SOME FACTORS ASSOCIATED WITH VEGETATIVELY PROPAGATING SUGAR MAPLE BY STEM CUTTINGS

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The Northeastern Forest Experiment Station project at Burlington, Vermont has, for several years, investigated methods of vegetatively propagating sugar maple (*Acer saccharum* Marsh.). These studies have been designed to produce a workable procedure for allowing propagators to vegetatively reproduce mature trees selected on the basis of high xylem sap sugar content. Although vegetative propagation of these "sweet trees" may offer obvious advantages to producers attempting to establish high-yielding sugar bushes, this species is quite difficult to reproduce asexually.

This report summarizes some of our findings and points out areas in which information is still lacking. The paper is divided into three major parts: 1) factors associated with development of adventitious roots; 2) methods of overwintering rooted cuttings; and 3) current propagation procedures.

FACTORS ASSOCIATED WITH DEVELOPMENT OF ADVENTITIOUS ROOTS

Seasonal changes in rooting response. Many species exhibit marked seasonal changes in ease of vegetative propagation (14). For some species, adventitious roots readily form on dormant, hardwood cuttings (11, 17, 19, 24, 26), whereas others must be propagated during the period of active growth (14). Rooting dormant cuttings offers distinct advantages; not only do they require less maintenance in the rooting bed, but also adventitious root formation during the winter allows the rooted plants to develop for a complete growing season before becoming dormant. This should improve subsequent vigor and survival of rooted material (16).

In an attempt to root hardwood sugar maple cuttings, we collected 60 cuttings at monthly intervals from each of six trees during the period mid-November through mid-March. At each collection date, half of the cuttings were immediately lined out in a heated greenhouse. The other half were stratified in moist sphagnum for 2 months at approximately 34° F and then inserted into the rooting medium. Although several broke bud, none of the 1800 dormant cuttings collected throughout the winter developed adventitious roots. Hartmann and Brooks (13) and Knight (15) reported similar results with cherry. Koelling (16) collected from 6 sugar maple trees at 2-week intervals during the period early February through mid-July. None of the dormant cuttings rooted, but almost 50% of the new shoots collected in early June developed adventitious roots.

In an attempt to correlate rooting response of softwood cuttings with phenological and physiological characteristics of the developing shoots, we collected 30 cuttings twice a week from each of four trees during the period June 2 to July 30 (5). The starting date was approximately 2 weeks after bud break. Twenty cuttings were lined out in rooting beds in the greenhouse after we had recorded their length and diameter. The 10 remaining from each collection were analyzed for starch, sugar, and nitrogen concentration. Average rooting response for the four trees increased from 16% on June 2 to 85% on June 23, and then decreased for later collections (Fig. 1).

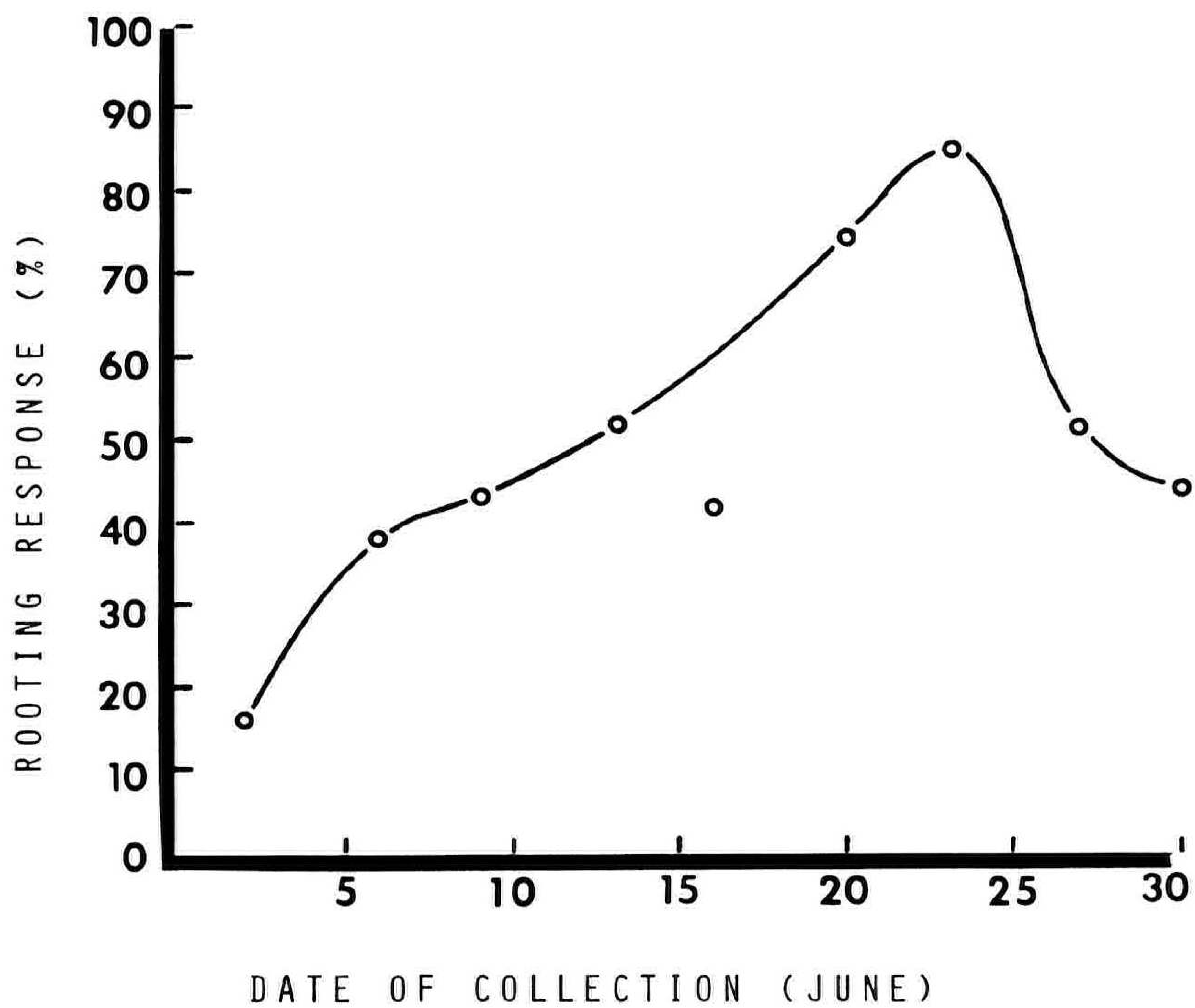

Fig. 1. Seasonal changes in average rooting of softwood cuttings from four mature sugar maple trees. From Donnelly (5).

The phenological characteristic of developing shoots most noticeably associated with rooting potential was the color of the developing shoot's terminal leaves. When a new flush of growth is produced each year, leaves at the shoot's base mature earlier than do those at the shoot tip. The date on which tip leaves appear mature in size and color coincides, approximately, with the date of maximum rooting potential. At this time, the shoot's stem is still green, and a new terminal bud has formed. This bud is approximately 0.1 inch long, and appears to consist of two dark brown scales.

