some of the more important points.

Propagation in flasks or test-tubes entails the growing of a small portion of a plant, the explant, on or in an artificial nutrient medium, generally composed of mineral salts, vitamins, growth substances and sugars which have beeen dissolved in distilled water. Unless, however, precautions are taken to ensure that everything is sterilised, bacteria and fungi flourish and multiply so fast under these conditions that they swamp and kill the explants. To avoid this, glass containers, with the appropriate volume of medium measured into them, are sterilized in an autoclave or, on a small scale, in a pressure cooker and plant material is surface sterilized using a suitable disinfectant. Explants are then removed and placed in the sterilized flasks or test-tubes which are opened in clean air in a special transfer room, where only filtered air enters, or under a transfer hood, or in a cabinet with an open front where filtered air flows over the bench towards the operator. The glass vessels must then be quickly closed using a sterilized stopper or cover to prevent the entry of unwanted organisms.

Actively growing plant material needs air — there are various ways of supplying this. The explant may be placed on the medium which has been made semisolid by adding agar gel, or just over it by standing it on a bridge made of folded filter paper whose legs stand in the liquid medium. In these instances the apparatus is, of course, stationary. Alternatively, the explant may be put in the liquid medium and aeration provided by attaching the containers to revolving wheels or by standing them on a platform of a specially designed shaker. According to requirements, light or darkness is given and generally a temperature of about 25° C is maintained.

Seeds and excised embryos. About fifty years ago, Knudson (3) developed a method for the germination of seeds and growth of young seedlings of orchids on a nutrient medium. Before then, the production of orchids from seed often resulted in failure as their embryos are not fully developed and there are virtually no food reserves. Today, excised embryos of other species may be cultured by plant breeders in cases where seeds may not develop to maturity as, for example, when crossing certain species of *Lilium* or making generic hybrids in orchids.

Small excised portions of plant material. Plant breeders may also find it helpful to use an *in vitro* culture technique as one step in a series of operations. For instance, when breeding cauliflowers one particular selected plant would only yield a limited amount of seed, but if it could be bulked up by vegetative means the amount of seed would be increased. Pow (8) of the National Vegetable Research Station, Wellesbourne has described how small pieces of curd, 3 to 7 mm in diameter, may be cultured to produce plants which when transferred to pots and later to open ground grow normally to produce curds and then seed. Similarly, the small buds which are exposed when leaves of a Brussels sprout are removed, one by one, may be excised and grown *in vitro* to give plantlets.

Small slices cut from stems of asparagus spears may also result in plants, although asparagus is much more difficult and tedious to culture than cauliflower or Brussels sprouts. Nevertheless, Takatori *et al.* (12) have developed a technique which may be used to bulk up an outstanding plant and is, in fact, being used at The John Innes Institution.

At the 18th International Horticultural Congress in Israel in 1970, M. Ziv and A.H. Halevy presented a paper on the production of corms from thin slices of flowering stems of *Gladiolus* and, later, showed flasks full of leaves and corms to those participants who visited the Faculty of Agriculture of the Hebrew University at Rehovot.

Meristem culture. Mention must be made of the large number of plants that have been cleaned up from virus diseases by removing, and culturing, the apical tip, which is usually less than 0.5 mm in height. In this way virus-tested chrysanthemums, carnations, strawberries, etc. have been obtained. It is due to Morel who was working with a *Cymbidium* cultivar infected with a mosaic virus disease that we have the present so-called method of "meristem culture of orchids". Morel (6) noticed that excised shoot tips of Cymbidium cultured *in vitro* did not continue to elongate and behave rather like a miniature cutting, but developed into a green spherule on which green protuberances then appeared. The exciting part of this discovery was that he was able to obtain from these "protocorms" either more and more new protocorms or plantlets, according to the conditions he imposed.

Since then, propagators have speculated on the future of plant propagation and have wondered what other plants might respond. Hackett (1) and Hackett and Anderson (2) have been successful, in a somewhat similar way, with carnations and Walkey and Woolfitt (13) have developed the technique for *Nicotiana rustica* L.

Walkey and Woolfitt (14) have recently reported a somewhat different technique for the mass production of cauliflowers. Small pieces of curd are placed in a nutrient medium and are then broken up into barely visible specks by vigorously shaking. When shaking ceases plantlets develop.

Cell suspensions. Steward's work at Cornell with aseptic cultures is well-known. For example, with carrots small pieces of tissue are bored from the edible root and cultured in specially designed flasks attached to wheels which rotate about a horizontal axis. Cells slough off to give a suspension of free cells, consisting of individual cells and clumps of cells. Under certain defined conditions these become organized again, but not to form the same tissue as before. Instead, "embryoids" form $\frac{1}{M}$ these behave rather like seeds, each producing a shoot and root and developing into a plant. Steward (9) has recently discussed the implications of this technique and the refinements necessary for extended use in crop production.

Wilmar and Hellendoorn (15) have described some fundamental work with asparagus (*Asparagus officinalis* L.) and now great interest is being shown in possibly extending this technique to other species.

Pollen cultures. During the last few months, there have been reports in the press headed "pollen grain plants" or "one parent plants". Indeed, a recent issue of the New Scientist carried an article (11) which discussed the significance of haploid plants. John Innes Institution also had an exhibit, showing how progeny may be obtained from pollen, at Chelsea Flower Show in May, 1970. So far, success has been reported with tobacco, a species of *Datura*, and with rice. Sunderland (10, 11) suggests that traditional plant breeding might, one day, be transformed and lead to improved varieties of crop and horticultural plants. The technique involves the removal of immature anthers at a precise stage of development and culturing these on a defined medium. Eventually, the anthers burst open to release not pollen but many multicellular plants. They continue to grow as if they were seedlings but, having developed from pollen, carry only half the genetical information compared with the parent plants, that is they have only half the number of chromosomes. Plants so raised are sterile and propagation must be by vegetative means.

If a chromosome-doubling agent, such as the drug colchicine, is applied to a germinating seed the chromosome number may be doubled. Current work (10, 11) is establishing that if colchicine is added to the nutrient medium and the anthers left on this for a short time the plantlets ultimately produced may be diploid. Since in this case the diploid is the result of doubling a haploid, it must necessarily be homozygous, even if the original plant were heterozygous. The important implication here is that such plants will be true breeding and may be multiplied by seed.

This method is likely to be of outstanding importance if it is successfully developed for plants which are difficult to propagate vegetatively, such as the oil, coconut and date palms. If the technique became successful for a wide range of plants the present position regarding vegetative propagation might radically change.

The future. Before we can look too far into the future the question of variation must be determined. Research workers with tissue cultures are well aware that the number of chromosomes of cells in culture may vary but if an explant develops directly into one plant, this should be a replica of the original. As far as is known, "meristem culture" of orchids reproduce the individual, but we must proceed with caution when many plants are produced following the production of callus and cell suspensions. Where there is stability, propagation using *in vitro* culture techniques offers the possibility of easy shipment from one country to another and storage of cultures in the laboratory while bulking up to produce large numbers of the most desirable cultivars.

