VEGETATIVE PROPAGATION OF EASTERN WHITE PINE BY CUTTINGS†

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ABSTRACT

Rootability studies of eastern white pine (**Pinus strobus** L.) cuttings taken from 17-year-old ortets showed, contrary to previous work, that cuttings taken in June consistently rooted best. Optimum concentration of indole-butyric acid (IBA) varied with the date cuttings were taken. With 0.1% IBA treatment, about 60% of cuttings taken in June rooted; with 0.4% IBA, about 50% of cuttings taken in May rooted; with 0.8% IBA, 42% of cuttings taken in April rooted. Cuttings taken in June produced significantly more roots than cuttings taken in other months. Approximately 60% of cuttings were rooted within 16 weeks when collected in May and June and treated with a suitable concentration of IBA + Benlate. On cuttings taken in June there was a positive correlation between the number of roots per rooted cutting and the number of young shoots. High mortality was observed in those cuttings with many young shoots. The results suggest that June cuttings with a medium number of young shoots are best for propagation. These findings make propagation by rooted cuttings practical for this species.

INTRODUCTION

Vegetative propagation is very valuable in forest tree improvement programmes as individual trees with desirable characteristics can be multiplied without changing their genetic makeup. Cuttings have many intrinsic advantages over grafts but those from a majority of conifers and many forest hardwoods are difficult to root (Thomas and Riker, 1950). With such species, it is essential to develop reliable techniques before the advantages of propagation by cuttings can be realized.

Eastern white pine (*Pinus strobus* L.) is one of the most important forest trees in the northeastern and Lake States regions and in eastern Canada; it has generally been considered difficult to root from cuttings (Deuber 1942).

An intensive study on rooting white pine cuttings was initiated in 1971 to develop a better technique. The specific objects of the investigation were to examine (1) the rooting response of cuttings collected in different months of the year, (2) the effects of indole-butyric acid (IBA) and fungicide treatments on rooting, (3) the rooting behaviour of cuttings, and (4) the subsequent survival of rooted cuttings.

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LITERATURE REVIEW

Vegetative propagation of white pine has received considerable attention; a brief review of past experiments will aid in a better understanding of the problems in rooting cuttings.

Age of Donor Tree

Age of donor trees (ortets) is the most important single factor in rooting white pine cuttings. It is generally agreed that cuttings from young trees (2 to 3 years old) root easily, but the rooting percentage decreases with increasing age of ortets (Gardner 1929; Thimann and Delisle 1939; Deuber 1942). Cuttings from trees over 10 years of age seldom formed roots (Thomas and Riker 1950; Patton and Riker 1958). All results of past experiment indicate that formation of roots is controlled by the age of ortets rather than by the age of the wood in the cuttings.

Seasonal Difference in Rooting Response

The time of collecting cuttings is an important factor in rooting response but there is no general agreement in past reports about the best time of year for collection. Farrar and Grace (1942) obtained the best results with white pine cuttings collected in late August, whereas Doran (1946, 1957) had best results with cuttings taken in February, but poor results with those taken in spring and early summer. Thomas and Riker (1950) reported that cuttings taken between the middle of July and the middle of September rooted best, and cuttings collected in the spring did not root as well. It was also reported that dormant cuttings rooted better than summer cuttings (Thimann and Delisle 1942; Stack 1970). In contrast, Thielges and Hoitink (1972) reported that soft cuttings collected in late June showed the best rooting response. Fluctuation in rooting response of white pine cuttings from year to year was observed by Patton and Riker (1958). They postulated that the environment affecting ortets prior to the time of taking cuttings might be important in the subsequent rooting.

Chemical Treatment

In many species the application of plant growth hormones generally improves the rooting ability of cuttings. White pine cuttings showed a positive response to auxin treatment in rooting and IBA proved to be more effective than both indole-acetic acid (IAA) and naphthalene-acetic acid (NAA) (Hitchcock and Zimmerman 1939; Thimann and Delisle 1942; Thomas and Riker 1950; Patton and Riker 1958). The method of treatment and the optimal IBA concentrations varied among investigators (Thimann and Delisle 1942; Doran 1946; Patton and Riker 1958; Stack 1970). The most common methods of treating cuttings were soaking and quick dipping the bases in an aqueous solution of growth regulators, or dipping the bases into a mixture of growth substances and talcum powder.

