ROOT REGENERATION STUDIES IN TAXUS

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ABSTRACT

ROOT REGENERATION STUDIES IN *TAXUS*.

By Arthur J. Olney

An investigation was conducted to establish if there was a difference in the rootability of *Taxus* clones and if this difference could be related to anatomical or sexual differences of the clones.

Seven clones of *Taxus*, plus male and female *T. cuspidata expansa* Hort. were propagated by tip cuttings during the winter of 1963-1964. The cuttings were placed in a sand media and kept under intermittent mist during the experiment. Anatomical studies were made of the stems of the rooted cuttings during the winter of 1965. The transverse sections of stem were examined for the number of fiber bands, and the thickness of bark to wood in each section.

Results of this study show a definite difference in the rootability of *Taxus* clones. *T. media* 'Hatfield' showed the highest rootability and *T. cuspidata* 'Nana' exhibited the lowest. Cuttings taken from male *T. cuspidata expansa* rooted more readily than cuttings taken from female plants. The anatomical studies showed no relationship between structures studied and rootability.

ROOT REGENERATION STUDIES IN TAXUS.

by

Arthur J. Olney

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INTRODUCTION

Plant propagation has been defined as "the controlled reproduction of plants by man to perpetuate select individuals or groups of individual plants which have specific value to him." (14) The propagation of plants is the starting point for all crop production, and as such is of fundamental importance to the field of horticulture. Plant propagation may be easily subdivided into two major divisions: sexual reproduction and asexual or vegetative reproduction. Due to the fact that many ornamental species have seeds with complex dormancy mechanisms which hinder germination, asexual reproduction is employed with these plants. Asexual propagation of ornamental plants on a commercial scale is done cheifly by means of cuttings. Since a greater uniformity of plants can be obtained, and a larger number of new plants can be produced from a relatively small number of stock plants, cuttings fits well into the scheme of mass production. Many factors affect propagation of ornamental plants by cuttings. One of the most important of these factors is the inherent rootability of the cuttings. Two of the inherent factors which affect rootability[1] are sexual and anatomical differences. Beakbane (4) has reported that the anatomy of a cutting may affect its rootability; Snow (26) observed differences in rooting associated with the sexual character of red maple cuttings.

Taxus, a dieocious plant, (1) occurs commercially in

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1 Rootability - the tendency of a cutting to form roots.

varieties of mixed sexes, and in clones which are either male or female. It has been observed that cuttings from different clones of Taxus vary in their degrees of rootability (30).

It has been the scope of this study to attempt to establish if there was a difference in the rootability of Taxus clones and if this difference could be related to anatomical or sexual differences of the clones.

A REVIEW OF PERTINENT LITERATURE

ANATOMY IN RELATION TO ROOTING AND VIGOR

Work which started in 1912, at the East Malling Research Station, England, led to the development of a series of clonal apple rootstocks (14). The different rootstocks were observed to influence scions grafted upon them by producing trees which ranged from large, vigorous trees to plants which were definitely dwarfed.

Beakbane, et. al. (2) studied the anatomical structure of the East Malling rootstocks in an attempt to correlate anatomical features of the plants with the rootstock effect. She found that in dwarfing rootstocks that the proportion of bark[2] to wood was very high, while in the vigorous rootstocks the proportion of bark to wood of the roots was quite small. On the dwarfing rootstocks the roots were observed to contain a large percentage of living cells, while the roots of the invigorating rootstocks were found to contain considerable lignified tissue, chiefly without living cells. Beakbane (3) also found a relationship between the proportion of fibers in the bark of apple roots and the vigor of the plant. The amount of fibers in the dwarfing rootstocks was found to be low, while in the more vigorous rootstocks the amounts of fiber generally were quite high. In plum rootstocks there was a relationship between the anatomy of one year old stems and the ease with which cuttings could be propagated. Rootstocks which had groups of primary phloem fibers separated

2 Bark - In this study the term bark will mean all structures outside of the cambium.

by large areas of living cells had the highest rootability; other rootstocks which had stone cells, or sclereids separating the primary phloem from the secondary phloem produced cuttings which were very difficult to root.

Beakbane (3) studied the anatomy of rootstock stems to which Lane's Prince Albert had been grafted, in an attempt to correlate the rootstock effect. The stems of the dwarfing rootstocks showed a higher bark to wood ratio than the more vigorous rootstocks. Hosse (20) in a study of unworked plants also found that the percent of bark was greater in the stems of the dwarfing rootstocks.