The shoot's nitrogen and carbohydrate concentrations changed significantly during June. During the first half of the month, nitrogen and alcohol-soluble sugar concentrations decreased and starch concentration increased. During the latter half of the month, starch decreased slightly. Rooting potential increased while sugar and nitrogen were decreasing, but decreased approximately 1 week after these concentrations stabilized. We do not know if a direct cause and effect relationship exists between these observed chemical changes, and the shoot's potential for developing adventitious roots.

Effect of shoot size. — There are, of course, tremendous variations in the length and diameter of shoots on individual trees. For many species, large cuttings generally root better than do small ones (2, 20, 21, 25), and this relationship appears to hold for sugar maple (6, 18). We collected 300 cuttings from each of three trees, recorded their length and diameter, and lined them out in rooting beds (6). Cuttings from one tree rooted poorly regardless of size (only 1% rooted); for the other two trees, rooting response increaed substantially with increasing shoot length (Fig. 2). Also, for one tree, thick cuttings tended to root better than did thin ones. Therefore, it is recommended that propagators select sugar maple cuttings which are as long and as thick as possible. These recommendations, based on cuttings collected from mature trees, may not hold for juvenile material collected from younger plants. Morsink (18) reported that cuttings 35 to 55 cm rooted better than did longer ones.

Age of parent tree. For most species, age of the stock plant significantly affects rooting response (14). This is probably true for sugar maple also, but we have not tested the relationship because we have been primarily concerned with developing methods for vegetatively propagating mature trees. However, there are several recommended methods for stimulating juvenile wood formation on mature plants (14) and some of these should be tested on sugar maple in subsequent studies.

Genetic variability. Genetic variation in rooting response has been reported for several species including maple (3, 12, 23). We also have observed clonal variation in our recent studies. In our study to test the effect of shoot size on rooting response (6) we collected cuttings from three trees. All cuttings were treated alike, but the response varied from 1% to 61%. Two of these trees were growing on similar sites and within 100 yards of each other. However, only 19% of the cuttings rooted from one tree whereas 61% rooted from the other.

In the study in which we collected cuttings twice a week to test the effect of date of collection (5), there was relatively little difference between the 4 individual trees in peak response (70, 90, 90 and 100%). But cuttings from one tree rooted well over a period of 2 weeks whereas those from other trees only rooted well at one collection period (Fig. 3). Therefore, average response (average for all collection periods) ranged from 25% for one tree to 85% for another. These differences in the length of time plants retain their potential for developing adventitious roots may explain some of the tremendous clonal variability propagators have frequently observed when attempting to vegetatively reproduce selected plants.

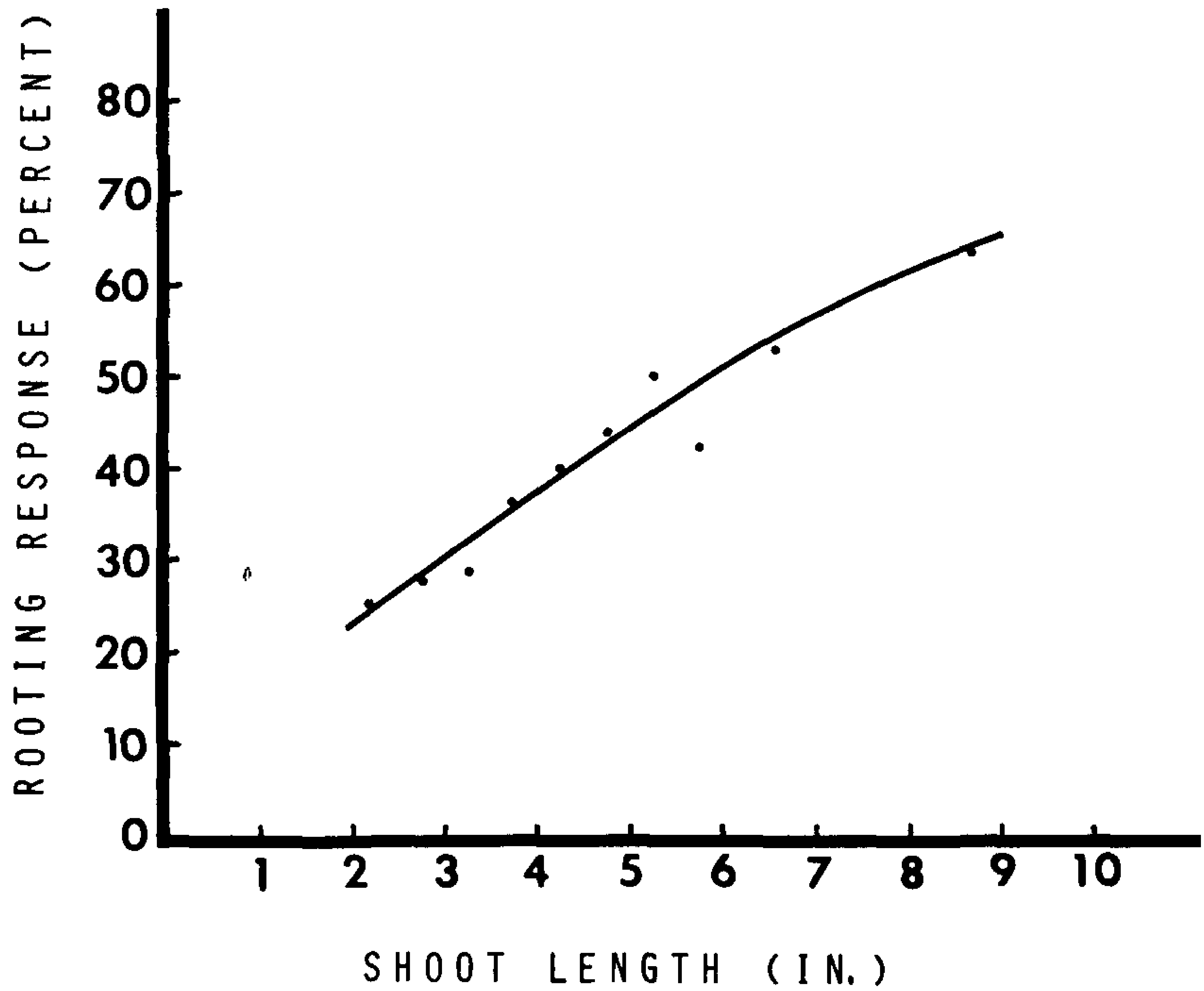

Fig. 2. Relationship between shoot length and rooting response of softwood cuttings from two sugar maple trees. From Donnelly (6).