Other chemicals were tried either singly or in combination with growth hormones, but the results were not as good as cuttings treated with IBA alone (Thomas and Riker 1950; Patton and Riker 1958).

Recently some fungicides such as Benlate, Captan and Phygon XL were used alone or in mixture with IBA in rooting white pine cuttings. The results showed that IBA and fungicide treatment improved the rooting percentage (Stack 1970; Thielges and Hoitink 1972).

Rooting Media

The most commonly used rooting media are sand, perlite, peat moss, and vermiculite. Zufa (1969) reported that coarse sand with a bottom layer of white pine humus was superior to sand alone or to a mixture of sand and humus. Thielges and Hoitink (1972) obtained better rooting with peat : perlite (1 : 1) than with sand : soil or soil : peat (1 : 1). No difference was found in rooting percentage between used and fresh media, nor between sterilized and unsterilized media (Doran 1946).

Cutting Size, Age, and Position on Trees

Deuber (1940) reported that white pine cuttings from current season shoots rooted better than older cuttings, and that short cuttings (5-15 cm) rooted better than longer ones. That softwood cuttings showed good rooting response was reported by Thielges and Hoitink (1972). However Nienstaedt *et al.* (1958) suggested that one-year-old branch hardwood cuttings were best. Riker (1948) found cuttings taken from rapidly growing shoots did not root as easily as those from slower growing twigs. It is generally agreed that cuttings taken from lower branches rooted better than those from terminal shoots (Thimann and Delisle 1939; Doran *et al.* 1940; Deuber 1942; Doran 1957; Thomas and Riker 1950). Doran (1946) found cuttings from the north side of the tree rooted slightly better than those from the south side, but the difference was statistically not significant.

MATERIALS AND METHODS

Seasonal Influence and IBA Concentrations

Sixty cuttings of current year wood were collected monthly from four 17-year-old white pine trees growing on the University of New Hampshire campus at Durham and 50 cuttings from a 30-year-old tree in Bedford, New Hampshire. Cuttings were trimmed to about 12 cm long. The newly-cut bases of cuttings were dipped for 5 seconds in five levels (0.1, 0.2, 0.4, 0.6 and 0.8%) of freshly made IBA in 1% Benlate-95%-ethyl alcohol solution. Treated cuttings were immediately inserted in a rooting medium contained in 10 × 5 × 25-cm polyethlene bags. Two bottom corners of the bags were cut open for drainage.

The medium was a mixture of peat moss : fine tree bark : old sawdust (1 : 1 : 1). Cuttings were kept in the mist bench in a glasshouse. At the end of 16 weeks they were examined and those unrooted or dead were discarded. Rooted cuttings were potted and kept in a cool glasshouse for planting out.

Root System and Number of Young Shoots on Cuttings

In order to examine whether there exists a correlation between the number of young shoots (candles) on the cuttings and the root system of rooted cuttings, 120 cuttings were collected in early June from six 18-year-old white pine trees on Durham campus. The cuttings were divided into 6 groups by the numbers of candles on the cuttings (0, 1, 2, 3, 4 and 5 or more). The cuttings were treated with 0.6% IBA solution, and planted in the rooting medium contained in metal tubes.

RESULTS AND DISCUSSION

Rooting Response and Time of Collection

The results showed that cuttings collected in June consistently rooted best; those taken in May were next best (Table 1) and those taken in the period September to

February inclusive gave poor results. This rooting pattern was also observed on cuttings taken from the 30-year-old tree. Cuttings taken from this older tree in June rooted 26% for two consecutive years. Very few rooted cuttings were obtained from cuttings taken in other months.

TABLE 1—Monthly rooting response of eastern white pine cuttings from 17-year-old trees (two-year average; all IBA concentrations pooled).