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FOURTH SESSION

PRACTICAL EXPERIENCES WITH POLYTHENE STRUCTURES

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The type of house I intend to relate my address to is based on the prototype Film Plastic Tunnel designed by the Lee Valley Experimental Horticultural Station, Hoddesdon, Hertfordshire. The practical aspects are based on my own experiences with five such houses, each measuring 60 feet long by 14 feet wide erected in September, 1969, and used for the production of ericaceous nursery stock.

It is worth noting at this stage the reasons for erecting this type of house in the nursery. We were faced with a shortage of covered space for growing nursery stock. To this end a cheap form of cover was needed that could be constructed with nursery labour. It had also to be of a semi-permanent nature so that if plans changed it could be moved to another site. Bearing these items in mind it was decided to try the type of house already mentioned.

At the time of erection of the houses, little work had been done with nursery stock grown in this type of house. The basic cultural techniques had to be adapted from those already laid down for glasshouse crops grown at the Lee Valley Experimental Horticultural Station.

The basic structure of the house is a metal hoop formed out of ½ inch bore medium barrel galvanized tubing to British Standard 1387. The entrances in either end are constructed of timber, and the whole structure covered with 500 gauge ultra violet light inhibited polythene sheet.

For those interested in full details of construction and costs, Leaflet No. 17 produced by the Lee Valley Experimental Horticultural Station should be consulted. Another leaflet worth noting is the Growers Technical Bulletin No. 1 produced by British Visqueen Limited, Stevenage, Hertfordshire. This provides comprehensive details of polythene and its properties, together with articles on ventilation, heating and plastic houses overseas.

Erection. Some preliminary site work was necessary, and this consisted of levelling across the width of the house and producing a constant fall down the length. The houses were sited running parallel with one another, with a gap of 3 feet between each individual house. This was the minimum distance possible, as room had to be given for trenching when the polythene was anchored in the soil. Having erected the metal framework the whole structure was tensioned up with the side and ridge straining wires, diagonal struts in the ends giving further rigidity. Prior to covering with polythene it is essential that all sharp metal edges be covered to prevent snagging the polythene.

To produce a taut covering to the house the following items should be carefully adhered to so as to obtain a good result. The air temperature should be at least 65° F., thus making certain that the polythene is expanded and pliable and will not sag once in position. The polythene should be secured as tightly as possible as the structure is then the most stable in wind and the film is not excessively worn by flapping about on the framework. To date the houses have been subjected to several severe periods of high wind and have suffered no damage.

Where a block of several houses are erected it is well worthwhile looking at the problem of rain water disposal from the immediate site, especially on a sloping area. It was found that quite a lot of soil was washed away between our houses during prolonged spells of heavy rain and loosened the polythene sheeting.

Practical techniques. Four of the five houses have been used for growing container plants. To provide a clean and well drained base on which to stand pots a layer of ¼ inch gravel has been spread to a depth of 2 inches. A 2 foot wide path runs down the length of the house. With the curvature of the house coming very close to ground level it has been necessary to leave a gap of 6 inches between the side of the house and the first row of pots.

It was discovered that local drying out occured in the areas around the entrances to the houses. This was especially acute when only partial ventilation was in operation, with the entrance flaps only a third open, and the house containing material in 3 and 4 inch diameter pots.

To streamline the operation of potting, a portable potting bench is connected to one end of the house. This consists of a tractor drawn trailer with a light wooden frame covered by polythene, to provide a weatherproof area in which to work.

With an estimated life of two years the polythene covering will be removed during the second summer. This will enable container stock to harden off and be sold directly from the site of the house, thereby eliminating the necessity to move stock to a separate standing-out area.

One of the disadvantages often connected with polythene is the question of condensation. This did prove troublesome during the winter months as all our plants were being grown in soilless compost of 3 parts peat to 2 parts sand. Many plants suffered, especially the dwarf rhododendrons as they remained in damp cold conditions. This was further aggravated by the fact that routine liquid feeding had started before the outside air temperature had risen appreciably during February and March. It is hoped to overcome this problem by incorporating grit with the compost to enable it to drain more freely and use a base fertiliser with a longer period of nutrient release.

Before decrying the fact of condensation on the inside of the house one should remember that a certain amount is beneficial during cold weather as it helps to slow down the heat loss of the house through the polythene.

During periods of bright sunlight in the spring it was found beneficial to apply shading to prevent leaf scorch on young stock. The main subjects affected were hybrid rhododendrons that had started producing the new season's growth.

The fifth house erected was used to force deciduous azaleas of Knap Hill and Exbury types. Stock plants 2 to 2½ feet high were housed in January, and were planted directly into the soil which had previously been cultivated and dressed with peat. To provide frost protection in the house a small paraffin heater was used. This produced 6000 B.T.U. per hour and enabled the frost to be kept out down to 27° F. Flower buds were rubbed out as they appeared. Vegetative growth started to appear during the first week of April, thus advancing our propagation programme by nearly six weeks against stock plants growing outside. A far more even type and size of cutting was produced without too much elongation of the internodes. The maximum number of flushes of growth was four, although some variability among varieties was apparent.

The experiences of the past months have proved very fruitful, and it is envisaged that the number of houses will be increased this year. To provide a better method of watering and liquid feeding other than overhead spray lines several of the houses will be adapted to a system of capillary sand beds. Propagating facilities are to be increased in the nursery and a larger house to our own specification is to be built. This will contain bottom heated mist beds and closed cases for the propagation of deciduous and evergreen azaleas and rhododendrons.

OVERWINTERING OF DECIDUOUS AZALEA CUTTINGS

PETER WELLS

Charles Townsend Limited

Fordham, Cambs.

England

The advent of the modern aids to propagation, i.e. mist units, bottom heat and rooting hormones made the task of rooting azalea cuttings fairly straightforward, but this was only half the story; the stumbling block to 100% success was getting the rooted cutting through during February and March. It is hoped to overcome this problem by incorporating grit with the compost to enable it to drain more freely and use a base fertiliser with a longer period of nutrient release.

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The first time I encountered the "overwintering problem" was in 1962, and we hoped to overcome it by avoiding any unnecessary root disturbance. This method entailed taking cuttings in July, using fairly firm material and inserting them in a rooting medium in a deep wooden tray. The trays of cuttings were then placed on the mist bench. Rooting took place slowly by present day standards and eventually the trays were transferred from the mist bench to a cold frame for the winter. A few survived to grow the following spring but by no means enough to make it a worthwhile proposition.

The next attempt took place in 1966 and the theory this time was that cuttings taken much earlier in the year, i.e. before July, would be well-established young plants, mature enough to overwinter.

Stock plants were chosen and, after potting, brought inside a cold house where they were watered and syringed regularly to promote new growth. This treatment resulted in a batch of cuttings which were ready for insertion on the 16th April. Rooting time with these softer cuttings was reduced to 6 weeks, when the cuttings were put into 3½ in. plastic pots and encouraged to keep growing during the months of June and July. This type of plant overwintered more successfully but still left room for improvement. Growth was slow to start the following spring and losses during winter still amounted to some 20 — 25%.

As is often the case further developments were accidental; the main crop at the time was *Camellia* and in an attempt to reduce the length of time necessary to produce a saleable plant, I read all the articles I could find that were connected with growing plants in a controlled environment. By chance, one such article was, "The Efficient Production of Deciduous Azaleas from Cuttings" by D.G. Leach in the Royal Horticultural Society's Rhododendron and Camellia Yearbook for 1968. This article dealt with two techniques of growing azaleas with the aid of artificial illumination. Artificial illumination! Of course! This was the answer, the key to success.