Santamour (24) studying anatomical characteristics of poplars reported that the percent of root bark appeared to be a definite clonal characteristic. He examined roots and stems of one year old cuttings taken from twenty-five clones in two, nine year old plantations. He found that the root bark percent of the one year old cuttings was significantly correlated with diameter, height, and volume of growth of the clone. It was found that clones with a low percent of root bark were vigorous, while the clones with thicker root bark tended to be less vigorous. Santamour also found a positive correlation between the amount of fibers in the root bark, and five growth variables; he found that the clones with the greatest area of fibers in the root bark were most vigorous. Other anatomical characteristics examined in the root, but which were found to be nonsignificant between clones were: percent of vessels in the wood, the size of the vessels, and the percent ray tissue of the wood.

Beakbane (4) reported that the sclerification of the primary phloem of one year old stems was closely related to rootability. Poor rooting varieties exhibited a high degree of sclerification in the phloem, while in the more easily rooting varieties the primary phloem parenchyma was living, even in the transitional stage to scleroids. The phloem rays in this type of plant appeared to terminate against living tissue, while in the plants which were difficult to root the phloem rays usually terminated against heavily lignified fibers and sclerids. These differences in the inherent sclerification of the primary phloem has been found to be quite stable for similar material. Beakbane also suggested that the major cause of poor rooting was not merely a case of lignified tissue mechanically blocking the development of roots, because in many plants root initials do not even form and try to force a passage through a lignified layer. She suggested that it should be entirely possbile to predict the rootability of cuttings taken from a plant chiefly by observing the apparent structure of its young stems.

Hiller (15) studied the effect of growth regulators on the origin and development of root primordia and callus tissue in Taxus cuspidata. She describes the anatomy of the basal region of a cutting taken from one year old growth. The secondary xylem was observed to consist of uniseriate rays and tracheids having bordered pits and being two to five cell layers thick. A primary xylem which contained pitted, reticulate, spiral, and annular elements. Since the cuttings had

been taken during the winter months the cambium was dormant. The author noticed a zone of immature elements of from three to four cells wide separating the xylem and phloem. "The phloem consists of alternating tangential bands of sieve cells and parenchyma and of phloem rays. The phloem cells at the periphery of the stele are crushed against the tangential band of parenchymatous cells approximately three cell layers wide, which surrounds the stele. These cells are considered to be the inner cells of the cortex." A starch test was conducted by the author to determine if an endodermis was present in the cortex. The test proved inconclusive. Hiller found the cortex to consist of from one to three outer layers which contained starch and chlorophyll, and the remaining portion to be composed of thin walled parenchyma cells. The epidermis was covered entirely by a thick cuticle. Taxus cuspidata does not have preformed root initials, so that in a cutting the root primordia arise in the secondary phloem in connection with a vascular ray, or in the wound tissue at the base of the cutting where the primordia arise within the undifferentiated phloem which has no vascular rays present.

Chang (7) studied the bark structure of Taxus brevifolia, and found that fibers were present in the outer part of the inner bark. The fibers usually occured as tangential uniseriate bands which alternated with bands of sieve cells and parenchyma. Esau (12) states that fibers are present regularly in Taxaceae phloem.

SEX RELATED TO PROPAGATION

The sex of individual plants or clones and the presence of flowering buds upon cutting wood have been found to affect the rootability of cuttings. Snow (26) found that male and female red maple trees from various selected greenwood cuttings differed in their ease of propagation. In a comparison study it was found that cuttings which had been taken from female trees did not root as well as cuttings which had been taken from male trees; he also noticed that some of the female clones exhibited a high frequency of root formation, while others rooted comparatively poorly. Egerton (11) followed up this study, and reported that cuttings from female trees which had borne a light crop of fruit rooted equally as well as cuttings taken from male trees. He suggested that the trees which bear a heavy crop of fruit tend to be low in carbohydrates, and thus root poorly. A study conducted by O'Rourke (22) on Blueberry, showed that cuttings which bore blossom buds rooted poorly in comparison to cuttings taken from vegetative wood. Chadwick (6), in a discussion on the use of flowering wood versus vegetative, states that the apparent effect of flower buds on cuttings is to increase the rate of respiration markedly over that of the vegetative buds, such that considerably more stored food is converted in the rooting process. This decrease in the stored food supply of the cutting appears to be a contributing cause of the poor rooting of cuttings bearing flower buds.