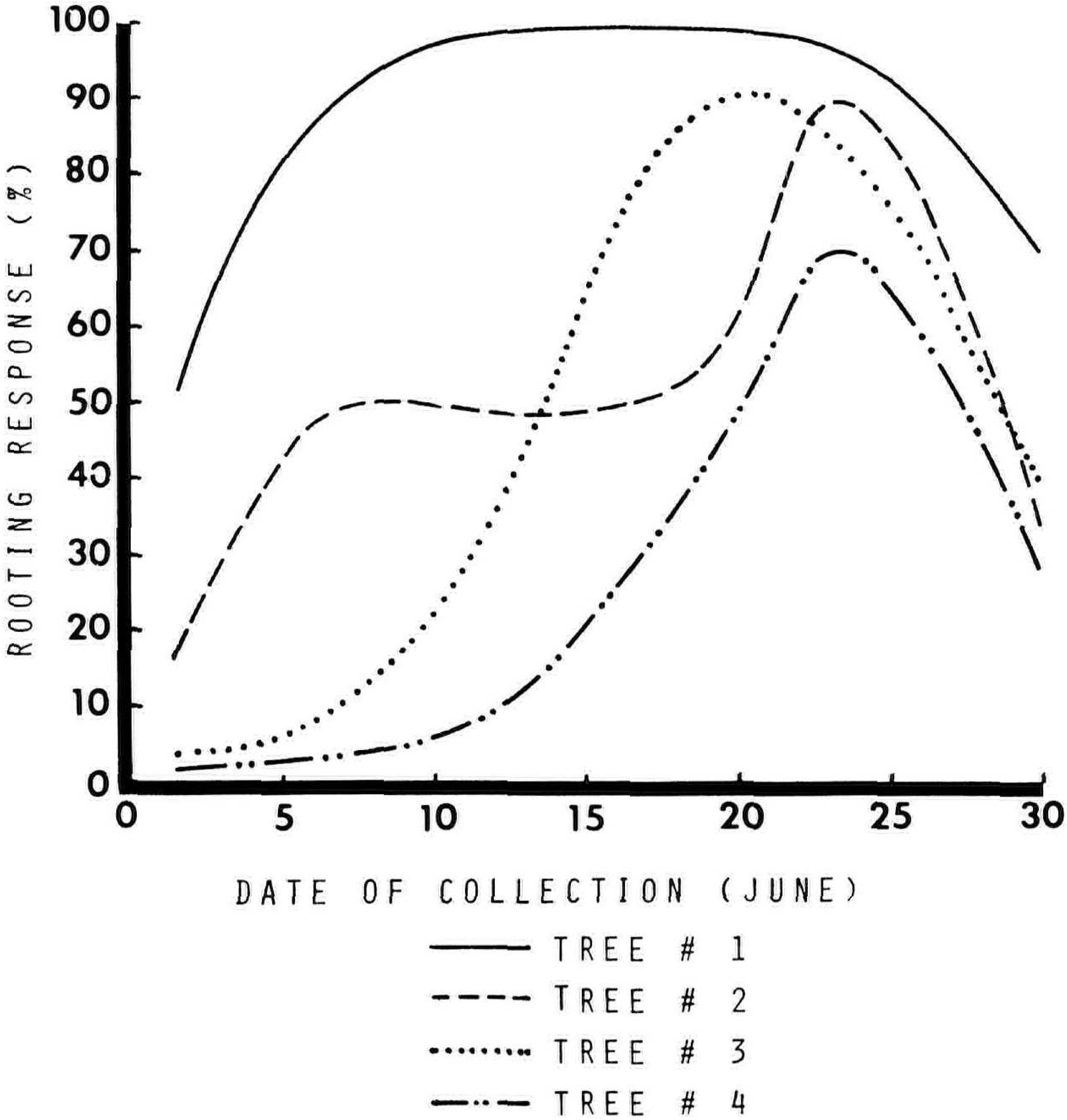

Fig. 3. Individual tree differences in the relationship between date of collection and rooting response of sugar maple cuttings. From Donnelly (5).

Effect of hormone concentration. It is generally recommended that stem cuttings be treated with some type of rooting hormone to stimulate adventitious root formation (14). We, therefore, tested the effect of several types and concentrations of hormones (4). Those tested were Hormodin No. 3, Jiffy Grow, Jiffy Grow diluted 1:1 with distilled water, diluted Jiffy Grow plus Hormodin No. 3, 0.5% IBA (indolebutyric acid) powder, 1.0% IBA powder, 2.0% IBA powder, 4.0% IBA powder, and distilled water (control). Twenty cuttings from each of three trees received each hormone treatment. When data from the three trees were lumped together and compared with controls, it appeared that undiluted Jiffy Grow and 0.5% IBA stimulated rooting; 1.0% IBA, 2.0 % IBA, diluted Jiffy Grow, and Hormodin No. 3 had no effect; and 4.0% IBA and the combination of

