August 6, 1957

To the Graduate Council:

I am submitting herewith a thesis written by Herman G. Hobbs entitled "The Storage of Rooted Cuttings". I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Horticulture.

H. B. Tukey
Major Professor

We have read this thesis
and recommend its acceptance:

Joe L. Alexander

Homer D. Sweigle

Roger B. Thompson

Accepted for the Council:

Dale Bentley
Dean of the Graduate School

The Storage of Rooted Cuttings

A THESIS

Submitted to
The Graduate Council
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the degree of
Master of Science

---

by

Herman G. Hobbs

August 1957

2 8
33

ACKNOWLEDGMENT

The writer wishes to express his sincere appreciation to: Prof. Joe S. Alexander, Department of Horticulture, for directing this study and his help in obtaining the equipment; Dr. B. S. Pickett, Department of Horticulture, for aiding in the initial stage of this study and in reviewing this thesis; Prof. Roger B. Thompson, Prof. Homer D. Swingle for reviewing this thesis and the Department of Horticulture for providing equipment.

379316

TABLE OF CONTENTS

CHAPTER		PAGE
I.	INTRODUCTION	1
II.	REVIEW OF LITERATURE	2
III.	MATERIALS, EQUIPMENT AND PROCEDURE	11
IV.	RESULTS	19
V.	SUMMARY	35
	BIBLIOGRAPHY	37
	APPENDIX	39

LIST OF TABLES

TABLE PAGE

I. Packaging and Storage Conditions for Holly and Arborvitae Cuttings 14

II. Temperature Ranges for Cooler Set at 32-36 Degrees F. 17

III. Temperature Range for Cooler Set at 36-44 Degrees F. 18

IV. Percent Survival of Burford Hollies Stored at 32-36 Degrees F. 23

V. Percent Survival of Burford Hollies Stored at 36-44 Degrees F. 24

VI. Percent Survival of Thuja occidentalis Stored at 32-36 degrees F. 28

VII. Percent Survival of Thuja occidentalis Stored at 36-44 Degrees F. 29

VIII. Percent Survival of Hollies After Eight Weeks 31

IX. Percent Survival of Arborvitaes After Eight Weeks 32

X. Comparison of Packing Materials on Survival of Burford Hollies Full Wrapped and Stored at 36-44 Degrees F. 40

XI. Comparison of Packing Materials on Survival of Thuja occidentalis Full Wrapped and Stored at 36-44 Degrees F. 41

TABLE PAGE

XII. Comparison of Packing Materials on Survival of Burford Hollies Half Wrapped and Stored at 36-44 Degrees F. 42

XIII. Comparison of Packing Materials on Survival of Thuja occidentalis Half Wrapped and Stored at 36-44 Degrees F. 43

XIV. Comparison of Packing Materials on Survival of Burford Hollies Packed in a Box and Stored at 36-44 Degrees F. 44

XV. Comparison of Packing Materials on Survival of Thuja occidentalis Packed in a Box and Stored at 36-44 Degrees F. 45

LIST OF FIGURES

FIGURE		PAGE
1.	Type of Cuttings Used for Storage Test	12
2.	Type of wraps Used in Storing Arborvitae and Holly Cuttings	15
3.	Holly Cuttings Stored in a Box Packed with Sphagnum	20
4.	Holly Cuttings Stored Bare Root	21
5.	Holly Cuttings Stored Full Wrapped Packed with Perlite	22
6.	Arborvitae Cuttings Stored for 90 Days at 36-44 Degrees F.	26
7.	Arborvitae Cuttings Stored Half Wrapped	27

CHAPTER I

INTRODUCTION

In recent years there has been an increased production of lining out stock in greenhouse and outdoor mist beds. Large numbers of rooted cuttings are produced by plant propagators in the fall and winter months for early spring planting. Increased efficiency in the production of liners has resulted in a storage problem for many propagators. In some instances the rooted cuttings are left in the propagation beds until planting time. This method of handling rooted cuttings prevents re-use of the beds. Other propagators remove the cuttings from the beds and then pot or store them in flats in the greenhouse. This procedure requires additional storage space for the pots and flats.

The possibility of low temperature storage of rooted cuttings for extended periods of time has been studied as a partial solution to the storage problem of propagators who produce rooted cuttings for early spring planting.

The experiments reported in this thesis were conducted under conditions that most commercial propagators can provide. All equipment and facilities used can be obtained easily.

Experiments conducted at other Universities indicate that controlled temperature storage of rooted cuttings shows promise of becoming an efficient method of handling cuttings.