Neal, et. al. (21) in a study of Ilex verticillata took

cuttings in June; nearly all of the male cuttings rooted, compared to approximately fifty percent of the female cuttings. Cuttings which were taken in the middle of July showed only minor differences in rootability between the sexes. Neal suggested that the apparent difference between the male and female rootability of cuttings taken in June was due to low levels of carbohydrates in the female plants, a result of heavy cropping the preceeding year. By July the carbohydrate deficit had been returned to more normal levels, and no apparent differences in rootability were observed between male and female cuttings.

DeBoer (10) found that Rhododendron cuttings rooted better when the existing flower buds were removed from the cutting, than when they were allowed to remain; she suggested that this result may have been connected with the plant's natural hormones and inhibitors.

TAXUS

According to Bailey, (1) Taxus spp. are evergreen trees or shrubs which have linear two ranked leaves. Flowers are dioecious, and occur axillary, when appearing in early spring. The seed, a hard nut, is enclosed on three sides by fleshy red fruit, and requires two years to germinate. Presently Taxus is considered a valuable plant in the nursery trade.

Keen and Chadwick (18), Davidson (9) and Wyman (28) have reported on the sex of the different clones of Taxus as they occur in the nursery trade, at the Seacrest Arboretum and the Arnold Arboretum. Table 1 lists some of the better known clones by their sex. Keen and Chadwick (18)

also have reported that they have observed several sex reversals in T. cuspidata, where several male plants have been observed to possess one or two female branches.

Except for special instances, most of the clones of Taxus are propagated by means of cuttings. Keen (17) presented a good review on the propagation of Taxus which covers some of the methods used for propagation other than by cuttings. Chadwick (5) found that the best medium in which to root Taxus cuttings varied during the year. Peat moss produced good results from July to November, but sand was proven a more satisfactory media after November. Vermullen (28) and Wells (29) also reported sand to be the best media for Taxus propagation. Commercially Taxus cuttings are taken from November to January, and propagated in the greenhouse. Wells (30) reports that the larger the cuttings taken, the easier they will root; thus economics determines the size of the Taxus cutting. Keen (17) reports that cuttings taken from Taxus continue to produce the type of growth characteristic of the position of the parent plant from which the cutting was taken. Cuttings taken from the side of the parent plant produce one sided plants, while cuttings which were taken from the top portions of the plant produce upright plants. Esper (13) found that a bottom heat of 65-70° F, and an air temperature of 50-55° F produced the best rootability. Several authors (30, 28) have reported an increase in rooting percentage using growth substances on cuttings. Wells (29) reports that the use of growth substances in the form of commercial talc dusts to be a common practice among nursery-

men. Photoperiodic effect on the rootability of Taxus cuspidata has been studied by Snyder (27); he found that the lateral bud growth on cuttings was inhibited by a short day of eight hours, and was stimulated by long days of eighteen hours of light. Although lateral bud growth was affected by the photoperiod, no significant effect was found on the rootability of the cuttings.

Clonal differences in the rootability of Taxus have been noted by several authors (23, 30). Most of the data are given in percent of the cuttings rooted; this does not indicate the true rootability of the cutting. O'Rourke (23) recommended the method of using ranks to score rootability of cuttings. Wells, (30) using this rooting index, gives a more accurate measure of the rootability differences between clones of Taxus. From his data it can be seen that T. media 'Hicks' and T. media 'Brown' are poor rooters. Cottage Gardens[3] has reported that clones of T. media 'Brown', T. cuspidata 'Anderson', T. media 'Ward', and the variety T. cuspidata 'Nana' all have poor rootability, while such varieties as T. cuspidata and T. media densiformis root easily.

Davidson et. al. (9) did a survey of the Michigan State University campus and several nurseries in the state and found that male plant of Taxus cuspidata expansa greatly outnumbered the female plants of this variety in all locations.

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3 Personal conversation with Mr. Albert Garlitz, of Cottage Gardens, Inc., Lansing, Michigan.