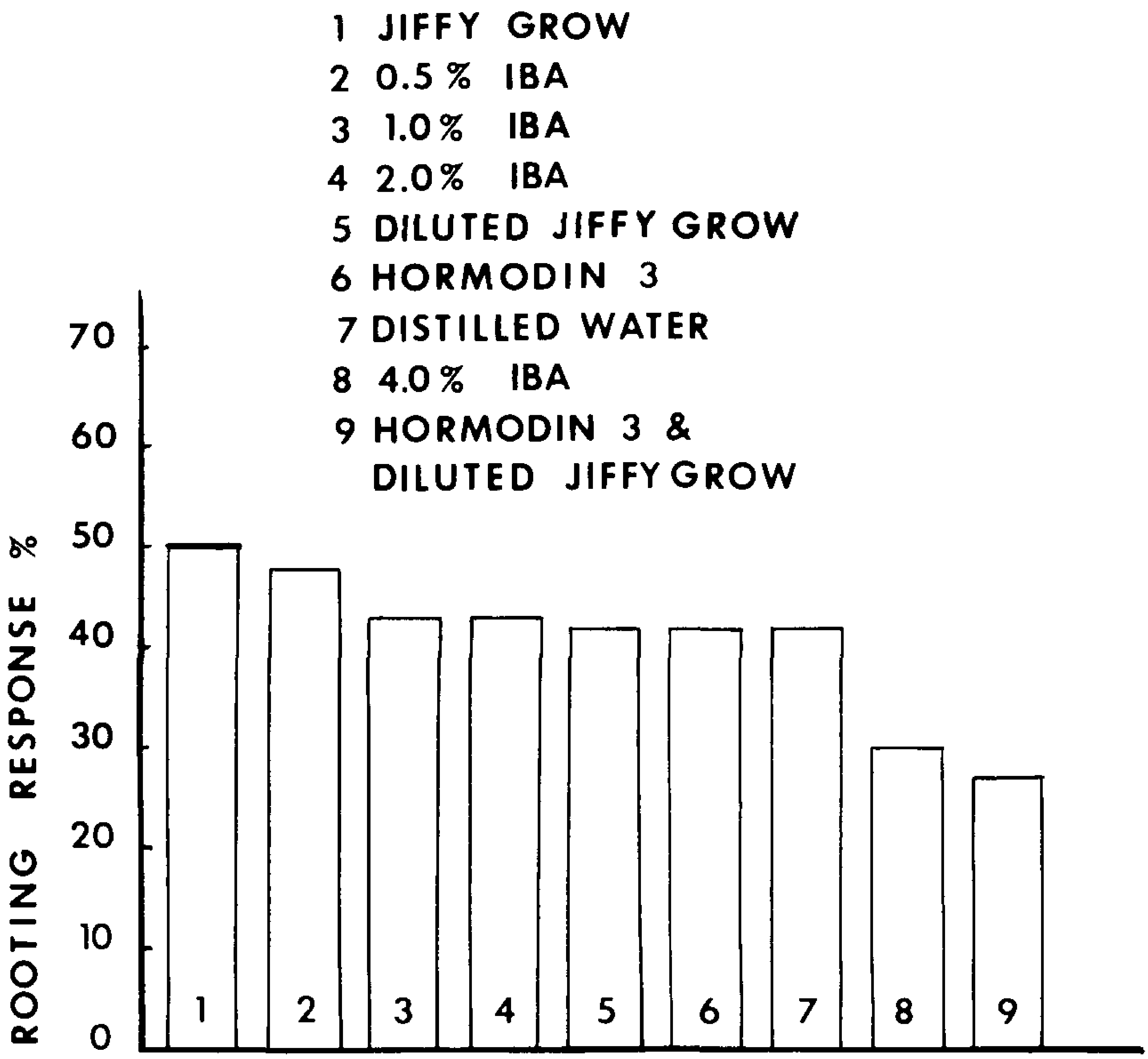

Fig. 4. Effects of different hormone treatments on rooting softwood cuttings from three mature sugar maple trees. From Donnelly (4).

Hormodin No. 3 plus diluted Jiffy Grow were inhibitory (Fig. 4). These differences, however, were not statistically significant because of the tremendous clonal variation in response. This became apparent when we compared individual tree response with various concentrations of IBA powder (Fig. 5). Cuttings from one tree rooted well (60%) without added hormones; hormones at any concentration retarded rooting. Cuttings from another tree also rooted well without hormones (60%); low hormone concentration stimulated further rooting, but high concentrations were inhibitory. The response curve for the third tree was similar to that from the second except that cuttings from this tree rooted very poorly (5%) in the absence of applied hormones.

The reason for these different responses to applied growth hormones is unknown, but it is hypothesized that they may be due to corresponding differences in endogenous auxin concentrations within the three study trees. Possibly, if auxin concentrations are low, applied hormones stimulated rooting; but if cuttings possess high concentrations of endogenous auxins, additional amounts might be toxic and inhibit rooting. The possiblility of genetic differences in the response of cuttings to applied hormones has been reported for other species (1, 7) and may have important implications in developing a program for vegetatively propagating selected hard-to-root trees.

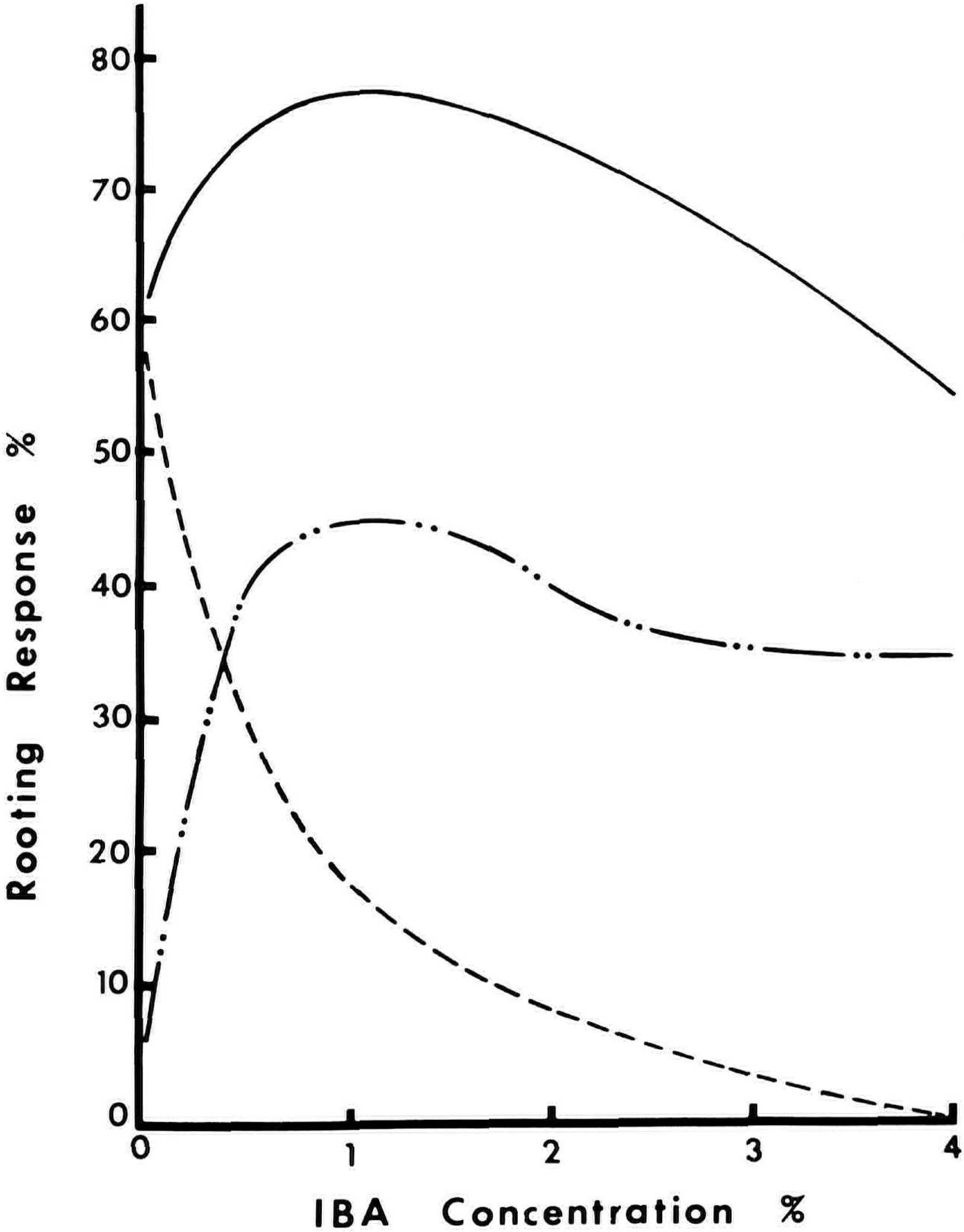

Fig. 5 Individual tree differences in the response of cuttings to various concentrations of IBA. Each line represents cuttings from a different tree. From Donnelly (4).

The significant clonal variability in rooting response observed in maple and other species may be due, at least in part, to different responses to applied hormones.

METHODS OF OVERWINTERING ROOTED CUTTINGS

Researchers have for several years been at least moderately successful in obtaining adventitious root development on sugar maple cuttings. However, most of these have failed to overwinter successfully (9, 10, 12). Therefore, in formulating a program for propagating sugar maple trees, refined methods for developing roots on selected cuttings has been only one of our objectives; a more formidable task has been to develop a method for successfully overwintering and establishing the rooted material. In attempts to improve overwintering survival, we have investigated the effects of "dormant feeding", root disturbance, and methods of storage.

