DR. SAX: We have propagated it very easily by softwood cuttings There is nothing to it You get almost 100 per cent take. You do have to be a little careful the first winter. It probably would be better to keep them overwinter the first year in a protective cold frame or pit. They will flower very early, sometimes when only two years old, from cuttings and almost invariably when three years old.

This would be the perfect plant to grow in containers. You can grow it in a rather small can and sell it in flower and double your price.

MR. J. C. McDANIEL (University of Illinois, Urbana, Ill.): Do many of these peach-plum hybrids have showy flowers? The only ones I have seen lost their buds before they opened.

DR. SAX. Ours have not flowered yet but I suspect that will be the case We have had crosses of *Prunus incana* and *P besseyi,* with nice vigorous plants and flowers, but no fruit The buds abort prior to flowering When you double the chromosomes you destroy some of the fertility If we can just get some of the *P. besseyi* blood into some of the peaches we would like that in the northern states

MR C. DeGROOT Dr Sax might be interested to know that we have had profuse flowering of the Arnold Dwarf forysthia.

DR. SAX. I suspect if we take our propagating wood from flowering shrubs they will flower earlier for us also. This is the old story of seedlings. They are very slow in coming into flower, but once they reach the adult stage they will come into flower very much quicker when vegetatively propagated

MR. JAMES WELLS: We are trying "Hally Jolivette" grafts. We find it flowers on the rooted cuttings and keeps on flowering from there on. It also grows beautifully in the can and has a splendid fall color.

What I want to ask you, Dr Sax, is what is the natural length of flowering time of this plant at Arnold Arboretum?

DR SAX· It depends on the season, but in most seasons it is good for at least ten days. Of course, it is usually fairly cool with us. This can be contrasted to *Prunus sargenti,* which is good for about two days.

MODERATOR JOHNSON. Our next speaker is one who needs no introduction to the majority of you. She has dealt with seed germination and seed germination problems for the past forty years at Boyce Thompson Institute Dr Lela Barton, Boyce Thompson Institute, Yonkers, New York

Dr. Barton presented her paper entitled, "Germination and Seedling Production of Species of *Viburnum*." (Applause)

GERMINATION AND SEEDLING PRODUCTION OF SPECIES OF VIBURNUM

LELA V. BARTON
Boyce Thompson Institute
Yonkers, New York

Seedling production of the genus *Viburnum* has long been a problem. It has been discussed in the literature without any definite and satisfactory answer. Giersbach (2) summarized the work done up to 1937. As early as 1894, Jack reported "about seeds with a hard bony covering," which might commonly be expected to grow in the second rather than in the first year, especially if not planted until spring. He mentioned *Viburnum* as one of these. Many of the reported germination tests of *Viburnum* seeds consisted simply in planting the seeds in soil out-of-doors at various times and recording the time of emergence of the seedlings. For the most part no planned experiments were conducted to determine the effect of various factors on germination.

Davis in 1926 (1) observed two stages of germination of the highbush cranberry The first was the growth of the radicle at a temperature of 68° F. or higher, the second the development of the cotyledons, still covered by the seed coat at a cold temperature of 40 to 50° F., during which time the root system enlarged After the cold period, seedlings developed normally in a warm greenhouse More extensive detailed tests conducted by Giersbach and published in 1937 (2) indicated that there were indeed two stages of germination, though the vital process of the second stage had to do with the breaking of the dormancy of the epicotyl rather than the development of the cotyledons. Much, if not all of the difficulty experienced in seedling production in this genus may be traced to the existence of these two stages of germination: the first stage, that of root production, the second stage, that of green shoot production. Once this is recognized and the requirements for completion of each stage known, seedlings may be produced at will, though a rather long period of time is necessary for most species.