CHAPTER II

REVIEW OF LITERATURE

The fall storage of hardwood cuttings is a common practice of plant propagators because clear weather in the fall provides ideal conditions for the collection of cutting wood from evergreen and deciduous shrubs. Hardwood cuttings of deciduous shrubs can be cut and stored before low winter temperatures have injured the buds or stem tissue (3).

Several types of injury may occur in plants as a result of low temperatures. Many evergreens die of desiccation because of relatively high winter transpiration rates during a period when absorption of water can proceed only at a relatively slow rate (8).

It has been established that some of the plant tissue damage due to freezing is caused by the formation of ice crystals within the plant (5). Crystals of ice may form either within the cells of the tissue or in the intercellular spaces. The formation of ice may take place in the protoplasm as well as in the vacuole. The formation of ice crystals in the intercellular spaces results in the withdrawal of water from the cells and thus causes drying out of the cells. This injury is similar to the injury caused by drying out at ordinary temperatures (6).

The rate at which ice crystals form depends upon

the temperature. The fastest rate occurs near the freezing point (5). If living tissues are frozen in such a way that the temperature is reduced very rapidly, the formation of ice crystals is slowed or prevented altogether. After the tissue has been frozen in this manner, if thawed rapidly the formation of ice crystals can be avoided (6). Under these conditions living tissue may be frozen and thawed without damage.

Plant tissues that can survive the formation of ice crystals are considered to be frost resistant. The degree of frost resistance is not a fixed quantity, but will vary in many plants as a result of the natural or artificial conditions to which they are exposed (9). All organs of a plant are not equally frost resistant at a given time. The mature leaves of deciduous woody plants are more hardy than young leaves (9). A high correlation between frost resistant and drought resistant plants has been found. Using this as a basis, it might be assumed that plants that withstand dry conditions could be stored at controlled low temperatures with relatively little loss, while those that are easily killed by drought might not withstand the low storage temperatures.

Many strawberry growers in New York obtain dormant strawberry plants and hold them in cold storage until planting time. The storage temperature should be between 26 and 34 degrees F. with a relative humidity of 85-90 per

cent (12). Strawberry plants will withstand temperatures as low as 20 degrees F. without serious damage. Temperatures much above freezing will result in crown growth, molds, storage rot or drying (12).

In 1934 a Minnesota nursery successfully stored more than 300,000 strawberry plants during the winter at 22 degrees F. The bunched plants were packed in orange crates with the tops toward the sides of the crate and with moss, shingletow or peat packed around the roots and between the layers of bunches (11). The air temperature in the storage shed was kept close to 22 degrees F. and the humidity was kept high by sprinkling the floor.

In Maryland strawberry plants have been stored in crates with the roots packed with sphagnum moss. Most of the plants stored at 17 degrees F. were dead after 3 months, but plants stored at 30, 32 and 36 degrees F. gave excellent stands when planted. Their results showed that plants stored at 32 degrees F. were superior to the plants stored at 30 and 36 degrees F. (12).

In Tennessee plants stored at 32 degrees F. are usually superior to freshly dug plants because of dormancy maintenance (4).

A storage technique used by the Henry Field seed and nursery company of Shenandoah, Iowa indicates that perennials dug in the fall while dry and not showing late growth can be pre-packaged in the fall. The plants are wrapped in

polyethylene, packed in orange crates and frozen at a temperature of from 29-31 degrees F. (2). They are kept in this state until several days prior to shipping and are then thawed and wrapped.

In the nursery industry as well as in the fruit and vegetable industry the pre-packaging of dormant stock is a common practice (7). Many vegetables such as lettuce, carrots, radishes and potatoes are pre-packed in cellophane bags and stored awaiting shipment to retail outlets. This type of packing does not reduce the quality of the product as much as other methods of packing does.

Pre-packaging in the nursery industry may be of interest not only from the standpoint of improving quality and sales appeal at the retail level, but also from the standpoint of labor distribution for the nurseryman. Cuttings can be taken at times when other field work cannot be accomplished. This also holds true for taking rooted cuttings from the propagation beds. The cuttings can be removed and stored during inclement weather, thus making a more economical use of labor.

It has been reported that cuttings of some evergreens can be wrapped in polyethylene bags or sheeting and stored successfully at 35-37 degrees F. (3). When placing the cuttings in the cooling unit good air circulation should be provided for. Evergreen cuttings can be taken and stored loosely in polyethylene bags until they are placed in the

benches. Taxus and arborvitae can be packed snugly without injury, while boxwood cuttings tend to defoliate and become diseased if tied in compact bunches (3).

Ligustrum and Spiraea vanhouttei plants have been wrapped in polyethylene and stored for as long as six months at 40 degrees F. without loss (7).