The usual batch of azaleas were by this time potted and standing on the greenhouse bench, in leaf but with no visible signs of new growth, so all that was needed was to suspend a series of 100 watt tungsten filament bulbs 3 ft. above the bench and spaced at 6 ft. intervals.

Work on this was completed by the end of August and the lights switched on. Initially illumination was continuous from dusk until dawn and this treatment had the surprising effect of starting the plants into growth, so that by November nearly all had 6 to 9 in. of new growth. With the onset of colder weather vegetative growth ceased but plants still retained their leaves so were, in fact, not **deciduous** azaleas but **evergreen**, and they remained in this semi-dormant state throughout the remainder of the winter. In spring we had a batch of leggy cuttings some 12 to 15 in. tall. These were pruned back by about half their height and then planted in peaty soil under lath shades.

This method was by far the most rewarding, giving the following results:

Young plants surviving in 1969, expressed as a percentage of cuttings taken in 1968 — Exbury, 70%; Mollis, 64%; Ghent, 50%.

Propagation facilities vary from nursery to nursery, so I do not think it wise to recommend a blue print for azalea production; instead I have summarized the important points, as I see them, in order of priority:

(1) The lights should be in position by the beginning of September and the time switch adjusted so that the plants have an 18-hour day. Azaleas also grow well under Grolux fluorescent strips — these being rated at 40 watts — they are cheaper to run but more expensive to install.

(2) The glasshouse or frame should be frost-proof; in fact the higher the temperature the better. With a temperature of 55° to 60° F and an 18-hour day the plants would continue to put on new growth throughout the winter.

(3) Cuttings should be soft and still hairy — approximately 2 to 3 in. long. I believe it is still worthwhile to have stock plants in pots because they are easier to manage and one can regulate growth to get the right type of cuttings, although I have now found that it is not strictly necessary to force stock plants for early cuttings. The right type of cutting taken in July roots and grows without any difficulty.

(4) The initial theory of minimum root disturbance should also be borne in mind as azalea roots are by nature delicate fibrous things — very easily broken. Any root damage particularly in the move from the propagation bench, is bound to result in a check to the plant and obviously should be avoided.

This makes me think that the ideal site for azalea propagation would be a frost-proof frame that could be wired for misting units, bottom heat, and lighting at the appropriate times. Cuttings would then occupy the frame from June of one year to April or May of the next year.

PLANT PROPAGATORS' QUESTION BOX

BRIAN HUMPHREY, *Moderator*

The subjects discussed include, in order, the following:

1. Control of Red Bud Borer
   (*Thomasiniana oculiperda* Rubs.)

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1. Control of Red Bud Borer
   (*Thomasiniana oculiperda* Rubs.)

2. Propagation of Leyland cypress
(x*Cupressocyparis leylandii*)
3. Excessive callus formation in Leyland cypress
4. Hormone application to cuttings
5. Effect of loss of light in cold storage of conifers
6. Possibility of rooting rhododendrons by *in vitro* culture
7. Timing of soft wood lilac cuttings.

QUESTIONER: Does Mr. Garner always grease the buds with petroleum jelly after budding his fruit stocks and does he recommend this procedure for other subjects?

R. GARNER: The object is to prevent damage by Red Bud Borer (*Thomasiniana oculiperda* Rubs.). This little fly is looking for a wound, such as the slit in the bark made during budding, to lay its eggs and the larvae hatch and feed in the cambium layers. This is a frequent cause of bud failure in apples and is common enough in Kent to warrant routine use of petroleum jelly. It does not occur in all districts. It is particularly bad on apple stocks and can occur on some other fruit stocks and on ornamentals, though we have not seen it on stone fruits. You must be very careful not to damage the bark when cutting off the raffia, because the Borer is still about at that stage.

D. HARRIS: It can cause damage to Acers and Aesculus.

S. HAINES: I notice that Mr. Garner does not remove the wood from the buds. Is this his normal practice?

R. GARNER: Yes, at East Malling, it is. All our trial work at the Station suggests that this is perfectly satisfactory.

P. McMILLAN BROWSE: In my view it is only necessary to remove the wood when stocks are very small, as sometimes with Norway maple, when the bud is more pliable with the wood out.

D. HARRIS: I should like to ask Brian Halliwell which are the best times of the year for rooting Leyland cypress cuttings? Usually September and May have been regarded as the best periods, but we have rooted throughout the winter and have found that we get much better rooting after the stock plants have been subjected to sharp frost. Thus, in late October, our rooting was better than in September; the weather became milder in November and, again, the rooting fell off and improved later. We were rooting under mist.

B. HALLIWELL: Yes, in spite of the convincing evidence supporting September rooting, I agree with Douglas Harris that rooting does seem to be improved after the stock plants have been subjected to frost. I prefer to root without mist in the winter as there is less tendency for the plants to rot off.

P. McMILLAN BROWSE: At Hadlow we have rooted Leyland at various seasons with 99% success. As far as our experience is concerned it is not so much a question of season as of selecting the right kind of material. We use leaders that are taken from lateral shoots and take them with about two scales of brown wood at the bottom. These are inserted directly in a peat and grit mixture and we find an advantage in using a rather higher temperature with Leylands than with most cuttings—about 75° F. We find no benefit from wounding or from the use of any hormone, except Seradix 3. We use mist but during the winter this is manually operated.

K. LAWRENCE: I get large calluses but no roots on Leyland Cypress. Why is this?

B. HALLIWELL: I should like to comment on the question of heavy callusing. I was getting this problem and found that if I reduced the Seradix 3—for example, if I mixed it with Captan—I got reduced callusing and better results with much less tendency to rot off during the winter.

B. HUMPHREY: This is not restricted to Leyland, of course; at Hilliers' as a general rule we consider that, when this happens, the concentration of hormone has not been high enough. Aeration of the compost will affect the amount of callus formation, excessive aeration causing excessive callus.

P. McMILLAN BROWSE: I think when we saw Dave Staton's cuttings this afternoon it gave us a good indication of why we get a lot of callusing on Leyland Cypress. If you looked closely at the series of cuttings he put out you could notice that he had some which were well rooted and some which had a lot of callus but not much root. One factor which could be correlated between the two was the amount of hard wood at the base of the cutting. Where there was a fairly soft cutting, only just into the brown scales, there was good rooting with little callus; where the cutting had a base of harder wood there were large lumps of callus at the bottom. At Hadlow, now that we are using the softer type of cutting, we have no problems of callusing at all.

C. D. DEMPSTER: I like to take cuttings in July in mist or leave them until November or December when they are inserted under double glass in a glasshouse. I find I get too much callus production in September and the percentage of rooting falls off. For use under mist I do not have the normal sand and peat mixture but use a compost I discovered in Canada where it is used for rooting rhododendrons in British Columbia. This comprises 40% perlite, 40% pebble polystyrene, 15% mica and 5% peat. The peat could probably be left out altogether provided your mist never lets you down.

A QUESTIONER: Has anyone any experience of propagating Leyland cypress in cold frames outside?