The work of Gierbach (2) which was conducted at Boyce Thompson Institute for Plant Research will be presented in detail The species studied were *Viburnum acerifolium* L, *V dentatum* L., *V. dilatatum* Thunb., *V lentago* L., *V nudum* L, *V. opulus* L, *V prunifolium* L., *V pubescens* Pursh., *V rufidulum* Raf., and *V. scabiellum* (T.&G.) Chapm The fruit of *Viburnum* is a one-seeded drupe with soft pulp and a thin stone. For the germination and seedling production tests the stones, referred to in this paper as seeds, for convenience, were freed from the pulp immediately after harvest Experiments as conducted may be divided into germination tests where root production was recorded and seedling production in soil where shoot production was recorded. As all *Viburnum* species studied showed a similar trend in behavior, *V. acerifolium* will be described thoroughly as a type, while the other species will be discussed in a general way, except where deviations from the pattern of *V. acerifolium* are shown. Constant and daily alternating temperatures were used. In the case of the latter, the cultures were left at the higher temperatures for 8 hours and at the lower temperatures 16 hours each day

GERMINATION (ROOT PRODUCTION)

Cleaned seeds of the ten different species were mixed with moist granulated peat moss and placed at constant temperatures of 33°, 41°, 50°, 59°, 68°, 77°, and 86° F. and daily alternating temperatures of 50°, to 86° F., 59° to 86° F., and 68° to 86° F. Different *Viburnum* species vary in germination rate and in range of effective temperatures (Table I.)

Table 1.—Effective treatment for producing plants from *VIBURNUM* seeds

Species	Requirement for root production Temp. (°F.)	Time (mos.)	Pretreatment for shoot production Temp. (°F.)	Time (mos.)
V. acerifolium		12-17	41,50	2 -3
V. dentatum		12-17	"	0.5-1
V. dilatatum	68	7-9	"	3 -4
V. prunifolium	50 to 86*	7-9	"	1.5-2
V. pubescens	68 to 86*	12-17	"	2 -4
V. rufidulum		12-17	"	2 -4
V. lentago	59,68,77	5	"	3 -4
V. opulus	50 to 86*	2	"	1.5-2
	68 to 86*			
V. nudum	Entire range	1-2	no dormancy	
V. scabrellum	41-86	1-2	no dormancy	

* Daily alternation.

The most satisfactory temperatures for growing the roots of all species have been found to be constant 68° F. and a daily alternation of 68° to 86° F. These are the temperatures which permit the most rapid growth of the very small embryo to the full length of the seed, a process which precedes the appearance of the young root. This is clearly demonstrated in figure 1 in which the development of the embryos of *V. acerifolium* after five months in moist granulated peat moss at various tem-