Recent studies at Cornell University conducted by Snyder and Hess indicates that rooted cuttings can be stored at low temperatures with satisfactory results (13). Rooted cuttings of a semi-woody perennial, Teucrium chamaedrys, and of four narrow leaved evergreens, Taxus cuspidata, Juniperus communis hibernica, Thuja occidentalis pyramidalis and Thuja occidentalis globosa were used. The cuttings were either bought from commercial nurseries or rooted in the greenhouses at Cornell and were selected for uniformity of roots prior to storage.

Freezers equipped with thermostats which permitted control of the temperatures within 1 degree F. were used for storing the cuttings.

On January 1, 1954 one group of Teucrium chamaedrys cuttings were divided into twelve lots with 10 plants per lot and stored in polyethylene bags.

Two lots were treated in each of the following six ways.

1. Roots packed with sphagnum and stored at 31 degrees F.

2. Roots packed with vermiculite and stored at 31 degrees F.
3. Bare root, stored at 31 degrees F.
4. Roots packed with sphagnum and stored at 34 degrees F.
5. Roots packed with vermiculite and stored at 34 degrees F.
6. Bare root, stored at 34 degrees F.

The plants were held at 40 degrees F. for 4 days before being stored at 31 and 34 degrees F.

After six weeks of storage one lot of each of the six treatments was removed from storage, potted and grown under greenhouse conditions of 60 degrees day and 50 degrees night minimum temperature. The remaining lots of each of the six treatments were left in storage until June 1, making a total storage period of 167 days before they were planted in the field.

The cuttings stored for 6 weeks were examined after one month in the greenhouse. Those stored at 34 degrees F. were satisfactory in all respects. They showed new top and root growth equal to the control group that had been grown in the greenhouse from the beginning of the storage period. The group stored at 31 degrees F. showed no top growth and very little or no root activity (13).

The cuttings stored at 31 degrees F. for 167 days were dead when taken from the storage and consequently were not

planted. Those stored at 34 degrees F. were satisfactory in all respects.

On the basis of these tests a commercial nursery near Cornell stored 30,000 rooted Teucrium cuttings in sealed polyethylene bags at 34 degrees F. for 61 days (13). The remainder of their cuttings were potted and maintained under glass at temperatures never less than 40 degrees F.

Random plants were selected from the fields of the commercial nursery at the end of the first growing season and no difference could be noted in the growth of the plants stored at 34 degrees F. for 61 days and those handled in the normal method by the nursery (13).

Well rooted cuttings of Taxus cuspidata, Juniperus communis hibernica, Thuja occidentalis pyramidalis and Thuja occidentalis globosa were stored bare-root, roots packed with sphagnum and roots packed with peat moss at temperatures of 31, 35 and 39 degrees F. from January 15 to June 3, a total of 139 days (13).

The cuttings were enclosed in polyethylene bags and control lots were carried in the same manner as were the Teucrium cuttings. At the end of the storage period the rooted cuttings were planted in beds provided with light shade for 8 weeks, after which they were exposed to full sunlight.

There was no significant difference between the cuttings stored bare-root and those stored with packing

material around the roots.

Taxus cuspidata cuttings stored at 39 degrees F. were grown successfully, but those stored at 31 and 35 degrees F. did not survive.

Survival of the cuttings of the Irish juniper and the two varieties of arborvitae stored at 39 degrees F. was equal to that of the control group. Storage at 31 and 35 degrees F. resulted in decreased survival as well as less growth as compared with the control group.

This experiment demonstrated that rooted Teucrium cuttings could be satisfactorily stored for 61 days in a commercial nursery operation. Rooted cuttings of Taxus cuspidata stored at 39 degrees F. produced plants equal to those of the control group. Rooted cuttings of Juniperus communis hibernica, Thuja occidentalis globosa, and Thuja occidentalis pyramidalis stored at 31, 35 and 39 degrees F. did not grow as satisfactorily as those potted and carried in the greenhouse.

Work done at Cornell showed that cuttings stored bare-root were as good as those stored with a packing material around the roots (14).

Many nurserymen are improving their operating methods and increasing profits by investing in cold storage units. Cold storage enables a nurseryman to keep stock of all kinds dormant over the winter season so that it will be in perfect condition when packaged for spring

shipment. Cold storage makes it possible to dig plants from the fields in the fall, grade, prepare and store for later shipment. It turns out a high quality product and enables the operator to plan his marketing activities (1). If a technique for storage of rooted cuttings can be successfully developed this would allow greater use of storage facilities by the nurserymen as well as serve to better distribute his labor.