B. HALLIWELL: Yes, I find this satisfactory and have propagated Leyland extensively in this fashion. Of course, if bottom heat is provided in the outside frames, conditions for propagation will be just about as good as possible.

A. THOMSEN: Why does Dr. Howard now recommend dipping only the base of the cutting into a hormone solution rather than wetting the sides by deeper insertion? Does this apply to a powder also?

DR. B. HOWARD: The deeper you dip a cutting the more solution is taken up; you can do this by leaving the cutting longer in the solution but the deeper you dip the more gets forced up inside. We have found that with the deep dipping so many root initials may form and so much of the internal substances of the cutting used up that none of the roots may develop. We did observe from sections of these cuttings that root initials began to grow, suddenly stopped, then began to lay down very thick-walled cells at their terminal end; this is reminiscent of the effect that is caused by treatment with high concentrations. We know that root initiation requires many thousand times the concentration of hormone required by root growth. Thus it is easy to appreciate that after deep dipping young roots may well meet a barrier of very high concentration; all this implies that there is fairly free movement of hormone into the cutting.

With a powder, of course, there is not the same movement, though there will be some diffusion into the cutting during the first few days or weeks. That is why one is recommended to use a higher concentration of hormone with a powder formulation than with a solution; the uptake of a hormone and its transport within the plant is much slower when the hormone is in powder form.

MRS. ABDEL-WAHEB: Can anyone give any information on the effect which lack of light might have on conifers held in cold storage for any length of time?

A. THOMSEN: I have no personal experience with this but I know that growers spray them with magnesium sulphate once or twice a week during winter.

J. GAGGINI: I know one grower who sprays Mahonias with a foliar feed and, I understand, that the Danish advice is that this should be done.

B. HUMPHREY: It is possible that there could be a confusion between yellowness caused by nutrient deficiency and yellowness caused by a breakdown of chlorophyll. However the Danes have had more experience with this than we have. I remember some reference from an American source of a grower who used illumination over his conifers in cold store but I cannot remember the details.

A. CARTER: I do not think lighting is necessary because we are aiming to keep the plants as dormant as possible. Furthermore if we want to get the maximum capacity from the stores we do not really want to keep them upright in such a way that they could be adequately illuminated.

H. JACKSON: In the one year's experience we have had we have seen no deterioration and, in fact, there has been no difference whether the lights were on or off. Towards the end of the season we tried the effect of leaving the lights on all the time. My own feeling was that in spite of keeping the plants around freezing point you could start these plants moving, particularly around June.

MISS DICK: Can I ask Dr. Marston if, in view of the fact the tissue differentiation occurs from callus, would it be possible to use the callus which forms on a cutting in *in vitro* culture?

DR. MARSTON: This has been suggested from time to time. It might work but you would have to take a lot of care to get it sterile.

B. HUMPHREY: I would like to make a comment here. Many years ago we experimented rooting rhododendrons, amongst others, *R. g.* Loderi. These did not root but when we sectioned them it was obvious, from examination under the microscope, that root primordia were present in the stem. This indicated that it must be possible to root this species and, indeed, the next season we did succeed in rooting it. The original cuttings formed copious callus and, in the sectioning, one was able to see tissues (prosphaeroblasts) differentiating into vascular systems within the callus. This seems to suggest the possibility of making new plants. If callus readily differentiates into vascular tissue in rhododendrons is it an indication that it is a good subject for *in vitro* culture?

DR. J. LAMB: With *Picea pungens* the first step towards success is the formation of vascular tissue but that is as far as I can go.

B. HUMPHREY: On these grounds then, I can mount my hobby horse, which is that rhododendrons could make a very good subject for *in vitro* culture.

S. SHERRARD: We saw at Coles Nurseries yesterday lilacs that had been rooted from cuttings taken whilst the plant was flowering. We have always understood that the cuttings should be taken 3 weeks before this.

P. McMILLAN BROWSE: We carried out an experiment with lilacs taking cuttings as soon as they were long enough in the spring and continued every 5 days. We found that regeneration was best with the first two or three batches of cuttings when the material was very soft; but these soft cuttings did not stand up to the misting conditions very well and subsequently rotted off with only the odd plant surviving. We found the same experiences as Coles have, namely, by taking cuttings as soon as the leaves mature, about flowering time, the survival was much better.

B. HUMPHREY: We get on fairly well with the very soft cuttings but I did notice that the cultivar 'Madame Lemoine' was good at Coles, whereas we have difficulty with this one. Perhaps this is one we should try with firmer cuttings, for this variety might not put up with our mist conditions.

P. McMILLAN BROWSE: Yes, this is, I feel, a varietal characteristic. Some varieties will survive but as a general rule I think that the firmer wood is safer.

B. HUMPHREY: I would expect to see a lilac at the end of the first year of rooting 8 inches high. They respond to high nitrogen which makes them more susceptible to blight (*Pseudomonas syringae*).

This is the last session and I have been left to wind up the proceedings, and it is indeed a great privilege to be allowed to do so. I have most sincerely enjoyed the meeting and hope you have all done so as well. It has all been thoroughly worth while and I look forward to seeing you when the Society visits our Nurseries in July or, failing this, let us make a date for the next Annual Conference at Merrist Wood in September, 1971.

THE CONFERENCE VISITS

(1) James Coles and Sons, Thurnby, Leics, England

23rd July, 1970

D. C. HARRIS

Conference Secretary

On both sides of the A47 road, 3 miles west of Leicester, the urban landscape suddenly relaxes into 65 acres of well-cultivated trees, shrubs and roses. This is the nursery of James Coles and Sons, renowned growers of top quality nursery stock and, on this particular afternoon, host to members of the I.P.P.S. A smiling William R. Coles with his son Geoffrey invited the visiting party to see as much as possible of the nursery and to ask questions freely during the brief 2-hour tour. With this hospitable welcome in mind, the visitors divided into small groups and, ably guided by members of the nursery staff, embarked on a detailed and rewarding study of the production areas.

Ornamental trees are an important crop within the nursery industry and budded trees of the more popular and valued cultivars are recognized as a speciality of the Coles nursery. Nursery Manager, Steve Haines, explained that the budding season for trees normally extends from late May until mid-August. *Acer platanoides* are budded first, followed in chronological order by *Acer pseudo-platanus*, *Crataegus*, *Prunus*, *Tilia* and finally *Malus*. In spite of the extra time required to produce a saleable tree especially with certain *Prunus* cultivars, such as *p.* 'Kiku Shidare' ('Shidare Zakura'), most understocks are budded just above soil level and are not top worked. Experience has shown that a better shaped head can be grown when the main stem is of the cultivar material. Understocks are headed back during the February after budding. Thereafter trees are staked, tied and grown on for 3 or 4 years before sale. Those few cultivars, for which propagation by budding is not always reliable, are normally whip grafted from the middle to the end of September. The graft union is tied with plastic tape and protected from wind by a clear

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Excellent young trees which had been budded a year earlier could be seen. Growth of *Tilia X euchlora* and *Tilia platyphyllos* 'Rubra' budded onto *Tilia platyphyllos* was exceptionally vigorous. *Malus* X *purpurea* 'Aldenhamensis', barely one year from budding onto seedling crab, had produced 6 ft. tall unfeathered shoots and were still growing strongly. Maiden whips 8 ft. tall are expected before the end of the year. *Malus* 'Lizet' which produces feathered growth during the maiden year had attained 4 to 5 ft. and looked as if stems at a minimum height of 5 ft. 6 in. would be formed before growth stops in October.