Effect of dormant feeding. In late fall, rooted cuttings from four trees were watered with one of the following solutions: a) complete nutrient solution (half strength Hoagland solution); b) 2% sugar solution; c) nutrient plus sugar solution; d) distilled water (control). The solutions were added just before potted cuttings were transferred to a walk-in cooler in mid-November and stored at approximately 34° F for 2 months. At the end of this storage period, cuttings were removed from the cooler and placed in a heated greenhouse. Only 23 of the 292 rooted cuttings overwintered successfully and none of the treatments significantly stimulated survival.

Effect of overwintering storage method. In order to test the effect overwintering storage has on survival, 468 rooted cuttings were randomly assigned to one of the following treatments: 1) cuttings outplanted into the nursery in the fall; 2) cuttings potted in the fall, stored in a walk-in cooler at approximately 34° F, transferred to a heated greenhouse in March, and lined out in the nursery in June; 3) cuttings potted in the fall, stored in the walk-in cooler until May and then lined out in the nursery in June; 4) cuttings potted in the fall, stored in a root cellar, transferred to the greenhouse in March, and lined out in the nursery in June, 5) cuttings stored, unpotted, in the root cellar with roots "healed" into sand; cuttings potted and transferred to greenhouse in March and outplanted in June; 6) cuttings stored, unpotted in the root cellar, completely enclosed in polyethylene; cuttings potted and transferred to the greenhouse in March and outplanted in June; 7) same as treatment 6 except cuttings stored in the walk-in cooler rather than the root cellar. None of the cuttings outplanted directly into the nursery in the fall overwintered successfully (Table 1). For the other treatments, survival[1] varied from 32% (treatment 6) to 48%

[1]We assumed that cuttings survived overwintering storage if they were alive on August 1 of the year during which they were outplanted.

Table 1. Overwintering survival of rooted sugar maple cuttings — by overwintering treatment[1].

Treatment (see text)	Overwintering Survival Percent
1	0
2	48
3	48
4	43
5	38
6	32
7	37

[1]Approximately 65 rooted cuttings per treatment.

(treatments 2 and 3). The complete lack of survival for cuttings directly outplanted in the fall was somewhat surprising. In a preliminary study 14% of the outplanted cuttings survived and many grew quite well in the following summer.

Effect of root disturbance. We thought that lack of overwintering success might be due to excessive root disturbance when cuttings are lifted from the rooting bed. Although we generally space cuttings at intervals of at least 6 inches in the rooting bed, roots from adjacent plants may become intertwined and subsequently broken when the plants are lifted. We, therefore, tested to see if overwintering survival was increased by rooting the cuttings in individual containers. We collected 216 cuttings from each of four mature trees. One-third of these (treatment A) were lined out in rooting beds at 7- by 6-inch spacing. The remaining cuttings (treatments B and C) were rooted in individual 6-inch plastic pots filled with rooting medium. In late summer rooted cuttings from treatment A were lifted from the rooting bed and potted in 6-inch pots. Those in treatment B were repotted (rooting medium exchanged for potting soil), and those from treatment C remained in the rooting pots. All rooted cuttings were gradually hardened off and transferred to a walk-in cooler where they were stored for approximately 5 months at 34° F. Plants were lined out in the nursery in early May. Thirty percent of all cuttings rooted and were successfully overwintered (Table 2). Treatment differences were not statistically significant, but success was somewhat higher for cuttings repotted in the fall (treatment A and B). Thus, root disturbance due to lifting and repotting does not appear to be an important cause of overwintering mortality.

We might now point out some possible reasons for the high overwintering mortality of rooted sugar maple cuttings. We have long felt that mortality is due to the low vitality of cuttings when they enter fall dormancy (12). Observations have tended to sub-

Table 2. Percent of sugar maple cuttings which develop adventitious roots and overwinter successfully — by treatment of cuttings in the rooting beds[1].

Treatment (see text)	Establishment percent
A	34
B	32
C	24

[1]288 cuttings per treatment.

stantiate this hypotheses. In the "dormant feeding" study we analyzed a sample of the rooted cuttings for their fall concentration of carbohydrates and compared these data with those obtained form 1-year-old maple seedlings. The total carbohydrate concentration was over 20% dry weight for seedlings, but less that 10% for rooted cuttings. These low carbohydrate reserves may have been insufficient to support spring growth (12). This may partially explain why over 60% of the plants resumed growth after winter storage (bud swell was evident), but only 8% remained alive in early May.

Assuming low vigor (as reflected by corresponding low levels of carbohydrate reserves) is a major cause of overwintering mortality, we might investigate reasons for this lack of vigor. Vigor appears to be related to inherent conditions present within the shoot when it was severed from the parent tree, and is also, undoubtedly, affected by the propagation techniques (environmental conditions) employed after the shoot has been collected. We pointed out that certain cuttings (those of a given size or those from a particular tree) have a high potential for developing adventitious roots. These cuttings also seem to have a high potential for overwintering successfully. We collected cuttings from eight trees and found rooting response to vary from less than 10% to more than 90%. Only about 18% of the rooted cuttings form the "poor rooters" overwintered successfully, whereas 65% of those from the "best rooter" became established (Fig. 6). In other words, less than 2% of all cuttings collected from "poor rooters" became established in contrast to nearly 60% from the "best rooter." Similar results were observed in another study in which cuttings were obtained from four trees. Rooting percentage for one tree was substantially lower than that for the others, and the percent of rooted cuttings from this tree which successfully overwintered, as well as the average shoot growth and vigor[2] of established plants was much lower (Fig. 7). We have observed a

[2]Relative vigor based on subjective evaluation of 1 point for cuttings in "poor" condition, 2 points for those in "fair" condition, 3 points for those in "good" condition and 4 points for those in excellent condition.