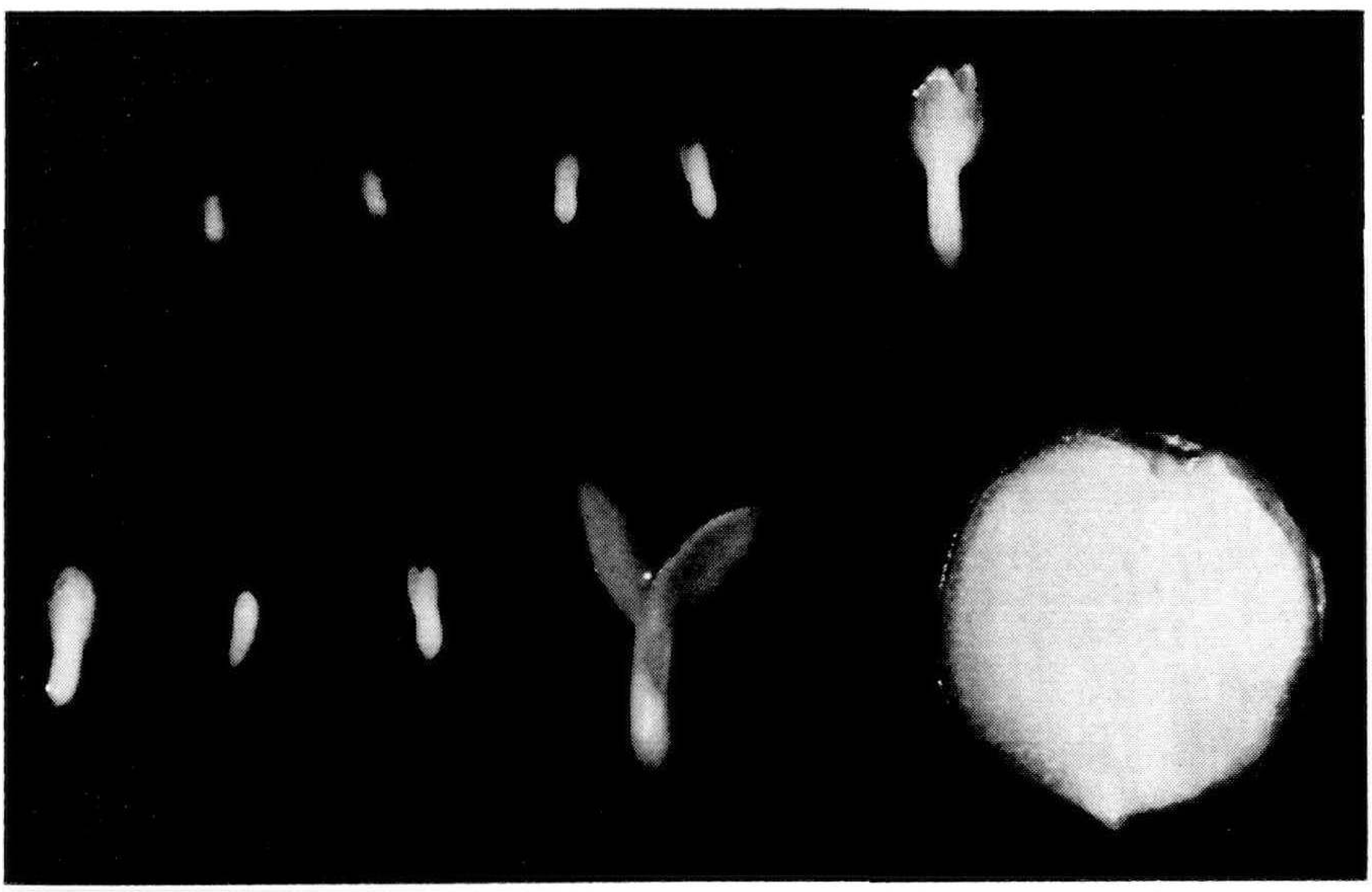

Figure 1. Embryos of V. acerifolium, excised after five months in peat at various temperatures. Left to right: (Upper row) dry seed, 41°, 50°, 59°, 68°, F.; (lower row) 77°, 86°, 50°, to 86°, 68° to 86° F., cross section through seed.

peratures is shown. Actual root production in this species occurred over a period of six to seventeen months. About the same amount of time was required for seeds of *V. rufidulum* and *V. dentatum*. In *V. prunifolium* and *V. dilatatum*, germination to form roots was completed in seven to nine months; in *V. lentago*, five months were required; and in *V. opulus*, two months at optimum temperatures. Seeds of the southern forms of *V. nudum* and *V. scabrellum*, on the other hand, germinated during the first month at the most favorable temperatures, and tolerated the whole range of temperatures from 41° to 86° F. These last two species also failed to exhibit the epicotyl dormancy to be noted below and shown by the other species studied, thus completing the seedling production process in one phase instead of two.

SEEDLING PRODUCTION

When germinated seeds with the roots developing satisfactorily are kept in a greenhouse, the green shoots fail to come through the coil.

