GROWTH PHASES IN RELATION TO PLANT PROPAGATION

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The physiology or internal functioning of plants changes as they progress from seedlings to maturity. These internal, physiological changes are sometimes manifested by a series of marked changes in morphological characters and rate of growth. Examples of morphological characters which change with maturation are leaf shape and arrangement, stem and leaf coloration, habit of growth and degree of thorniness. English ivy (*Hedera helix*) is a good example of a plant which exhibits marked changes in morphology with maturation. As a seedling and for many years thereafter, it is a vine with lobed leaves, reddish stem, dorsa-ventral leaf arrangement, and aerial roots. Mature ivy plants are woody shrubs with entire oval leaves, green stems, spiral leaf arrangement and no aerial roots. In other plants, however, the morphological differences may be so slight and gradual that they are not apparent to the casual observer. Another indicator of physiological change with maturity is the greater tendency of cuttings taken from young seedling plants to initiate adventitious roots than those taken from older plants. This has been shown for many species including apple (10), pine, spruce, maple, ash, oak (25), hemlock (4) acacia (23), and many others. Still another indicator of physiological change with maturity is the fact that seedlings go through a period of growth and development during which they *will not* flower and form reproductive structures even when known environmental requirements for flowering such as photo period or low temperature are fulfilled. Ultimately, however, these plants mature and acquire the ability to flower.

The immature condition as manifested by the physiological and morphological characteristics associated with young seedling plants is referred to as juvenility (11) and plants or parts of plants with these characteristics are said to be in the juvenile phase of growth. Plants or parts of plants with mature characteristics such as the ability to flower are said to be in the adult or mature phase of growth.

Growth phases are of interest to plant propagators, growers, and breeders for the following reasons:

1. First, ease of adventitious root formation is associated with juvenility and therefore plant propagators would like to prolong or reestablish the juvenile phase to take advantage of this characteristic.
2. Secondly, plants in the juvenile phase can not be induced to flower and therefore plant breeders and growers would like to be able to shorten the juvenile phase to obtain early early flowering and fruiting.

Because of the importance of growth phases to most people who grow plants, it is worthwhile to review what is known about growth phases and see how this information can be applied to plant propagation and production.

Over the years since about 1900 considerable information has been gathered concerning growth phases. Observations show that the duration of the juvenile phase and accompanying characteristics is variable and may be only a few days or weeks in some plants, whereas in others, such as *Hedera helix*, it may persist for years. The change from the juvenile phase to the adult phase may be rather gradual so that there are different degrees of juvenility. This is true for both rooting ability and morphological characters, as indicated by transitional leaf shapes and transitional degrees of rooting ability. It can also be said that the various juvenile characteristics are lost at different rates. For example, juvenile leaf morphology may disappear faster than ease of rooting. Thimann and Delisle found this to be true in white pine where the change-over to secondary needles is completed in the second year while the ability to root from cuttings shows a gradient lasting five or six years. So there seem to be gradients of juvenility and the gradients may not be the same for all characters.

It is interesting and of practical importance to note that the bases of many plants retain a certain degree of juvenility or the ability to produce juvenile shoots even when they are quite old (24). This is reflected in the fact that cuttings taken from the lower portions of a plant sometimes root better than those taken from the upper part (13). This is also the reason that cuttings taken from hedges and suckers or root sprouts may root easier than cuttings taken from the upper parts of intact plants.

One of the most striking features of growth phases is that in many cases both the juvenile and the adult state are transmitted by vegetative methods of propagation such as cuttage or graftage. Vegetatively propagated offspring from the juvenile phase continue their normal sequence of maturation and finally flower. Vegetative propagations from adult shoots continue to grow as adult for indefinite periods of time. Frost (9) has shown this to be true for buds of *Citrus* where plants grown from buds taken from the base and inner portion of a seed-grown tree are thorny, while plants which developed from buds taken from the peripheral portion are likely to be nearly thornless and will flower and bear fruit earlier.

It is also known that environmental factors influence the rate of maturation. This is, the duration of the juvenile phase is not fixed and can be prolonged or shortened to some degree. These influences of environment on rate of maturation are indirect evidence that juvenile characteristics are associated with physiological age or condition rather than chronological or time age. Hess (14) has presented direct evidence to show that juvenile and adult forms of *Hedera helix* are physiologically different as indicated by differences in amounts of rooting cofactors.