Table 1: Sex of Taxus Clones

Taxus Baccata	Sex and Authority
___ ___ 'Adpressa'	Female 17, 23
___ ___ 'Aurea'	Female 17, 23
___ ___ 'Columnaris'	Male 23
___ ___ 'Dovastaniana'	Female 23, Male 17
___ ___ 'Elegantissima'	Male 23, Female 17
___ ___ 'Erecta'	Male 17, Male and Female 23
___ ___ 'Expansa'	Female 17
___ ___ "Fructu-Luteo'	Female 17
___ ___ 'Glauca'	Male 17
___ ___ 'Lutea'	Female 23
___ ___ 'Mioun'	Male 23
___ ___ 'Nigra'	Male 17
___ ___ 'Pendula'	Female 23
___ ___ 'Repandens'	Male and Female 9 Female 23, 17
___ ___ 'Variegata'	Female 23
___ ___ 'Washington'	Female 17
Taxus cuspidata	
___ ___ 'Adams'	Male 17, 8
___ ___ 'Aristocrat'	Female 23
___ ___ 'Aurescens'	Male and Female 23 Male 8
___ ___ 'Bobbink'	Female 23
___ ___ 'Columnaris'	Male 23
___ ___ 'Densa'	Female 17, 23
___ ___ 'Expansa'	Male and Female 8 Male 23

Table 1: Sex of Taxus Clones (continued)

Taxus cuspidata (continued)	Sex and Authority
___ ___ 'Intermedia'	Male 23, 8
___ ___ 'Jeffery'	Female 17, 28
___ ___ 'Nana'	Male and Female 8, 28
___ ___ 'Nana Compacta'	Male and Female 28
___ ___ 'Ovata'	Female 17
___ ___ 'Prostrata'	Male 8, 17, 28
___ ___ 'Robusta'	Male 28
___ ___ 'Stoveken'	Male 8, 17
___ ___ 'Thayerae'	Female 8, 17, 28
___ ___ 'Thompson'	Female 28
Taxus Media	
___ ___ 'Adams'	Male 28
___ ___ 'Andorra'	Female 28
___ ___ 'Amherst'	Male 8, 28
___ ___ 'Anderson'	Male and Female 28
___ ___ 'Berryhill'	Female 8, 28
___ ___ 'Brevimedia'	Female 8
___ ___ 'Brown'	Male and Female Male 17, 28
___ ___ 'Cedar Hill'	Male 28
___ ___ 'Chadwick'	Female 8, 28
___ ___ 'Clifton'	Female 8, 17, 28
___ ___ 'Cole'	Female 28
___ ___ 'Compacta'	Female 28
___ ___ 'Densiformis'	Male 8, 28
___ ___ 'Erecta'	Male and Female 28

Table 1: Sex of Taxus Clones (continued

Taxus Media (continued)	Sex and Authority
___ ___ 'Fastigiata'	Male 28
___ ___ 'Flushing'	Female 28
___ ___ 'Halloran'	Female 28
___ ___ 'Hatfield'	Male and Female 8 Male 17, 28
___ ___ 'Hetz'	Female 28
___ ___ 'Hicks #1'	Female 8, 17
___ ___ 'Hicks #2'	Male 8, 17
___ ___ 'Hill'	Male 28
___ ___ 'Hoogendorn'	Female 28
___ ___ 'Kelsezi'	Female 8, 17, 28
___ ___ 'Moon'	Male 8, Female 28
___ ___ 'Newport'	Male 28
___ ___ 'Nigra'	Male 8
___ ___ 'Ovata'	Female 28
___ ___ 'Prostrate'	Female 8
___ ___ 'Stricta Viridis'	Male 28
___ ___ 'Siebold'	Female and Male 8
___ ___ 'Taunton'	Male 28
___ ___ 'Totem'	Female 28
___ ___ 'Vermeulen'	Female 8, 17, 28
___ ___ 'Ward'	Male and Female 8 Female 17, 28
___ ___'Wilson'	Male 28