Hollies enjoy a regular demand on the Coles nursery and a standard method of production was outlined by Ron Dewick. Tip cuttings collected in September are wounded, treated with S.B.2 rooting powder (0.3% IBA) and struck under polyethylene film in unheated cold frames. The following spring the rooted cuttings are bedded out in the open and grown on for 2 years. The resultant liners are replanted and grown on for a further 2 years before sale. Fastest growth is obtained from plants grown on acid land. Approximately 20 different cultivars of *Ilex aquifolium* and *Ilex* X *altaclarensis* are raised. *Ilex aquifolium* 'J.C. van Tol' ('Polycarpa') is considered to be the best commercial cultivar, combining fast growth with profuse and regular berrying. *Ilex aquifolium* 'Pyramidalis' although slightly slower in growth makes a fine plant and can also be relied on for regular and heavy crops of berries. *Ilex aquifolium* 'Pyramidalis Aurea' is the most favored variegated holly. On the Thurnby land 9 to 12 in. of growth produced in two distinct spring and autumn flushes is obtained from this variegated plant each year.

Discussing a block of French hybrid lilacs, I.P.P.S. members learned that *Syringa tomentella* is being used on a trial basis as an understock. Initial observations indicate that *Syringa tomentella* establishes more quickly after planting and produces fewer suckers than the more usual understock, *Syringa vulgaris*. French hybrid lilacs are either field-budded during early August or bench grafted during the winter. Propagation by cuttings has also been tried but in spite of satisfactory rooting being obtained, the rate of subsequent growth has been disappointingly slow. Plants 27 months old at a height of 1½ to 2 ft. were observed. By comparison, budded plants of the same age were 2½ to 3½ ft. tall.

Looking over the many fine blocks of plants, it was obvious that throughout the nursery an intensive system of planting is followed. Rooted cuttings of *Deutzia*, *Philadelphus*, *Weigela*, *Potentilla* and similar shrubs are planted at a spacing of 1 ft. x 4 to 6 in. One year transplants are spaced at 1½ to 2 ft. x 1 ft. The practice adopted for weed control under this intensive planting system was described. Simazine is applied in early spring at a rate of 1½ to 2 lb. active ingredient per acre. By midsummer when the herbicide has lost much of its activity, a canopy of foliage from the closely spaced plants effectively inhibits further weed growth. Persistent weeds are removed by hand. Trees are treated in a slightly different way. Rootstocks or young whips are planted, one ft. apart, with 3 ft. between the rows. This still represents intensive planting but both mechanical cultivators and herbicides can be used between the rows for weed control throughout the year.

During the afternoon, half an hour was spent in the Glasshouse Propagation Department with Leslie Wykes and Tom Allen. Comparisons were made between grafted and cutting-raised plants of large flowering hybrid *Clematis*. An interesting discussion of the two propagation techniques ensued. Cuttings taken from plants grown under glass are inserted in a peat/sand rooting compost during May or June. Four to six weeks later when rooting has occurred, the young cuttings are potted into 2½ in. pots and grown on under glass for a further 6 months. At this time the plants are cut back to near soil level, repotted into 3½ in. long pots and staked. By the end of the following summer, flowering plants are 3 to 4 ft. high and ready for sale. Grafted plants, although requiring more attention than cuttings, produce saleable stock within 6 months. Small scions of selected cultivars are grafted on to the understock *Clematis vitalba* during February. Two or three root grafts can be made from one rootstock crown. Completed grafts are potted into 2½ in. pots and maintained under conditions of warmth and high humidity for about 4 weeks until a union has been formed. Thereafter, the rapidly growing plants are potted into 3½ in. long pots and are ready for sale as flowering 3 to 4 ft. high plants by August or September.

At the end of the tour it was agreed that the first nursery visited during an I.P.P.S. Conference had set a very high standard. Much of value and interest had been learned and the I.P.P.S. is grateful to Mr. W.R. Coles, his son, and the nursery staff who gave of their time and experience so generously.

THE CONFERENCE VISITS

(2) Harry Wheatcroft and Sons, Edwalton, Notts, England

24th July, 1970

In a warm address of welcome David Wheatcroft announced that earlier the same day Harry Wheatcroft and Sons had acquired additional premises in the locality and henceforth rose production from the combined nurseries would be increased to 1½ million bushes, 20,000 standards and 75,000 miniatures. This stimulating stop press news set the tone for a thoroughly interesting and lively afternoon.

The visiting party was divided into 3 groups and guided through the various departments of the home nursery. In the glasshouse propagation block, Dave Staton explained the production of miniature roses.

Short one-bud scions are whip grafted onto 4 to 6 mm bare-rooted *Rosa canina* understocks during January and early February. Scions in full leaf are obtained from pot-grown stock plants potted in the autumn and gently forced into growth from mid-December onwards. Particularly good scion wood is produced from plants grafted onto *Rosa multiflora*; although preferred for stock plants, this rootstock is not used for saleable plants because it induces excessive vigor in the scion. The graft union is made on the collar of the understock with approximately ¼ in. of the scion cut showing above the top of the cut-back understock. Thin twine is used for tying. Two grafters with one assistant can graft and put away 2,500 to 3,000 plants in an 8-hour day. Grafted plants are placed vertically in a double glazed propagating case with the understock roots loosely packed in moist peat. During the ensuing 3 weeks while callusing takes place plants are sprayed with Captan on alternate days in order to prevent Botrytis infection on the soft new growth. Scions which lose their leaves at this stage callous less freely. After a union has formed plants are plunged in peat under cold glass with plants touching in the rows and 1½ in. between adjacent rows. Shading is required during periods of bright sunlight.

As soon as a suitable tilth can be prepared on outside land, usually during April, plants are set out at a spacing of 12 in. x 4 in. x 4 ft. wide beds. Protection from wind is provided by 6 ft. high lathscreens permitting 50% wind filtration. At the end of the year plants are approximately 11 in. high and ready for sale.

Concerning the availability of scion material it was explained that early in 1970 an experiment had been undertaken to determine the effect of supplementary mercury lighting on stock plants. Eight plants each of 9 cultivars were placed under mercury lamps during early January. A similar number of plants of the same 9 cultivars were grown without supplementary lighting. Records showed that the illumination treatment almost doubled scion production.

In answer to a question on alternative methods of propagation, Dave Staton replied that budded plants tended to produce tall shoots during the maiden year and at the time of sale were too big. Cuttings of certain cultivars of miniature roses were easy to root, but the plants did not seem to overwinter satisfactorily in the open.

While in the glasshouse unit I.P.P.S. members were shown a '3-site" mobile glasshouse used for the double purpose of exhibition bloom production and temporary winter storage of lifted plants. Bush roses of selected cultivars are planted on 2 of the 3 sites. One of the planted sites is protected by the glasshouse from March until September and the second planted site is rested. Show quality bloom is produced from the protected site from May onwards. Each winter the glasshouse is moved over the third site and used as a temporary store. The earth floor together with polyethylene sheeting attached to the superstructure helps to maintain a high humidity.