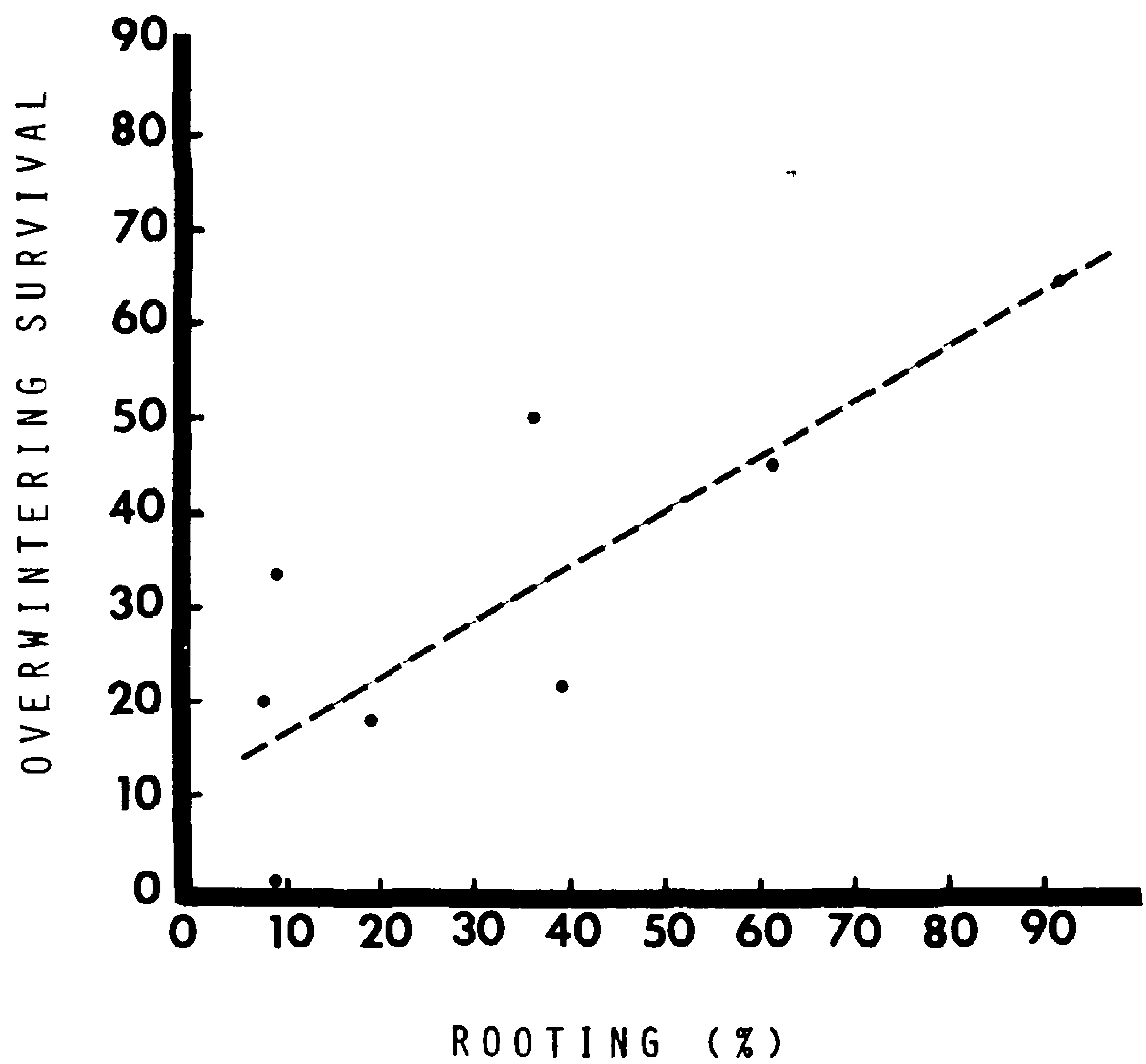

Fig. 6. Relationship between rooting response and overwintering survival of sugar maple cuttings.

similar relationship for shoot size. Not only do large cuttings have a greater potential for developing adventitious roots (Fig. 2) but also a greater percentage of the large rooted cuttings become established plants (Fig. 8).

Of course, propagation techniques, as well as inherent qualities, influence the relative vigor of the rooted plant. After we acquired a rooting greenhouse with relatively sophisticated environmental controls in 1966 and refined our methods for collecting and handling cuttings (as outlined in the next section), the quality of our rooted material improved substantially. And, as might be expected, a close correlation exists between overwintering survival and quality of the adventitious root system (Fig. 9).

Although we have not completely solved the problem of successfully propagating mature sugar maples, we are making progress. In an early report from our project (12) few of the collected shoots overwintered successfully, and in the 1965 "dormant feeding" study only 23 of approximately 2500 shoots (less than 1 percent) survived. This is in contrast with the 30 percent survival we have obtained in a subsequent study.

CURRENT PROPAGATION PROCEDURES

Some of the recommendations in this procedure are based on the results of studies previously discussed; others are based on generally accepted propagation practices.

We collect softwood cuttings when their terminal leaves appear mature and new terminal buds have formed. In northern Vermont, shoots generally reach this stage of development in mid-June, but

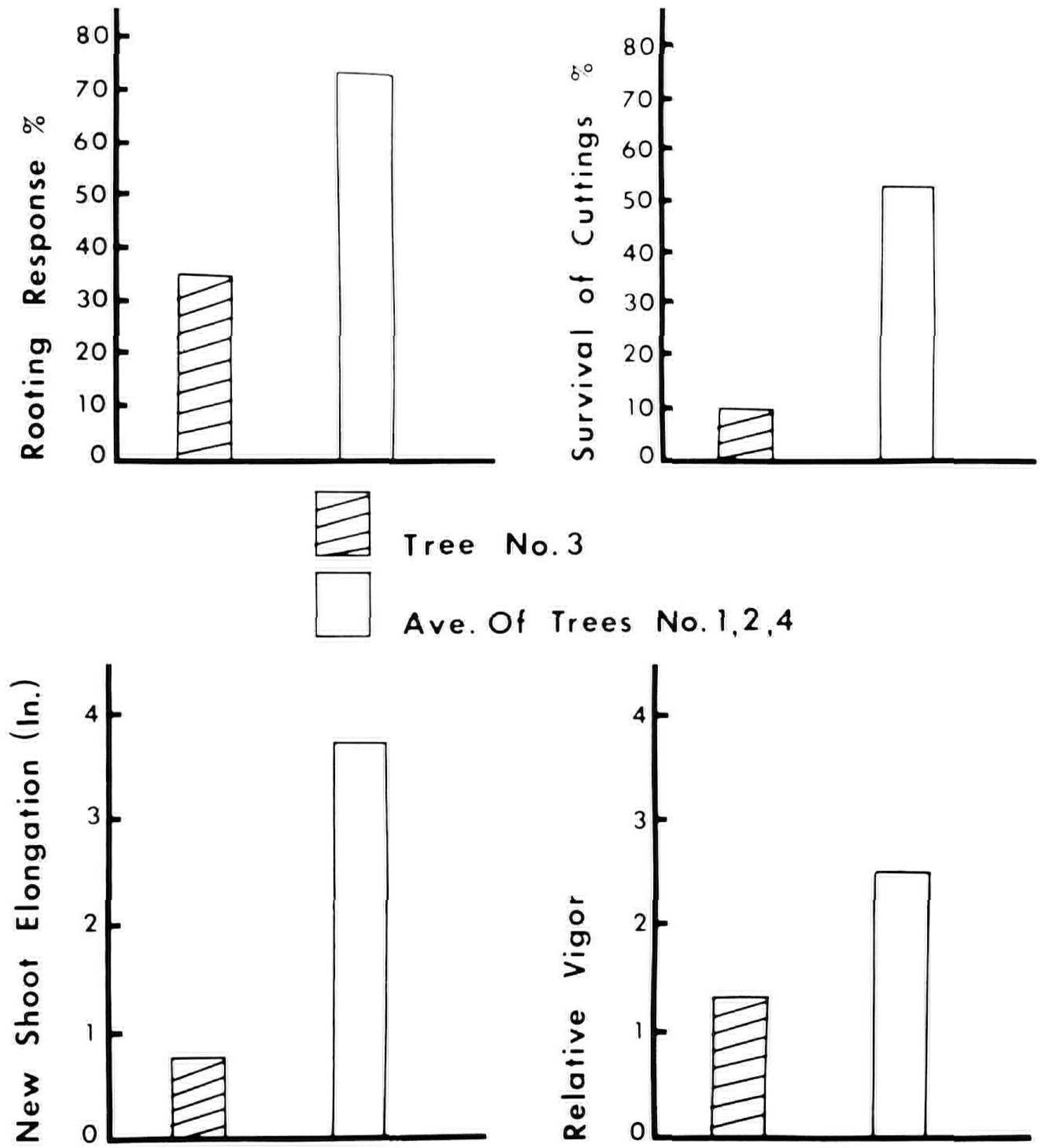

Fig. 7. Individual tree differences in rooting response, overwintering survival, new shoot elongation, and relative vigor of surviving plants.