EXPERIMENTAL PROCEDURES

EXPERIMENT I

Cutting wood of both male and female plants of Taxus cuspidata expansa was obtained from the horticultural gardens at Michigan State University. The wood was taken on November 16, 1963, from the current seasons growth. This wood was wrapped and stored for two days in moist sphagnum moss at a temperature of 40 degrees Fahrenheit. On the eighteenth of November the 200 male and 200 female cuttings were made and placed in a coarse sand media. The rooting experiment was conducted in a propagation bench of the pit house at the Michigan State University greenhouse range. A completely randomized experimental design was used with ten replications of each sex, and consisting of twenty cuttings per replication. Each replication consisted of a row of cuttings which extended half-way across the width of the propagation bench. The cuttings in each replication were placed one inch apart in the row, and approximately two inches between rows. The temperature of the rooting media was maintained between 60 and 70 degrees Fahrenheit for much of the rooting period. In the initial stages of the experiment the cuttings were watered as necessary. Due to partial drying out of the media during the weekend of January 19, 1964 it was decided to continue the experiment under an intermittent mist. The mist system was activated on January 20, 1964, and remained in effect for the remaining part of the experiment. The mist system was operated on a cycle of six

seconds on out of every three minutes from 9 a.m. to 3 p.m. daily.

On May 10, 1964, the cuttings were evaluated on the basis of rootability according to the method of ranks as outlined by O'Rourke and Maxon (23). The results of this evaluation were analyzed statistically by analysis of variance for a completely randomized design.

EXPERIMENT II

The purpose of this experiment was to determine if there was any natural difference in the rootability of Taxus clones. Cutting wood from seven selected clones of Taxus (Table 2) was obtained from nurseries in the Lansing area. The wood was taken on November 27, 1963 and stored in moist sphagnum moss at 40 degrees Fahrenheit. The wood was made with slanting basal cuts into uniform seven inch tip cuttings. These tip cuttings were placed in the medium without application of rooting hormones. The experiment was conducted in the pit house of the Michigan State University greenhouse range. The cuttings were made and placed in the coarse sand media on December 3, 1963. A completely randomized design consisting of ten replications per clone with twenty cuttings per replication was used in the placement of the cuttings. The arrangement of the replications was similar to that of the first experiment, except that the replications were approximately one inch apart. The cuttings were maintained under the same watering system, and after January 20, 1964 under the same mist system and cycle as described for the first experiment.

TABLE 2: Taxus clones used in the Experiment II

Clone	Sex
Taxus media 'Hatfield' Rehd.	Male
Taxus media 'Ward'	Female
Taxus media 'Densiformis'	Male
Taxus media 'Halloran'	Female
Taxus media 'Brown' Rehd.	Male
Taxus media 'Hicks' Rehd.	Female
Taxus cuspidata 'Nana' Rehd.	Male

Rootability of the clones was evaluated on May 10, 1964 using the method of ranks as outlined by O'Rourke and Maxon. The differences between clones were analyzed statistically by analysis of variance for a completely randomized design (16) and differences separated by Duncan's multiple range test (19).

HISTOLOGICAL TECHNIQUES

The purpose of this phase of both experiments was to determine if any anatomical feature of Taxus could be used to account for the variance in rootability which had been observed.

After the cuttings from the two experiments had rooted, and were evaluated they were transferred to a cold frame. The media in the cold frame was an equal mixture of sand and peat moss. The plants were maintained under a screen shade and watered every other day. The material remained in the cold frame until March 19, 1965; at this time plants were removed to the laboratory to be sectioned. Four plants of

each clone and each sex of T. cuspidata expansa were chosen at random from the cold frame to be sectioned. The plants were washed and the distil one half inch of the stem of each plant was placed in the clamps of an American optical sliding microtome and sectioned to a thickness of 30 microns. The material was sectioned within an hour after being brought into the laboratory, and the sections were started through a safranin and fast green staining procedure as outlined by Sass (25). Stained sections were then mounted in Canadian balsam on standard microscope slides for further examination.

EVALUATION OF SLIDES

On examining the microscope slides, bands of fibers were noted to occur in the secondary phloem. It was decided to count the number of fiber rings appearing in the different clones, and in both sexes of Taxus cuspidata expansa. The purpose of this was to see if there appeared to be a relationship between the number of fiber rings that any one clone contained and the rootability of that clone. In order to facilitate the counting of Ken-a-Vision microscope slide projector was used to project the image of the section, and the count was made from this projection. A 6.5 mm lens and a 10 x magnification was used to project the image. Three counts were made per microscope section and these values were used to find an average number of fiber rings per section. Twenty sections per clone, and twenty of each sex of T. cuspidata expansa were evaluated in this manner. Analysis of variance was used to test for significant differences in the

number of fiber rings.