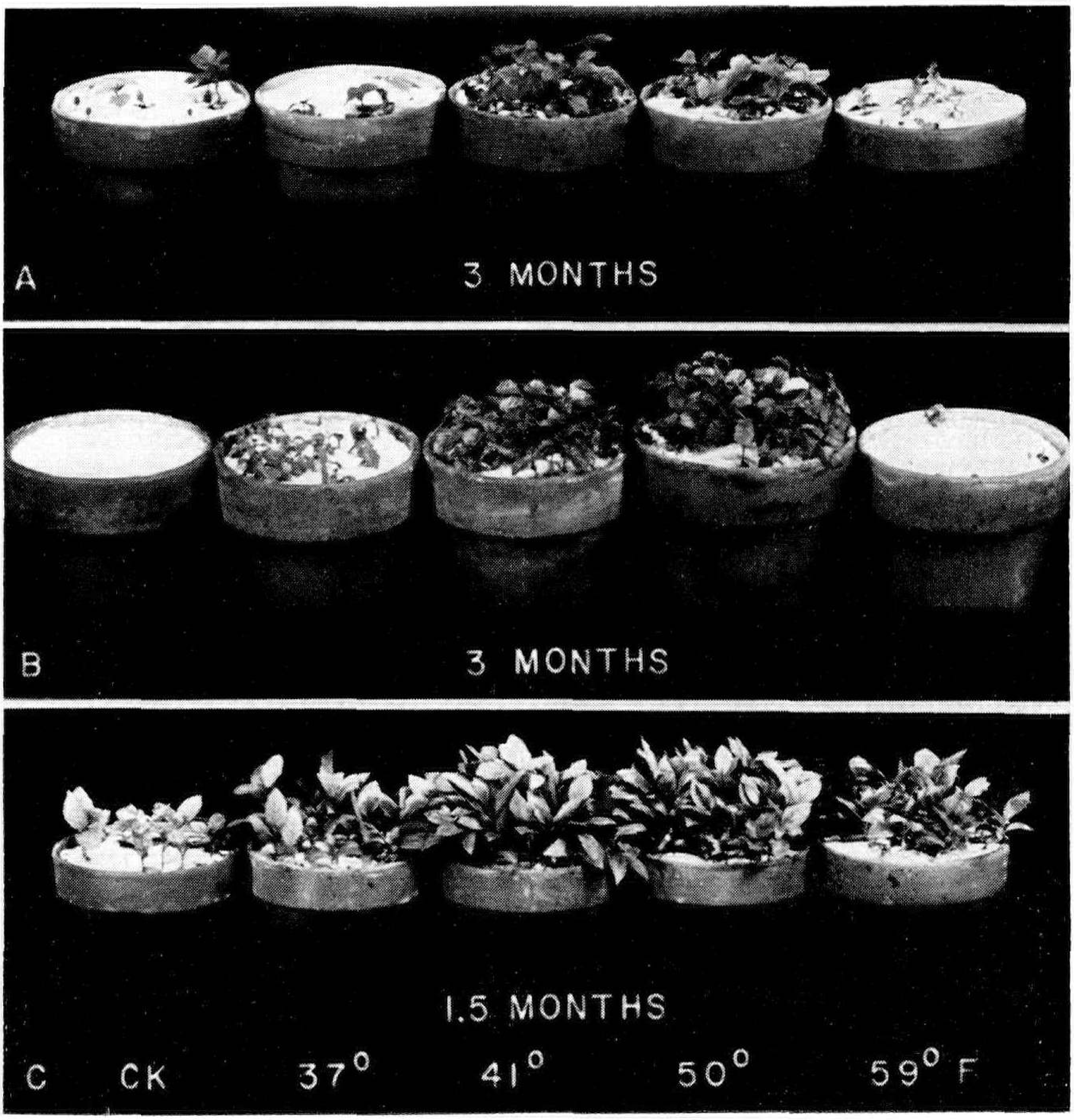

Figure 2. The effect of low temperature on shoot development of *Viburnum* species. (A) *V. acerifolium*. (B) *V. dilatatum*. (C) *V. prunifolium*.

The roots will continue to grow until the food supply in the seed is exhausted, after which they will die unless they have had a period at low temperature to after-ripen the bud that forms the shoot. Thus we have the second phase of the seedling production process for these forms For the initiation of this phase a temperature in the range of 41° to 50° F. for a period of two to four months, depending upon the species is required (Table I). This type of germination response has been designed as epicotyl dormancy and is characteristic of the seeds of the tree peony and of certain, so-called, two-year lilies.

Experiments at Controlled Temperatures To determine the optimum length of time at low temperatures and also the optimum low temperature needed to overcome the epicotyl dormancy typical for most species of *Viburnum*, seeds of *V. acerifolium*, *V. dentatum*, *V dilatatum*, *V. prunifolium*, and *V. opulus*, pregerminated in peat at 68° to 86° F daily alternation, were planted in pots and kept in rooms of 37°, 41°, 50°, and 59° F as well as in a greenhouse of about 70° F. Series of pots were transferred from the various rooms to the greenhouse every half month, and subsequent appearance of green shoots above ground was noted. The general appearance of seedlings of three different species is shown in figure 2 It will be seen that the best response in all cases was to pretreatment at 41° and 50° F. The seeds of *V prunifolium* were the least dormant of these three species as shown bv the growth of some green shoots in the greenhouse without any pretreatment (fig. 2C, control). Germinated seeds of *V dentatum* produced up to 41 per cent seedlings in the greenhouse without any cold pretreatment, but such seedlings were always poorly developed. Actual germination percentages obtained are shown in Table II for *V. acerifolium.*