As mentioned above environmental factors affect the rate of maturation and may even cause reversions from adult to a more juvenile condition. It has been shown with some herbaceous plants (3, 15) that high light intensity reduces the length of the juvenile phase and stimulates earlier flowering. With geranium seedlings (2) it is known that higher daytime temperatures up to about 75° or 80° F. coupled with high light intensity will reduce the time from sowing to maturity. The juvenile phase of rhododendron (6), camellia, pine and birch (17) seedlings have been reduced by growing them under long photo-periods in a glass house. The common effect of this treatment was to produce a larger plant in a given period of time. In each case the time to first flowering was reduced.

Low light intensity or shading has the opposite effect of high light intensity and prolongs the juvenile phase in beech trees (22) and some herbaceous plants. Etiolation (the development of plants or plant parts in the absence of light) has a great stimulatory effect on root initiation and in our laboratory we have recently shown that etiolation causes a reversion from adult to juvenile morphological characteristics in *Hedera helix*. It has also been shown that growth under glass (as in a glasshouse) prolongs the juvenile characteristics of *Acacia melanoxylon* (23). This could be due to a combination of factors including light intensity and light quality (glass screens out portions of the ultraviolet light).

High temperatures (especially night temperatures) are known to prolong the juvenile phase or cause reversions from the adult to juvenile phase in raspberry shoots and some herbaceous plants (7, 16, 18). For the water fern *Marsilea*, a deficiency of either organic nutrients such as carbohydrates or inorganic nutrients such as nitrogen prolongs the juvenile leaf form and induces reversions on adult plants (1). This relationship of low nutrient levels to juvenility has also been shown for the South American rubber tree. Finally, it has been observed that application gibberellic acid, a plant growth substance, to adult *Hedera* plants will induce a reversion to the juvenile type growth, if minimum temperatures are 60° F. or above (12, 20).

Some of the knowledge which we have concerning growth phases can be applied through commercial techniques and practices. The use of hedges and root sprouts as a source of cuttings which are easier to root is based on the knowledge that juvenility is retained in the base of trees even when they are quite old. The stool or mound layering technique which is used for the propagation of Malling apple stocks, currants, and gooseberries is at least partially based on this information. In graftage and cuttage propagation of plants it is important to remember that both the juvenile and the adult phases are transmitted by vegetative propagation. This means that scion wood and cuttings should be taken from adult shoots which have flowered if rapid flowering and fruiting are desired on the new plants. The knowledge that the length of the juvenile phase of some herbaceous and woody plants can be shortened by environmental factors which increase the rate of growth is being used by plant breeders to speed up flowering. Commercial growers also utilize this knowledge when they time their planting dates to take advantage of environmental conditions most favorable for the growth of their crop.

It should also be mentioned that many techniques have been used to produce earlier flowering of vegetatively propagated clonal varieties. These techniques include grafting on dwarfing stocks, girdling or ringing of trunks or branches, bark inversion on trunks or branches, and tying a knot in the stem. Sax (21) indicates that these techniques probably do not promote earlier flowering juvenile seedlings.

At the present time we really have very little control over growth phases and our desire to prolong or shorten the juvenile phase can be accomplished only in a very limited way with a limited number of species. It is encouraging to note that environment can be utilized in a few cases to modify the rate of maturation and to cause reversions from adult to the juvenile phase. Perhaps with more information the use of environment to control growth phases could be widened. The fact that adult *Hedera* can be rejuvenated by grafting onto juvenile plants (5) or by growing in the same solution culture with juvenile plants (8) indicates that translocatable chemical substances may be involved in controlling growth phases. Robbins (19) has suggested that it may some day be possible to isolate and identify substances from the juvenile stage which when introduced into the adult would cause it to become juvenile.

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MODERATOR BORK: Our next speaker is from the Department of Entomology, Cornell University. Dr. John Weidhaas.

OBTAINING EFFECTIVE DILUTIONS OF INSECTICIDES WITHIN PROPAGATING STOCK

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This paper is essentially a review of research and a progress report on systemic insecticides as they may be used on woody ornamental plants. The wording in the title was chosen to emphasize the complex nature of systemics in relation to conventional contact insecticides which are simply diluted to the proper degree and applied externally on plants. My objective here is to discuss the nature of systemic insecticides as they are used on trees and shrubs, the knowledge gained to date, and the research needs of the future if systemics are to become useful tools of the plant propagator.

A systemic insecticide was defined by Bennett in 1949 as a substance which is absorbed and translocated to other parts of the plant rendering it insecticidal. Such a definition does not include chemicals which are simply absorbed into the plant, but not translocated. Some insecticide compounds are soluble in plant lipoids and, therefore, are absorbed into plant tissue (Gunther and Blinn, 1956).

The concept of systemic insecticides has been known for centuries. Yet practical use of this method is quite recent.