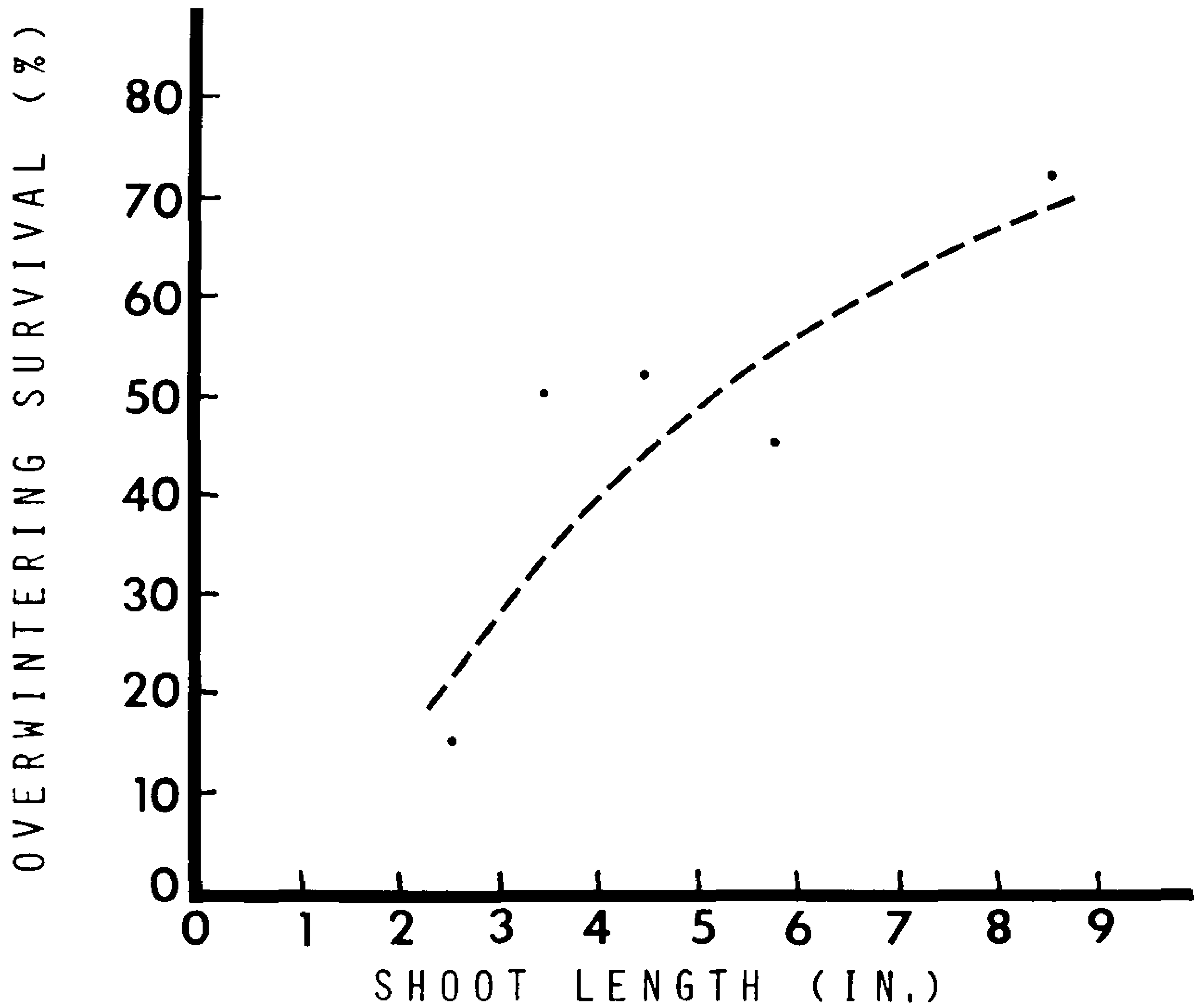

Fig. 8. Relationship between shoot length and overwintering survival of cuttings from one mature sugar maple tree.

this may vary by at least 2 weeks depending upon current-year weather conditions. Selected cuttings from mature trees should be as long as possible because of the relationship between shoot length and rooting response When clipping cuttings we sever them from the tree with a pruning pole and immediately cover with moist sphagnum enclosed within wet burlap or place them in a styrofoam cooler to prevent desiccation. We collect the entire current-year's growth plus a couple inches of older wood. In the rooting greenhouse, cuttings are prepared by removing the older wood, wounding the stem by making an approximately 1/2 inch long cut on two sides of its basal end, removing all leaves from the stem's lower 2 inches to facilitate sticking, dipping the cutting into Jiffy Grow and sticking it to a depth of 2 inches into the rooting medium (1·1 mixture of coarse perlite and shredded sphagnum moss).

Our primary rooting facility is a 20 x 60 foot greenhouse covered with clear polyethylene plus a layer of 50% saran shade cloth to reduce insolation. In order to further reduce overheating, the greenhouse is supplied with two coolers and two exhaust fans and a series of thermostatically controlled nozzles spray mist on the greenhouse roof. With this equipment we are generally able to keep