It will be seen that the optimum cold treatment for seedlings of this species was two and one-half months at 41° F. with 61 per cent shoot development and four months at 50° F. with 81 percent. Shoot development was very poor in the pots held at 37° or 59° F for pretreatment, and only two shoots appeared above ground in the greenhouse controls (no pretreatment).

The two southern species, *V. nudum* and *V. scabrellum*, did not show any epicotyl dormancy. When seeds of these species were planted in flats and kept at a high temperature seedlings came up in one to one and one-half months When seeds were sown in flats in greenhouses of various temperatures, seedlings grew somewhat more slowly in the cooler houses At temperatures above 70° F and when flats were alternated between 61° and 80° F. seedlings damped off easily.

The high percentages obtained throughout the epicotyl dormancy tests were due to the fact that only germinated seeds were used

Plantings Out-of-doors. We have seen the seeds of *Viburnum* germinate to form roots at temperatures that correspond roughly to those of spring and summer in many localities. Since a period at low temperature needs to follow this root production before seedlings appear above ground, it would seem logical to sow the seeds out-of-doors in the spring. Roots will be produced before the summer is over and then the epicotyl will after-ripen the following winter and seedlings will ap-

Table 2.—Effect of pre-treament of germinated seeds of *Viburnum acerifolium* at various low temperatures on shoot production in the greenhouse. Crop 1932

Pre-treatment		Per cent shoot production after months in the greenhouse (about 70° F.)					
Temp. °F	Months	0.5	1	1.5	2	2.5	3
	1	0	0	0	5	6	9(7)*
	1.5	0	3	4	7	9(5)	
37	2	1	3	4	4		
	2.5	3	4	7			
	3	1	2	4			
	4	16					
	1	0	1	4	11	12	
	1.5	0	12	35	42	46	
41	2	0	29	49			
	2.5	13	61	61			
	3	6	49	51			
	4	51					
	1	0	9	23	30	35(20)	
	1.5	0	9	27	33(7)		
50	2	1	13	31	31(2)		
	2.5	3	25	36	40		
	3	34	60	67(6)			
	4	77	81(2)				
	1	0	2	9	13	19	
	1.5	0	7	13	13		
59	2	5	9	17	19		
	2.5	4	7	8			
	3	7	13				
	4	13					
None		0	0	0	1	1	2(2)

* Numbers in parenthesis indicate seedlings above soil but with seed coats attached

pear above ground the spring after planting. This has been tried and found effective. Some of the results are shown in Table III and figure 3.

Table 3.—Effect of planting *Viburnum* seeds at various times during the year and wintering in a board-covered cold frame.

Species	Per cent seedling production in spring from seeds planted preceding					
	Apr. 1	May 1	June 1	July 1	Aug. 15	Sept. 15
V. acerifolium	40	55	17	15	—	0
V. dentatum	31	32	30	26	—	0
V. dilatatum	79	88	79	54	—	0
V. prunifolium	10	26	0	1	0	0
V. opulus	60	64	76	87	1	0

It will be seen that seeds of *V. acerifolium* produced up to 40 and 55 per cent seedlings after one winter when planted in April or May at