It was decided to determine if the thickness of the region on which the fibers occured varied between T. media 'Hatfield' and T. cuspidata 'Nana'. These clones were chosen on the basis of their rootability, the former being high and the latter low. The microscope slide projector was also used in this determination. The sections were projected as before, and a sketch was made of the image. Notation was made of the ring of xylem and the outer limit of the region of fibers. Due to the irregular shape of the Taxus stem it was impossible to determine an exact center of the section. A method was devised by which a section center was designated. By inspection, a ruler was placed across what appeared to be the diameter of the xylem and a point was placed at the center. This was done three times using what appeared to be different diameters of the xylem. The three points were connected and the center of the triangle was chosen as the center of the section, or if the three points fell in a straight line a point half way along that line was chosen. Three radaii were drawn with a straight edge out through the region of fibers. A measurement was made of the thickness of the region of fibers along the radaii. These measurements were averaged to give an average measurement per section. Twenty sections of each clone were evaluated in the above manner. Significance was tested with analysis of variance.

It has been reported by Mosse (20) that the percent of bark to wood could be a clonal characteristic. A study

was conducted upon the clones of Taxus to determine the percent of bark to wood. The 6.5 mm lens of the Ken-a-Vision microscope slide projector was used to project the image of the microscope sections. A sketch of the section was drawn. The same method of determining the section center was employed as in the fiber ring study. Three radaii were drawn to the edge of the section. Measurements of the bark and wood were along each radius. These measurements were used to determine the average thickness of wood and bark per section. Twenty sections per clone, and of each sex of T. cuspidata expansa were evaluated in this manner. The means of bark and wood per clone were determined. The two means then were used to determine the percent of bark to wood.

RESULTS

EXPERIMENT I - Propagation Results

The rooting indices (Table 3) for cuttings of male versus female plants of *Taxus cuspidata expansa* indicate that cuttings taken from male plants rooted much better than cuttings taken from female plants. The ratio between the rooting indices was in the order of two to one in favor of the male cuttings. The difference between the means was found to be significant at the 1% level.

Table 3. The Rooting Indices of Male vs. Female Cuttings of *Taxus cuspidata expansa*

Replications	Female	Male	Ratio
1	32	72	2.25
2	54	61	1.13
3	24	66	2.75
4	21	63	3.00
5	42	80	1.90
6	38	78	2.05
7	33	70	2.12
8	18	77	4.28
9	27	32	1.19
10	25	54	2.16
mean	31.4	*65.3	2.08

*significantly different at the .01 level

EXPERIMENT II - Propagation Results

Differences in rootability were found in the seven clones of Taxus that were tested in this experiment. The average rooting indices and separation of the clones were determined by Duncan's multiple range test is shown in (Table 4). Taxus media 'Hatfield' proved to be the superior rooting clone, while T. cuspidata 'Nana' proved to be the poorest in the clone experiment rootability. A comparison between the male and female clones revealed that the rootability of female clones was superior. The difference was found to be significant at the 5% level.

Table 4. Rooting Indexes of the Taxus clones

Clone	Sex	Index
T. m. 'Hatfield'	Male	64a
T. m. 'Hallerana'	Female	42b
T. m. 'Hunnewelliana'	Female	36b
T. m. 'Densiformis'	Male	21c
T. m. 'Brevifolia'	Male	20c
T. m. 'Hicksii'	Female	17c
T. cuspidata 'Nana'	Male	4c

Anatomical Results

In the anatomical study of the stems from male vs. female plants of Taxus cuspidata expansa, it was found that the number of fiber rings was the same in either sex. Both sexes contained an average of 7.1 rings of fibers, also the ratio of bark to wood was found to be the same.

Table 5. Percent Bark to Wood of Taxus cuspidata expansa

T. cuspidata expansa	Wood Average	Bark Average	% Bark
Male	6.4	4.1	39%
Female	7.2	5.0	40%

The number of fiber rings in the seven selected clones of Taxus proved to be the same. The average number of fiber rings was 7.2 and the range was 5 to 9 fiber rings.

In the study of the width of the region of fibers, no significant differences were found between T. cuspidata 'Nana' and T. media 'Hatfield'.

Results of the study of percent bark to wood (Table 6) showed some variation of this characteristic among the clones.