At the time of the visit field budding of bush roses was in progress and I.P.P.S. members were able to watch the operation while nursery manager, F.A.B. Newenham, explained the technique.

Soil is removed from the collars of earthed up *Rosa laxa* understocks by an Egedal Blower machine. Four small shares which form part of the basic 2 row unit remove soil from 2 sides of the understocks. High velocity air ducted from turbines to points immediately behind the shares blows the remaining soil from the base of the plants leaving the collars exposed. Trained teams of budders and "tyers" complete the operation. To ensure that work is not delayed due to an irregular supply of buds, budwood is collected 2 or 3 days in advance of use and held in cold stores until required. It was emphasized that although budwood is deleafed before storage, thorns should not be removed until immediately before budding or buds will deteriorate. Flexible rubber patches are used for tying in. In one day 1,000 to 2,000 buds are normally inserted by each budder, but a rate of 3,000 per day is occasionally achieved by a few experienced knifesmen. A "take" of 90 to 95% is expected.

Commenting on a point of management, F.A.B. Newenham explained that to ensure a high percentage "take", budding is not undertaken on a piece work basis. Weekly wage rates paid throughout the full working year are however adjusted according to personal output during the vital propagating period.

The selection of cultivars, number of buds required, and order of budding is planned well in advance. The season normally starts during the second week of June, with almost all available staff involved. As the season progresses the number of budders is gradually reduced until approximately mid-August when field budding is usually completed. By maximizing output early in the season full advantage is taken of fine weather and long days. Almost 80 different cultivars are grown, but it is hoped to reduce this number if future years. Some of the more popular cultivars are 'Super Star', 'Fragrant Cloud', 'Prima Ballerina' and 'Diorama', but a high demand for the recently introduced 'Oriana', 'Whisky Mac' and 'Alecs Red' is anticipated.

Mechanization is an important aspect of large scale rose production. This was clearly demonstrated by an array of 26 different machines and items of production equipment assembled from various parts of the nursery for our inspection. Ernest Parsons, who is responsible for the maintenance of all production equipment and also controls a machinery sales and service unit which operates from the nursery, explained in seasonal order the mechanization involved in a 2-year rose production cycle. Implements ranging from heavy subsoilers to bundling and tying machines were discussed. There was much to be seen during the 40 minutes allocated to this part of our visit, but of particular interest were standard horticultural and agricultural implements which had been modified to accommodate the specific needs of the nursery. The plant carrying capacity of a Super Prefer planting machine had been almost doubled by fitting 2 side mounted panniers in place of a single front mounted pannier. For the same machine a reinforced nylon 'All Weather Cabin' had been constructed to protect operators from wind and rain. It was mentioned that the cabin could be easily detached from the planter and used as a canopy for detailed field work if required. Much interest was shown in a set of spring tine harrows which were suspended from an elevated tool frame by rigid arms to permit harrowing through a standing crop of bush roses. Other one-off machines included a Horstine Farmery Band Fertilizer Applicator on which the landwheel drive had been modified to facilitate operation under particular conditions which prevail at the Wheatcroft nurseries.

A rapid tour of a jacketed cold store and a quick examination of stored budwood completed a most successful and thoroughly absorbing afternoon. Grateful thanks were extended to all those concerned at the host nursery.

NOTES ON THE PROPAGATION OF VIBURNUMS

P. D. A. McMILLAN BROWSE, *et al*

(Ed. note. The ensuing report is the result of a request from the Executive Committee of the G.B. and I. Region, IPPS, to their members for information, particularly from personal experiences, in the technique of propagating viburnums Ten persons contributed — R. D. Anderson, G. P. Chandler, D. M. Donovan, R. J. Hares, S. J. Haines, B. R. Halliwell, P A. Hutchinson, J. G. D. Lamb, P. D. A. McMillan Browse and K. Mickelburgh Mr. P. D. A McMillan Browse collated the information into a report, which was circulated to G B. and I. meetings in September, 1970. The exercise is a continuative one and we should like to have additional relevant information).

VEGETATIVE PROPAGATION

Viburnum x bodnantense and its vars. 'Charles Lamont', 'Dawn' and 'Deben', *V. fragrans* and var. 'Candidissimum', *V. grandiflorum, V. foetens*.

This group of deciduous, winter flowering Viburnums lends itself to several techniques of propagation; small quantities can be reliably produced by 'French' layering but for large scale production a system nursery, explained in seasonal order the mechanization involved in a 2-year rose production cycle. Implements ranging from heavy subsoilers to bundling and tying machines were discussed. There was much to be seen during the 40 minutes allocated to this part of our visit, but of particular interest were standard horticultural and agricultural implements which had been modified to accommodate the specific needs of the nursery. The plant carrying capacity of a Super Prefer planting machine had been almost doubled by fitting 2 side mounted panniers in place of a single front mounted pannier. For the same machine a reinforced nylon 'All Weather Cabin' had been constructed to protect operators from wind and rain. It was mentioned that the cabin could be easily detached from the planter and used as a canopy for detailed field work if required. Much interest was shown in a set of spring tine harrows which were suspended from an elevated tool frame by rigid arms to permit harrowing through a standing crop of bush roses. Other one-off machines included a Horstine Farmery Band Fertilizer Applicator on which the landwheel drive had been modified to facilitate operation under particular conditions which prevail at the Wheatcroft nurseries.

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This group of deciduous, winter flowering Viburnums lends itself to several techniques of propagation; small quantities can be reliably produced by 'French' layering but for large scale production a system of propagation from stem cuttings is the most economic method. These Viburnums regenerate quite readily from the softwood cuttings which are produced in the first flush of growth after bud break. If the soft tip is used at later dates it regenerates less readily because basically it is 'less vigorous' due to its slower growth. Later cuttings are more difficult to over-winter because of the fact that they have not had an opportunity to start growing again before leaf fall. Plants produced from softwood cuttings represent the longest time cycle of production, i.e. from propagation to saleable size, because of the small size initially of the young plants. Consequently the propagation of these plants is best achieved by rooting hardwood cuttings, as this represents a compromise in terms of the initial size of the young plant produced, the economic use of available propagating material, and the expense of the technique involved.

The most important factor is to develop stock plants which produce hardwood material of high capacity to regenerate (i.e. ability to root). This is best achieved by following the recommendations of Garner and Hatcher (1) which they prepared for the propagation of fruit tree rootstock material; this implies that stems developed as a result of continuous, annual, vigorous pruning have a high vegetative 'vigor', are less likely to flower and have a high capacity to regenerate. In addition, the cutting material should have a high level of stored carbohydrates and a low level of free nitrogen. The former is achieved by growing the stock plants in good light conditions and the latter by increasing root competition and hence the stock plants can best be managed on a 'hedge' system. In practice, suitable young, true-to-name, stock is planted in a row about 40 cm apart, cut back to a stool, and subsequently each winter, the annual growth is cut back to a basic framework or a stool. When established on good soil conditions the stock will produce good, clean straight stems of some 1·5m which can be used for hardwood cuttings. It is important, however, in order to maintain good material of high capacity, that the stock hedges are pruned correctly each year, whether the material is to be used or not.