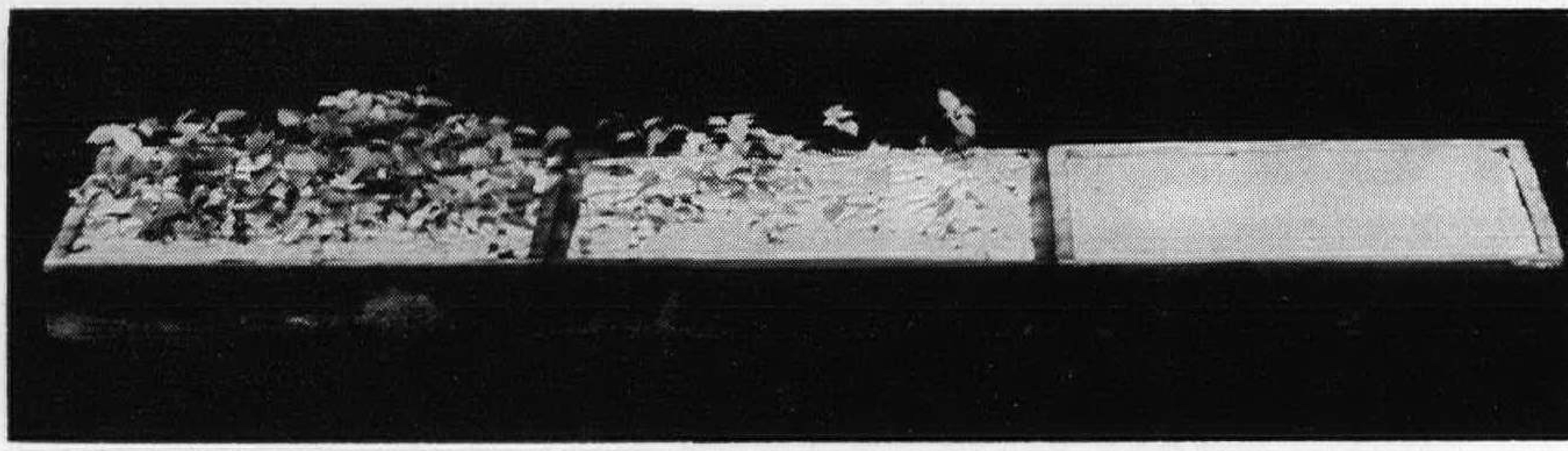

Figure 3. V. *acerifolium*. The effect of various planting times on seedling production the following spring. Left to right: Planted April 1st, June 1st, September 15th.

Yonkers, N.Y. Seedling production decreased rapidly for plantings made in June and later, with none at all for the plantings in September.

The effective length of exposure to warm temperature followed by a cold period varied for the different species. The response of *V. prunifolium* to high temperature was somewhat similar to that of *V. acerifolium* with 26 per cent seedling production for the May planting, and only occasional seedlings for any later plantings. Seeds of *V. dentatum, V. dilatatum,* and *V. opulus* sown as late as July gave 26, 54, and 87 per cent seedling production, respectively, the following spring. Seeds sown in August or September, however, gave good seedling production only after being in the ground for two winters. In other words, late summer or fall planting is too late to give the seeds the necessary amount of warm weather for root production, so the first winter the seeds remain ungerminated. With the advent of warm weather the next year, the roots germinate and develop and the following winter after-ripens the epicotyl. Low temperature is ineffective if given before the roots have formed. Flats kept at 70° F. for the duration of the experiment where seed received no low temperature for breaking epicotyl dormancy, contained a few weak seedlings.

It has been reported that seeds of *V. lantana* and *V. lentago* planted in early October in Ohio produced seedlings to the extent of 84 and 73 per cent respectively by the following July (5).

DISCUSSION

To summarize, then, it may be said that the *Viburnum* species described above, except southern forms, require a constant temperature of 68° F. or a daily alternating temperature of 68° to 86° F. for root production followed by a low temperature pretreatment for shoot production. Except for southern forms, seeds sown in flats in the fall and placed in cold frames produce seedlings only after the second winter. Spring plantings, however, give a good crop of seedlings after one winter. All of these effects have been confirmed by germination tests in moist granulated peat moss and seedling production tests in soil at controlled temperatures. Leweling (4) used this method effectively for *V. Carlesii.* He placed the seeds in moist sand at 65°-71° F. for 60 days; 40° F. for 60 days; then 70°-90° F. for seedling production.