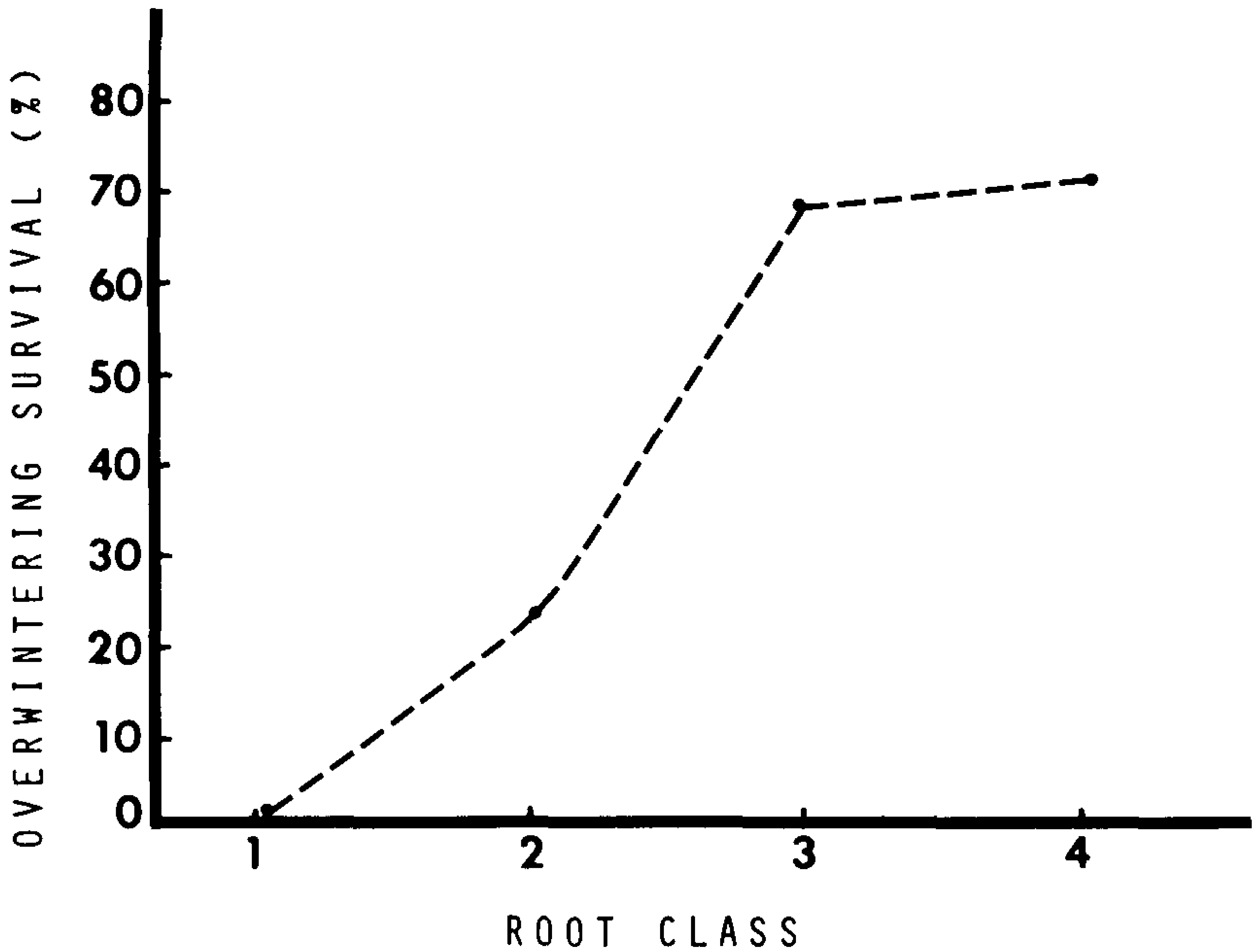

Fig. 9. Relationship between relative root quality (root class) and overwintering survival of rooted sugar maple cuttings.

maximum day time air temperature below 85° F. Electric heaters maintain a 60° F minimum night temperature. Temperature of the rooting medium is maintained at 80° F with thermostatically regulated heating cables. Cuttings are kept moist with an intermittent mist system automatically regulated by a MacPenny mist control. In recent studies we used clock timers set to apply mist for 3 seconds every one-half minute. Supplemental lighting, 150 watt incandescent lamps placed approximately 3 1/2 feet above the rooting beds, provides a 20-hour day length.

The three rooting beds are 4 feet wide and 48 feet long. Cuttings are lined out at a spacing of 7 x 6 inches (7 inches between cuttings within a row; 6 inches between rows). With this spacing the 20 x 60 foot greenhouse will hold approximately 2000 cuttings.

Adventitious roots generally develop within a period of 1 to 3 months. Our current method of preparing rooted cuttings for overwintering storage is to begin hardening-off procedures in early September by gradually cutting down on the rate of mist application and reducing the day length while plants are still in the rooting beds. Plants are lifted and potted in mid-September (approximately 3 months after sticking). The potting medium is a 1:1:1 mixture of perlite, loam and peat. Potted plants are kept in the greenhouse, the heat is turned off, and plants are hand watered when necessary. In mid-November plants are transferred to a walk-in cooler and stored at approximately 34° F. Physiological dormancy is broken within 2 months. At this time (mid-January) plants may be transferred to a heated greenhouse or they may be allowed to remain in the cooler until early May and then outplanted directly into the nursery.

We are currently testing a different procedure for treating rooted cuttings. As previously stated, adventitious roots may develop after 1 month, or may not form until at least 3 months after sticking. Because of this, we are experimenting with lifting and potting each cutting as soon as it has developed a 1/4 inch long adventitious root. After the rooted cutting has been potted, the surface of the pot is covered with a piece of stiff plastic and the potted plant is placed back under the mist. In this way, the plant's leaves are kept moist, but the soil does not receive an excessive amount of water. In early September mist applications are gradually reduced. By this time, an extensive root system has generally developed within the pot. These plants are then treated in the same manner as that previously outlined for those not potted until September. We have no data yet on overwintering survival for rooted cuttings treated by this method, but the plants currently appear to be in very good condition.

SUMMARY

In this report we have outlined some of our results from studies designed to stimulate rooting and overwintering survival of sugar maple stem cuttings. Studies designed to stimulate rooting have investigated seasonal changes in response, effects of shoot size, and effects of hormone concentration. Sugar maple cuttings root best if collected in late spring when elongation of the current-year shoot has essentially ceased and developing leaves appear mature in size and color. Considerable variation exists in the size of current-year shoots on a particular tree, and our findings point out corresponding variations in rooting response; for best results with mature trees propagators should collect cuttings that are as long and as thick as possible. We have obtained mixed responses with hormone treatments: for some trees, low concentrations of growth hormone appears to stimulate rooting; for others, hormones in any concentration are inhibitory.

In attempting to increase overwintering survival, we have tested the effects of "dormant feeding", methods of overwintering storage, and effects of rooting cuttings in individual containers to reduce root damage when plants are lifted and potted. "Dormant feeding", by watering rooted cuttings in the fall with sugar and nutrient solutions,

did not significantly stimulate survival. Neither did rooting cuttings within individual pots. In general, few of the rooted cuttings lined out in the nursery in the fall have survived. Survival is much better if cuttings are potted in late summer, hardened off, transferred to a cooler and stored at 34° F, and lined out in the spring.

Overwintering survival definitely appears to be correlated with relative vigor. Large rooted cuttings overwinter better than do small ones, those with a well-developed root system overwinter better than do those with small roots, and those collected from a "good rooter" overwinter better than do those from a "poor rooter."

Our goal has been to successfully root and overwinter 25 percent of the cuttings collected. We feel that with our improved greenhouse facilities and rooting techniques we can consistently attain this goal for cuttings collected from certain easy-to-root trees. For other trees, however, our success rate has been very low. Refinement of procedures to successfully propagate cuttings from these latter trees will be one of our objectives in subsequent investigations.

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RALPH SHUGERT: Thank you very much; that was certainly an interesting report

Our next speaker is another long time friend of the Society, Ray Halward; he is going to discuss the propagation of *Rhus aromatica* by softwood cuttings