Timing is also a relevant factor in the propagation of these subjects from hardwood cuttings and experience has shown that best results are achieved if the cuttings are made just prior to leaf fall, i.e. when it is possible to remove the leaves by running the hand speedily along the stem.

If plenty of material is available, then the basal sections of the shoots should be used, as there is a demonstrable positional effect on the capacity of the material to regenerate; in addition this also engenders a more prolific root system. In making the cuttings, size is the first factor to be considered. Ideally the cuttings must be big enough to contain sufficient stored food for survival and regeneration but must be small enough to use the available stem material effectively, and for most of its length to be easily inserted in the compost. Hence the cuttings are nodal and between 12 and 16 cm long.

The base of the cutting is usually treated with Seradix 3 but it would be a useful exercise to see whether higher levels of IBA would improve the rooting performance. One correspondent suggests slitting the basal 50 mm of the cutting before dipping in hormone powder. The cuttings are then inserted in a cold frame containing a well-prepared compost, to a depth such that only the top 1 or 2 cm are exposed. As the cuttings will remain and establish *in situ* until the following autumn sufficient space must be allowed—say 6 to 7 cm by 10 cm. The cuttings are watered in and the frame closed and, if necessary, shaded until light intensity decreases and, subsequently during the cold part of the winter, the frames are insulated with rush mats or similar material. In spring the frames are not allowed to dry out but, as the cuttings break into growth, the frames are aired to keep the young shoots hard; because of their early flushing habits, special attention should be paid to *V. foetens* and, to some extent also, *V. grandiflorum*. During the ensuing summer the rooted cuttings are watered and fed so that by autumn good rooted cuttings for field lining have been produced.

This latter system is indeed just a standard technique for propagating hardwood cuttings in cold frames, the significant factors, which raise it from a marginally useful method to a successful one, are the provision of material of high rooting capacity, and the timing of the operation.

V. carlesii, its vars. 'Aurora' and 'Charis', *V.* 'Anne Russell', *V. x juddii*, *V.* 'Fullbrook', *V. x burkwoodii* and var. 'Park Farm Hybrid', *V. bitchiuense*, *V. x chenaultii*, *V. macrocephalum*, *V. x carlcephalum*.

Traditionally this group of early summer-flowering Viburnums has been produced by bench grafting onto pot-grown rootstocks, although many nurseries have produced good crops by layering, or by budding onto lined-out rootstocks in the field. Layering has the advantage that the crop is produced on its own roots and is, therefore, free from the problem of rootstock suckering which troubles those who graft or bud onto rootstocks of *V. lantana*. The use of *V. opulus* as a possible alternative rootstock appears to give perfectly good results with a minimum of sucker production. However, the economic production of large numbers of these plants can only be achieved by propagation from stem cuttings.

The rooting of stem cuttings of this group is not a great problem, especially under mist, provided that a few simple precautions are observed; it is the survival of the cuttings during the ensuing winter which is the greater problem. If this can be surmounted, however, the rooted cuttings grow away well the following spring and produce good-sized bushy shrubs in a further two growing seasons.

Winter survival appears to depend on two alternative systems:

(1) the encouragement of secondary vegetative growth once the cutting has developed and established its initial root system, thus producing before the winter not a rooted cutting but an integrated and established young plant, or,

(2) keeping the rooted cutting itself, which can be done by not disturbing it (i.e. leaving it in its propagating container) and keeping it relatively dry and cold.

As it has been often emphasized the success of any propagating technique depends on a source of stock material which has, inherently, a high capacity to regenerate. Well established plants which are flowering prolifically tend to produce slow growing extension shoots which ripen quickly and exhibit a low capacity to regenerate, whereas stock plants which are pruned regularly each year produce rapidly grown shoots of high capacity.

Vast numbers of stock plants are not necessary, as properly prepared plants produce many cuttings, a well-established hedge of 6 to 8 plants spaced 80 - 100 cm apart and between 120 and 150 cm tall, should produce 1,000 or more cuttings; obviously this figure will vary according to the particular species. The time of taking the cuttings appears to be of some significance although the season appears to extend well into July for some of the easier types. Later cuttings appear to have hardened too much and do not regenerate well, although high levels of hormone appear to improve matters during the marginal July period, i.e. high hormone appears to compensate to some extent for the lack of 'softness'. Most of the correspondents favour an early cutting, not necessarily because it is soft, but because it roots readily at this stage and thus allows a longer season for the secondary regrowth to develop which is necessary for winter survival. A nodal cutting with one pair of fully expanded leaves and the tip intact appears to be most favoured. Heel cuttings also represent satisfactory material, but if large quantities are stripped from the stock plants this can have a reducing effect on the yield in the following year; ideally at least one pair of leaves should be left on the stock plant from each stem where a cutting has been taken.

Wounding of the base of the cutting appears to be favored by some propagators but, as with hormones, little can be concluded from the evidence available. Where cuttings are relatively soft neither treatment appears to be especially effective; it is only when the material begins to harden that treatments may be critical.

The cuttings are inserted under a mist propagation unit using a well-drained compost and are well-rooted in 5 to 8 weeks — dependent upon the condition of the material inserted — the earlier the cuttings the shorter the period of rooting.

The most reliable subsequent treatment is the 'non-disturbance' technique which involves feeding the cuttings after they are well-rooted and weaned from the mist; if they produce new growth, so much the better, but at leaf fall the containers are cleaned up, dried off and then kept in a well ventilated **cold** glasshouse. Watering or a damp atmosphere should be avoided as the buds rot very easily and the danger increases if the atmosphere is warm; presumably the buds begin, perhaps imperceptibly, to break and are more subject to rotting. Potting-on should take place in the following early spring just prior to bud break. If the cuttings are struck early and are potted-on it is most important that new vegetative growth should be produced; this may occur naturally if potting is done early enough and provided the plants are kept warm and humid but, if it has not occurred by mid-August, supplementary light (14 hour day length) to delay leaf fall will be necessary. As soon as some new growth occurs — and only a very small amount is necessary — the plants can revert to normal conditions and be over-wintered in a cold glasshouse.

When early season (soft) cuttings are employed, it is advisable to allow the rooted cuttings time to establish, as experience has shown that potting-on freshly rooted soft cuttings often causes the buds to rot although the root system may remain vigorous and healthy.

The only plant of this group which does well consistently, regardless of propagating season and subsequent treatment according to most correspondents, is *V. x burkwoodii.*

Most of this group can also be readily propagated by budding onto *V. lantana* rootstocks. Well-established field-lined rootstocks are budded in August using a conventional 'T' bud as near ground level as possible. Non-rotting ties, such as raffia, need releasing immediately a union is made because of the continued expansion of the rootstock, otherwise considerable constriction will occur. The rootstocks are headed back in February after which continued attention to remove sucker growth is necessary.

The traditional system of production is by bench grafting during August and September. Seedling rootstocks of *V. lantana* are potted during the autumn into 3-inch pots using 7 to 8 mm grade. These potted stocks are then plunged into a cold frame in peat and are subsequently never allowed to dry out during the growing season, so that a good root system is developed and the stocks grow vigorously.

The stocks are headed down to within 5 mm of the soil level and are grafted with a scion containing two pairs of buds, using a whip graft or based whip graft. The grafts are tied firmly and are plunged into peat in a grafting case, keeping the air temperature at 17° to 18° C. The frame is covered with 250 gauge polythene and then closed with the top lights, shading being necessary on very bright days. A good union should develop in 4 to 5 weeks, after which air can gradually be admitted.