The fact that germination to form roots extends over such a long period indicates that some treatment should be effective in bringing about more prompt and more complete germination Giersbach (2) was not able to accomplish this by giving temperature pretreatments or by removal of the hard coats. However, Knowles and Zalik (3) found coat removal effective for seeds of *V trilobum* Marsh. They reported dormancy in both seeds and seedlings of this species. Dormancy of seeds placed at 68° F, expressed by slow growth in some seeds and by failure to germinate in others, was associated by these authors with the presence of a water-soluble inhibitor, coupled with a need for an appropriate temperature treatment. An increase of 19 per cent germination followed removal of the endocarp which contained the inhibitor, but highest germination was obtained by endocarp removal accompanied by alternating temperature treatments (36° to 68° F., or 41° to 68° F). Smith (6) in a recent publication also found that the waxy coat of recently harvested seeds of *Viburnum lantana* and the entire integument of fresh seeds of *V. lentago* exerted slight inhibitory effects on germination. He believed the cause of this effect may have been impermeability to gaseous exchange or to the presence of an inhibitor. Epicotyl dormancy was broken in *V. trilobum* in the light following exposure in the dark to either 41° or 68° F. (3). This is contrary to the results presented above which indicate that lower temperatures are required for the after-ripening of the epicotyl Knowles and Zalik (3) concluded, further, that epicotyl growth of *V. trilobum* was governed mainly by the cotyledons. Dark treatment of seedlings for two weeks at 41° or 68° F followed by removal of the cotyledons 14 days after transfer to the light resulted in 100 per cent epicotyl growth within 10 days. Intact seedlings with the same treatment failed to develop epicotyls. No data were given for the effect of cotyledon removal following longer temperature pretreatment periords. Also, *V. trilobum* seedlings were grown in vermiculite for short periods, which gave no evidence of further vigorous development.

One of the effects of longer periods at low temperature may be to remove an inhibitor from the cotyledons. However, cotyledon removal would not be feasible for large scale production of seedlings since it would involve tedious manipulation and the young seedlings would be deprived of their original food supply It, perhaps, should be noted that Vacha and Harvey (7) stated in 1927 that ethylene or propylene 1:500 for 8 days in three doses gave good germination of dormant seeds of highbush cranberry. Species and details of the experimental procedures were not given, and no other reports on this subject have appeared in the literature

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MR. MARTIN VAN HOF. Did I understand that the seed that was gathered in 1958 was sown immediately?

DR. BARTON. Yes, it was sown as fresh seed. It was stored dry until April without stratification.

MODERATOR JOHNSON· I am sure that Dr Barton would answer any questions you might have on this subject

DR. CHARLES HESS: In what publication did Knowles and Zalik publish?

DR. BARTON. Their article was published in the *Canadian Journal of Botany,* Volume 36, 1958.

MR. VAN HOF: Have you tried soaking the seeds in gibberellic acid in order to speed up germination?

DR. BARTON: We have had no luck. We tried Arnold crab apple seed also, because there was an indication that it might work on natural dwarfs. When you spray seedlings you eliminate the dwarf condition by causing internode elongation. We thought therefore, that we could soak the seeds and partially overcome dwarfism but it didn't work.

MR HOOGENDOORN: Have you ever tried to break the dormancy of *Sciadopitys verticillata?*

DR BARTON: Yes, we have. This was done a number of years ago and I don't remember the details. We tried low temperature at the time, as I recall, and we didn't do well with it. We obtained maybe 20 or 30 per cent germination, after low temperature treatment for two months in 41° F

MR. COGGESHALL. I have two questions. First, am I assuming correctly that you people at Boyce Thompson Institute do not consider it necessary or practical to clean the seed prior to sowing?

Second, have you done anything along the lines of collecting viburnum seeds green, before the formation of a hard seed coat?

DR. BARTON: We always clean the seed before sowing. The only trouble with cleaning them after you store them is the pulp dries and you are apt to injure the seeds trying to get them clean.

As to the second question, we have not tried collecting any immature seeds of viburnum to see if they would be non-dormant. We tried that for a lot of other seeds, because this has been reported in the literature from time to time We have never found that you could clean immature seeds and get non-dormant seeds The immature seeds, if they are too immature, rot before you can germinate them, and if they are older, they are dormant This has been our experience We took apples one time at the beginning of the formation of the embryo thinking we could get at this dormancy factor but we found about the same thing there

MR MARTIN VAN HOF: I think this question which I have in mind was asked, but maybe I came a little bit late. Some of the seeds, of course, which are gathered, soaked, cleaned and stored, sprout

DR BARTON: I think that is almost universally true of any seeds that show any type of dormancy You have all these variations in dormancy in the individual seeds.