Table 6. Ratio of Bark to Wood in Taxus Clones

Clone	Wood Average	Bark Average	% Bark
T. media 'Hatfield'	6.4	4.0	40%
T. media 'Brown'	5.6	5.0	47%
T. media 'Hallowan'	5.8	4.6	44%
T. cuspidata 'Nana'	5.6	4.2	42%
T. media 'Wardi'	6.4	4.2	40%
T. media 'Densiformis'	7.3	4.2	39%
T. media 'Hicks'	7.3	3.2	31%

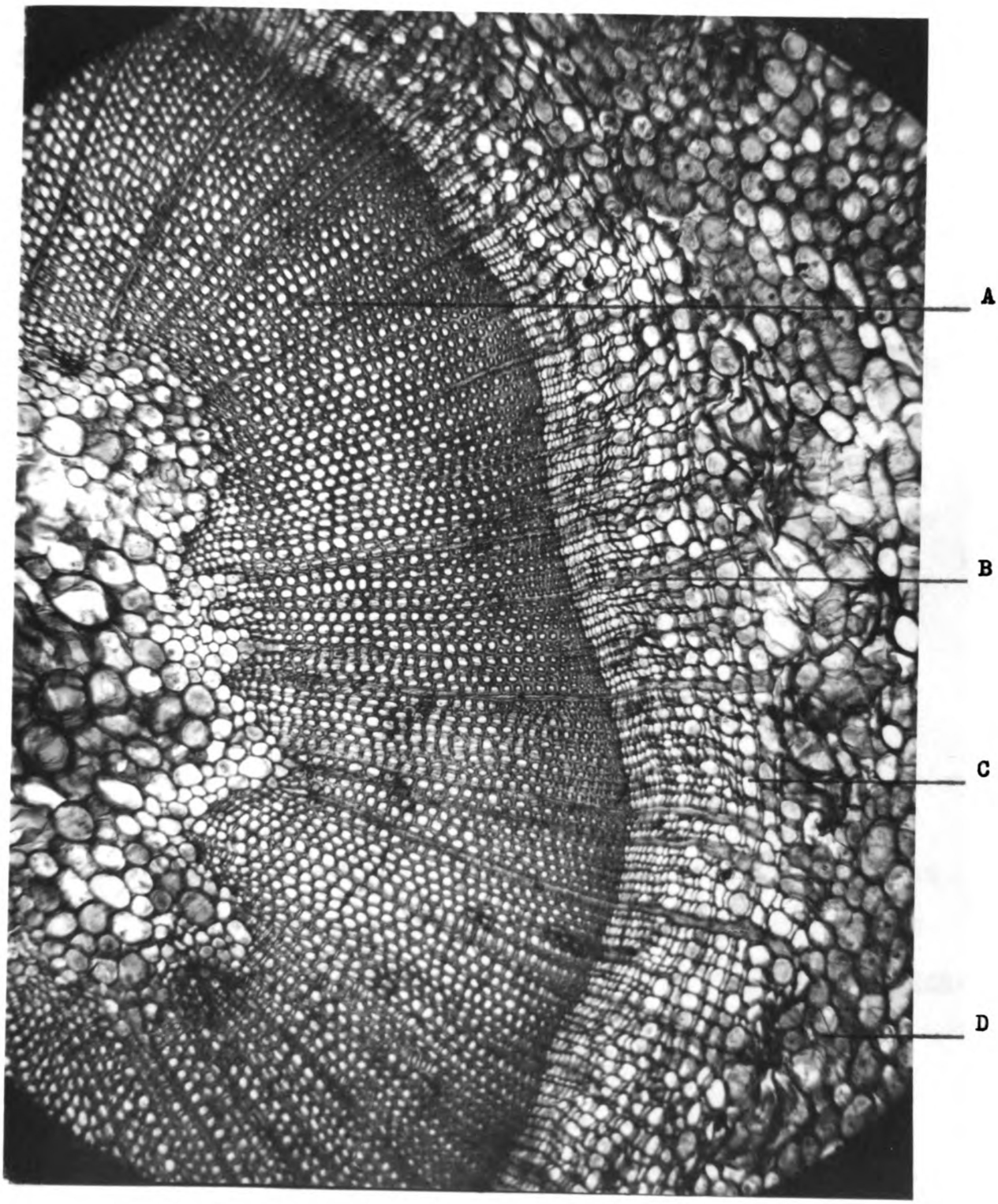
FIGURE I. - Stem cross section of *Taxus media* 'Hatfield'

A - Xylem

B - Vascular ray

C - Fiber band

D - Cortex


A
B
C
D

DISCUSSION

The results of the studies show definite differences in the rootability of male versus female Taxus cuspidata expansa (Table 3), and inherent differences in the rootability of the selected clones of Taxus (Table 4).