The use of rootstocks produced from cuttings which have had the lower buds removed is steadily gaining favor because of the elimination of the problem of suckering. Because of ease of rooting, *V. opulus* appears to be replacing *V. lantana.*

V. tomentosum and its vars. 'Lanarth', *mariesii*, 'Plicatum' and 'Sterile Grandiflorum'.

This particular group of summer-flowering Viburnums presents problems and no method of propagation seems foolproof. The plants can, of course, be grafted or layered but economic production can only be achieved by a successful system of propagation from stem cuttings.

Perhaps the most reliable method of production is by layering. These plants, if stooled back to produce a stock plant with a low crown and many vigorous annual shoots, can be very successfully 'French' layered. All damaged, small or thin shoots are removed, leaving 10 to 12 of the most vigorous shoots during the early winter. The surrounding soil is well-prepared and all these shoots are pegged down to ground level early in the New Year. The timing is important to allow sufficient time before bud break for apical dominance to be dissipated. In the spring when the buds have grown out 10 to 15 cm in length, the layer leads are dropped to 10 cm into the soil and then earthed up to the tips of the young shoots. Further attention is unnecessary until the autumn, when the layer leads are severed close to the crown, lifted and divided up to provide a number of rooted layers for field lining. As these plants have opposite buds some plantlets will have two shoots. Bushy layers can be produced if the tips are stopped early in the season. Meanwhile a new crop of shoots will have arisen in the crown of the plant and the whole process is repeated.

Stem cuttings, however, present the most economic form of production and this can be achieved successfully either by hardwood cuttings in a cold frame during the winter or summer cuttings under mist.

Hardwood cuttings can be easily rooted if the source of material is in a vigorous vegetative condition, i.e. if the stock plants have been pruned hard to induce this sort of material. The amount of stem growth is by no means as great as that obtained from *V. fragrans* types and, at the most, two cuttings will be obtained from each shoot; otherwise the technique is the same as for winter flowering deciduous types. If only large plants are available these can be prepared by pruning reasonably hard, which also induces a fair number of 'feather' shoots from the old stems during the following season which can be stripped with a heel and trimmed to length. The cuttings are made at or about leaf fall, nodally, about 15 cm long, and are inserted into a well-prepared compost in a cold frame, exposing only one pair of buds. Providing sensible frame management is then followed, the method should be reasonably successful, but further observations on the hormone level to be applied to the base of the cutting might help to improve the technique.

Summer cuttings under mist appear to root tolerably well if the stock plants are pruned to produce vigorous young growth annually. Providing the softer tip of the shoot is used the cuttings will root from early May (when the cuttings are only 8 cm long) to late July, but as with the *V. carlesii* group, over-wintering of the rooted cuttings is the chief problem although it is perhaps not quite so critical. It is not so difficult to encourage new vegetative growth after rooting for — given warmth and humidity — these plants will continue to grow well on into late summer.

V. opulus and its vars. 'Xanthocarpum', 'Sterile', etc., *V. sargentii* and var. 'Flavum'.

This group of summer-flowering Viburnums is particularly easy to propagate and presents few problems. For small quantities layering is a satisfactory method, either by simple layering of individual stems in mid-summer or by operating a system of 'French' layering. In either case it is necessary to stool the plants so that sufficient annual, vigorous shoots are produced from a low crown. Although no information is available it is probable that these plants would propagate satisfactorily from hardwood cuttings if the method already described is adhered to; the only salient feature that would need attention is to ensure that the cuttings are made nodally as these plants tend to develop a large pith.

Soft summer cuttings are relatively simple to root and respond well to the usual conventional treatments. If the cuttings are taken as softwoods from the first flush of growth in early summer and placed under mist, this provides a long growing season and well-established plants will be produced by autumn.

It is probable that this group would succeed under the misted, polythene tunnel system now gaining ground, especially if the cuttings were among the earlier batches to be inserted in early June.

V. tinus and its vars. 'Variegatum', 'Purpureum', 'Eve Price', 'French White', 'Pink Prelude', etc.

This species, with its varieties, is particularly easy to propagate from stem cuttings and it is merely a question of determining when is the best time to fit this work into the propagation calendar.

Soft tip cuttings in mid-summer will succeed very well under mist; autumn evergreen-type cuttings placed under mist will also do well; still later, cuttings taken in the winter will succeed if the mist unit is used as a heated bench and the mist itself as manually controlled irrigation. Cuttings in a cold frame during the autumn, autumn cuttings under thick-gauge, polythene tunnels or softer, summer cuttings under misted, thin-gauge, polythene tunnels are all feasible methods of propagation.

V. rhytidophyllum and its var. 'Roseum'.

Although the species itself is often produced from seed it is equally easily propagated by vegetative means. The only drawback to vegetative methods is the coarseness in growing habit and the size of the leaves. Where small quantities only are required, simple layering in the spring is a reasonably easy technique provided that the stock plant has been pruned to produce some strong annual shoots for the purpose.

Propagation from cuttings is relatively simple and as this plant is evergreen it can be propagated at a number of seasons. Summer cuttings, fairly small in size, can be rooted very successfully under mist with apparently no seasonal decline in rooting capacity. Perhaps autumn cuttings, overwintered under a misting system, is a more economical use of space; the cuttings are necessarily bigger but it is usual to reduce leaf size to save space. Wounding, plus the use of Seradix 3, appears to produce the best results under these conditions.

V. cinnamomifolium and V. davidii.

These two very similar and closely related species are fairly readily propagated from stem cuttings and appear to respond well at any of the conventional propagation seasons. Very soft tips, taken early in the season and placed under mist, root well. Autumn cuttings, taken when growth has ceased and with any flower buds removed, can be given the winter 'mist' treatments already described; Seradix 3 is beneficial at this period. It has been suggested that cuttings of male plants root better than those taken from female plants!

V. dentatum.

According to the literature this plant is easily propagated from root cuttings and can also be produced from hardwood cuttings. However, softwood cuttings under mist root easily and growth re-establishes quickly.

V. buddleifolium.

Cuttings root reasonably well if treated in the same way as described for *V. carlesii.*

V. hupehense and *V. betulifolium.*

Cuttings can be rooted under mist as described for *V. tomentosum.*

SEED PROPAGATION

Little information has been forthcoming on the propagation of Viburnums from seed and all that comes to light from surveying the literature is confusion! The only facts that can be reported are that most Viburnums exhibit fairly complex forms of seed dormancy and to overcome this problem the only technique one might recommend is to collect the berries before they ripen, extract the seeds and sow before the seed coat hardens and before dormancy factors develop. The stratification of the seed in cold conditions does not necessarily overcome dormancy as many Viburnums require a warm period prior to the cold. It is often this factor which delays germination until the second spring after collection; in other words, the limiting factor is not necessarily cold treatment in the first winter.

In British nurseries it would appear that *V. lantana*, *V. opulus* and *V. rhytidophyllum* are the only species commonly raised from seed. The experience of one correspondent suggests that if germination can be induced in the first spring after collection much larger and more vigorous seedlings are produced.

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