One of the biggest advantages in after-ripening in breaking dormancy is to get all of your seeds germinating at the same time This is true in many forms that will germinate without low temperature, pines, for example. There are some pines where you get a seedling without low temperature, but if you pretreat them, even a short period, depending on the pine, you get a uniform stand

DR SIDNEY WAXMAN (University of Connecticut, Storrs, Conn.): We did some experiments with *Sciadopitys* three years ago. They will germinate under normal conditions in about 100 days. We tried various treatments, including photoperiod and misting. The result was that when they are under mist they will not germinate on long days but will germinate on short days or in total darkness In darkness they germinate at 65 degrees when treated with thiourea. It takes about 35 days to germinate on short days under mist. If we treat with chemicals and then place the seeds in the dark they will germinate in 30 to 35 days

DR. CHARLES HESS: What type of dormancy does the *Ilex* seed have?

DR BARTON: I wish you people would ask me easy ones. *Ilex* is one of those that in the early days we did a great deal of work on at Boyce Thompson, and we have never done anything that gives any better germination than fall planting. The next spring you get seedlings and the next spring more seedlings, and the next spring probably still more seedlings, it is quite sporadic.

American holly is the plant that we worked on principally, and it has a very undeveloped embryo, just a mass of undifferentiated cells.

Dr. Peter Nelson, of the Brooklyn Botanical Garden once did a lot of work on excising the embryos of holly seed. He never published it. I asked him awhile ago why he hadn't published it, and he said he had not found out much of anything.

DR. L C. CHADWICK (Ohio State University, Columbus Ohio): We appreciate the importance of the changes of temperature from the warm temperature of 68 degrees to break the seed coat to 41 degrees to overcome the epicotyl dormancy I am wondering if you have any information, whether or not you can make that switch from the warm temperature to the cold previous to the protrusion of the root radicals through the seed coat: in other words, make the change while it is still in the seed

DR. BARTON: It will not work for these particular forms that show epicotyl dormancy You must have the root growing first, before you can get any effect of the low temperature to the shoot This we have worked out morphologically. The differentiation of the tissues takes place for the epicotyl only after the root is growing.

Gibberellic acid has the same effect. It will not have any effect until the embryo gets to that stage.

MODERATOR JOHNSON: I think we had better go on. Thank you, Dr. Barton, for a most interesting talk and discussion

Our next speaker, I am sure, needs no introduction. Dr. Baumgartner is known to all of you for his work as a consultant to the nursery industry. Dr. Baumgartner

Dr. Baumgartner read his prepared paper entitled, "Basic Factors in Good Water and Soil Management for Balanced Plant Growth." (Applause)

BASIC FACTORS IN GOOD WATER AND SOIL MANAGEMENT FOR BALANCED PLANT GROWTH

L. L. Baumgartner
Baumlanda Horticultural Research Laboratory
Croton Falls, New York

When our program chairman asked for a discussion of this subject we were well aware of the fact that it is a broad title and that books have been written on each of its three phases Therefore, if this presentation should be acceptable to you, it will probably represent a greater contribution to the art of organization and condensation rather than a contribution to scientific discipline Our primary objective is to re-examine the handling of water and plant foods in the light of operational problems in nursery management. Some of my statements based on my experience will undoubtedly be contrary to your experiences and I hope that this may provide the basis for further discussion. This subject often appears overly-complicated and possibly mysterious because of the many special circumstances and exceptions which make many facts appear to be contrary to each other. I am certain that this will appear very elementary to some of you and I beg your indulgence as I attempt to develop a subject without including the many exceptions and special circumstances. This is prepared for the non-professional.

WATER

Sources of Water: One of the most controversial subjects revolves around the belief that rain water is better for plant growth than irrigation water. In New England there have been reports that the use of irrigation water actually harmed nursery crops, while in Arizona similar crops could never have been raised without irrigation. Now what might the answer be?

The divinity of water from heaven has not been generally accepted but if it comes often enough it is certainly satisfactory Rain water generally falls in small droplets and continues for an extended period of time. It not only producers a beneficial cooling of the air surrounding the plants but soil can better absorb water that is applied slowly. Rain does entrap some nitrogen and sulfur from the air and carries it to the soil.