The reason for the superior rooting performance in male cuttings of T. cuspidata expansa over the female cuttings in apparent opposition to the superior rootability of female cuttings in the clonal study has not as yet been determined. It is possible that if an entirely different set of clones had been selected from the population, that the results might have been quite different from those observed.

The data would seem to explain the results of the survey conducted by Davidson (9) of Michigan nurseries and landscape plantings, in which the ratio of male to female T. cuspidata expansa was found to be three to one. Plant propagators, unknowingly may have been selecting for male Taxus cuspidata expansa due to the poorer rootability of female cuttings. Generally, nurseries select their cutting wood from the trimmings from plants which have been lined out in the field. Several decades of this practice could result in a preponderance of male over female Taxus cuspidata expansa.

Edgerton (11), Neal, et.al. (21) and Chadwick (6) have suggested that the differences in rooting observed between the sexes of maple and holly was related to the carbohydrate content of the cuttings. It was suggested that since the female plants produce fruit, they would have a lower carbohydrate content; hence cuttings taken from female

plants would exhibit poorer rootability. If it were only a matter of carbohydrate supply, one would expect that all female clones would show lower rootability than the male clones. As has been noted, (Table 4) this was not the case; the male clone of T. cuspidata 'Nana' had a low rooting index, while the female clones of T. media 'Halloran' and T. media 'Ward' had high rooting indices. Snow (26) also noted female clones of maple which had high rootability. This would seem to indicate that another factor in addition to carbohydrate content of the wood could be influencing the rootability of Taxus clones.

Plant hormones and inhibitors could be a controlling factor in the rootability of male versus female T. cuspidata expansa. Deboer (10) suggested that plant hormones and inhibitors could account for the poor rooting of Rhododendron cuttings bearing flower buds. Whether the differences in rootability are due to hormones and inhibitors, or due to the high respiration rate of flower bud and the resulting low food supply concept as expressed by Chadwick (6), or due to a combination of several such factors must be decided by further experimental investigation.

Since the number of fibers found in the phloem of the different Taxus clones was the same, no relationship can be drawn between the number of fiber rings and rootability.

In studies of the stems of apple rootstocks, Beakbane (3) and Mosse (20) found that the stems of the dwarfing rootstocks showed a higher bark to wood ratio than the more vigorous rootstocks. From results observed in this experiment,

there seems to be no relationship between the characteristics which were observed by Beakbane and the ease of rooting of *Taxus* clones. *Taxus media* '*Hatfield*' with the highest rooting index also was found to have the highest bark to wood ratio (Table 7). *Taxus cuspidata* '*Nana*', a slow growing semi-dwarf form, had the lowest rooting index of the clones (Table 4); but only had a medium thickness of bark to wood.

From the results of the anatomical features which were examined, it seems that the anatomy of *Taxus* cuttings has little influence in determining the rootability of the male versus female *T. cuspidata expansa* or of the different *Taxus* clones.

SUMMARY

The purpose of these studies was to examine the effect of sexual and anatomical differences on the propagation of selected Taxus clones and upon male and female forms of T. cuspidata expansa.

Propagation was by cuttings placed in a sand media under mist during the winter of 1963 - 1964. The cuttings were evaluated by a method of ranks to give rooting indices for each clone or sex.

Anatomical studies were made of the same plants that were used in the propagation experiment during the fall and winter of 1964 - 1965. A count of the number of fiber rings occuring in the clones was made, and a study of percent of bark to wood was conducted.

Significant differences were found in ease of rootability between male and female cuttings of T. cuspidata expansa. The cuttings taken from the male plants exhibited a much higher rootability than cuttings taken from female plants.

A definite difference was found in the rootability of the selected Taxus clones. T. media 'Hatfield' proved the easiest to root while T. cuspidata 'Nana' was the most difficult.

The number of fiber rings was the same for all the clones of Taxus. The percent of bark to wood did vary among the clones, but it did not bear a relationship to the ease of rooting of the clones.

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