	Rooting %	Callus %	Dead %	No. of roots/ rooted cutting	Symmetrical root* %
Jan.	0	0	42	0	0
Feb.	0	0	40	0	0
March	0	8	20	0	0
April	23	10	38	1.9	8
May	29	0	29	2.2	33
June	46 (26)†	17 (45)	20 (8)	3.0 (1.6)	43 (5)
July	26	21	13	1.6	16
Aug.	3	35	15	1.3	0
Sept.	4	29	18	1.0	0
Oct.	2	14	20	2.0	50
Nov.	0	8	54	0	0
Dec.	4	61	28	3.0	40

* cuttings with 3 or more roots in balanced positions
† results of cuttings taken from the 30-year-old tree

The rooting percentage increased steadily from cuttings taken in April and May, reached a peak in June, and then began to decline. This rooting pattern was contrary to previous reports by other authors (Farrar and Grace 1942; Thimann and Delisle 1942; Doran 1946).

In our experiments current year hardwood cuttings were used, with the exception of softwood cuttings in July. In June all buds are in the soft candle stage and cuttings were made from one year hardwood with rapidly elongating young shoots.

Rooting Response and IBA Concentration

Cuttings taken in different months of the year responded differently to IBA concentration (Table 2). June and July cuttings rooted best when treated with 0.1% IBA solution. May cuttings did best with 0.4% and 0.6% IBA treatment. However, cuttings from trees of different ages also seem to respond differently to IBA concentration. June cuttings from the 30-year-old tree rooted best with 0.6% IBA treatment.

TABLE 2—Percentage rooting of white pine cuttings from 17-year-old trees treated with various IBA concentrations

IBA (%)	0.1	0.2	0.4	0.6	0.8
Jan.	0	0	0	0	0
Feb.	0	0	0	0	0
March	0	0	0	0	0
April	30	10	20	10	42
May	20	10	50	50	18
June	60 (15)*	50 (10)	35 (10)	30 (45)	50 (20)
July	40	35	15	20	8
Aug.	20	0	0	0	4
Sept.	0	0	0	10	0
Oct.	0	0	0	0	8
Nov.	0	0	0	0	0
Dec.	0	13	4	0	0

* Percent rooting of cuttings from the 30-year-old tree

However, when the total rooting percentage was compared by Duncan's multiple range test (Duncan 1955), the rooting differences of cuttings treated with various concentrations of IBA were found to be non-significant. There seems to be no optimal IBA concentration for all seasons, but there does seem to be an optimal concentration for particular months.

The seasonal variation of cuttings in response to IBA concentration may be explained by seasonal fluctuation in the level of endogenous growth substances in shoots (Ogasawara 1961; Hong 1969). The biological activity of growth substances, which are active in root promotion may depend on their concentration in the plant (Hong 1969). It has been reported that juvenile tissues contain high levels of growth substances and root-promoting substances (Hess 1962; Hong 1969). It is probable therefore that cuttings from older trees contain smaller quantities of growth substances than those from younger ones, and that dormant shoots contain lower levels of growth substances than actively growing ones. Thus, cuttings collected from an old tree may need a higher concentration of IBA treatment to induce a good rooting response and, because of the presence of actively growing shoots, cuttings taken in June need to be treated with a high concentration of IBA solution for root formation.

Number of Roots and Root System

Past reports indicate that white pine cuttings usually produce a small number of roots with a poor root system (Farrar and Grace 1942; Thomas and Riker 1950). Our results showed that June cuttings gave the highest average number of roots and the

highest proportion of rooted cuttings having a symmetrical root system (Table 1). Cuttings treated with 0.4% IBA produced more roots per rooted cutting (Table 3).

TABLE 3—Effects of various IBA concentrations on rooting white pine cuttings*

	IBA concentration (%)				
	0.1	.2	.4	.6	.8
Average % rooting	50	38	31	29	32
No. of roots/rooted cutting	2.5	2.0	3.7	2.3	2.2

* including 2 years' cuttings from four 17-year-old ortets taken in April, May, June, and July. Cuttings taken in other months excluded

Thomas and Riker (1950) found it difficult to lift and transplant rooted cuttings because of their horizontal and unilateral root systems. In our investigation cuttings were planted either in polyethylene bags or in metal tubes (Hill and Libby 1969). No rooted cuttings with horizontally growing roots were observed. Tubing greatly improves the root system and the rooted cuttings can be lifted and transplanted with a minimal loss.

Clonal Variation in Rootability

Variation in rooting ability of cuttings from the four 17-year-old ortets was observed (Table 4). Duncan's multiple range comparison showed that cuttings from ortet 4 rooted significantly better than those from ortet 3. When the average number of roots per rooted cutting was compared, cuttings from ortet 4 produced significantly more roots than those from the other three ortets. The correlation coefficient ($r = +.77$) between percentage rooting and average number of roots per rooted cutting was highly significant among the four ortets.

TABLE 4—Comparison of rootability among four 17-year-old ortets†

	Ortet 1	Ortet 2	Ortet 3	Ortet 4
Average % rooting	40	22	17	49
No. of roots/rooted cutting	1.8	1.7	1.6	3.6

† including 2 years' cuttings taken in April, May, June, July. Cuttings taken in other months excluded.

Length of Time to Root

The evidence indicates that very few cuttings initiated roots after a 16-week period in the rooting medium. In order to test the effect of a longer rooting time, 40 unrooted healthy cuttings taken in June and September were returned to the mist bench after examination. Twelve weeks later, only one of them had rooted. Evidently cuttings not rooted after 16 weeks can be discarded.

The Root System and Number of Young Shoots

A significant variation in the number of roots per rooted cutting was found among the six groups of cuttings with different number of candles (F test) (Table 5). The correlation coefficient between the number of candles and the number of roots on rooted cuttings was highly significant ($r = + .41$). Using Duncan's multiple range comparison, cuttings with 5 or 5+ candles produced significantly more roots per rooted cutting than those with 0, 1, and 2 candles. Cuttings with 3 and 4 candles also produced more roots than those without candles. A significant difference in cutting mortality was also observed: it increased with an increasing number of candles.

TABLE 5—Relationship between the number of young shoots on white pine cuttings and rooting response

No. of young shoots	0	1	2	3	4	5+
Percent rooting	55	45	50	30	20	10
No. of roots/rooted cutting	1.5	2.4	2.6	3.7	3.5	4.5
Percent cuttings mortality	5	5	20	50	55	85

Why cuttings with more candles produced better root systems is unknown. It is probable that the candle contains a high level of root-promoting substances. The high mortality observed in cuttings with a greater number of candles can be attributed to the fact that soft candles are very susceptible to dehydration and pathogen attack. Another possible explanation is that in addition to the high content of growth substances in candles, a high concentration of IBA treatment may have injurious effects on cuttings with higher number of candles.

Viability of Rooted Cuttings

The rooted cuttings (ramets) were kept in a cool glasshouse for one year before being planted in the field. The ramets showed vigorous growth in the glasshouse in the first spring, some even produced strobili. During a one-year period in the glasshouse, less than 2% of the ramets died. In mid-August 26 ramets were transplanted to the field, and all survived the first winter, with vigorous growth in the spring.

CONCLUSIONS

Two years' investigation on rooting cuttings of eastern white pine showed that cuttings taken in June consistently rooted better than those taken in other months, with May cuttings next best. IBA in 1% Benlate-95% ethyl alcohol solution was found to be effective in inducing rooting. Seasonal variation in rooting response to IBA concentration was observed. The optimal concentration of IBA for cuttings collected in June was 0.1%, for those taken in May 0.4%.

Good results were obtained by using current year hardwood cuttings in 10 to 12-cm lengths from lateral branches.

Cuttings planted in polyethylene bags or galvanised steel tubes filled with a mixture of peat moss : tree bark : sawdust (1 : 1 : 1) were found to produce good root systems.

Cuttings treated with 0.4% IBA on average produced a greater number of roots. A positive correlation between the number of candles on cuttings and the number of roots was found in cuttings taken in June. The cutting mortality increased with the

number of candles on cuttings. Cuttings taken in June with a medium number of candles gave the best rooting percentage with good root systems.

Clonal variation in rootability was observed. Cuttings from easy-to-root trees tend to produce more roots.

Approximately 60% of cuttings from 17- and 18-year-old trees and 45% of cuttings from a 30-year-old tree were rooted in 16 weeks when the cuttings were collected in June and treated with a suitable concentration of IBA and Benlate solution. Vegetative propagation by rooted cuttings on a large scale is feasible for this species.

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