CHAPTER III

MATERIAL, EQUIPMENT AND PROCEDURE

Rooted cuttings of Burford holly, Ilex cornuta clon Burford, and pyramid arborvitae, Thuja occidentalis pyramidalis, were selected for this experiment. Cuttings of a narrow leaf and a broadleaf evergreen were used in order that a comparison of the storage reactions of each might be made.

Cuttings taken from strong terminal growth of one year old wood were rooted in the greenhouse at the University of Tennessee during the fall of 1956 and early winter of 1957. Selection of the rooted cuttings for storage was made on February 12, 1957, and any cutting considered to be not well rooted enough to withstand transplanting was discarded. Figure 1 shows a typical sample of the cuttings used in this test when removed from the cutting bench.

The arborvitae and holly cuttings were packaged in bundles of 50 cuttings each and one lot stored at 32-36 degrees F. and the other at 36-44 degrees F.

Sphagnum moss and perlite were used as packing materials around the roots of some cuttings while others were stored bare root. Sphagnum was selected as a packing medium because of its high water holding capacity which would allow evaporation from the tremendous surface area over a long period of time. Perlite was selected because



Figure 1. Type of cuttings used for storage test. Left, *Ilex cornuta* clon Burford; right, *Thuja occidentalis* var. pyramidalis.

it does not have as high a water holding capacity as sphagnum. Bare root cuttings were used to determine whether cuttings could be stored without the use of a moisture retentive material.

The type of wraps used were designated as full, half and box.

Cuttings full wrapped were placed in plastic bags and completely enclosed. In the half wrap package, rooted cuttings were inserted in the plastic bag with roots and one-half of the stems enclosed, and the foliage and upper one-half of the stems exposed.

Cuttings stored in quart strawberry boxes were packed with either sphagnum, perlite or stored bare root without any covering over the box.

Table I shows the packaging and storage conditions to which the arborvitae and holly cuttings were subjected.

Figure 2 shows the methods used in wrapping the cuttings.

A group of 50 rooted cuttings for each variety was left in the propagation bench and was not removed until the packaged cuttings were taken out of storage. The two groups were then planted with the stored cuttings to compare results.

Two refrigerated units were used for storing the cuttings. The unit set at 32-36 degrees F. was a Thermo King, 100 cu. ft., Model Me 9-1 refrigeration unit that was obtained from army surplus. It contained a radiator and a

TABLE I

NUMBER OF ARBORVITAE AND HOLLY CUTTINGS STORED

Storage Temp.	Packing Medium	Arborvitae Wraps			Holly Wraps		
		Full	Half	Box	Full	Half	Box
32-36° F.	Sphagnum	50	50	50	50	50	50
	Perlite	50	50	50	50	50	50
	Bare root	50	50	50	50	50	50
36-44° F.	Sphagnum	50	50	50	50	50	50
	Perlite	50	50	50	50	50	50
	Bare root	50	50	50	50	50	50



Figure 2. Type of wraps used in storing arborvitae and holly cuttings. Left to right: full wrap, half wrap and boxed Ilex cornuta, and full wrap, half wrap and boxed Thuja occidentalis.

fan for circulation of the cold air. The fan operated each time the motor ran.

The cooler set at 36-44 degrees F. had the cooling coils running into the box and evenly distributed around its interior. This type of cooling provided a more even temperature at all points in the box, and the movement of air was greatly reduced, since there was no fan for circulation. Tables II and III show the temperature ranges of both coolers.

In order to maintain a high relative humidity, flats of wet peat moss were placed in the coolers. Some difficulty was encountered with the unit set at 32-36 degrees F. The top layer of the peat moss would freeze and prevent the release of moisture from the subsequent layers of peat.

The humidity was checked for a period of one hour at 7-10 day intervals with a hygro-thermograph having hair elements. The humidity in the unit set at 32-36 degrees F. ranged from 50-60 percent, and from 90-100 percent in the cooler set at 36-44 degrees F. Icing of the radiator coils in the unit set at 32-36 degrees F. is assumed to have extracted moisture from the air which resulted in a lower relative humidity and an increase in temperature after April 15.

TABLE II

TEMPERATURE RANGES FOR COOLER SET AT 32-36° F.
MINIMUM AND MAXIMUM TEMPERATURES
REACHED BETWEEN DATES RECORDED

Date	Minimum	Maximum
February 12	32	36
" 14	32	36
" 18	32	37
" 22	32	37
" 26	31	37
" 28	30	36
March 3	32	38
" 7	32	38
" 11	31	38
" 15	32	37
" 19	30	38
" 23	31	38
" 27	31	37
April 1	30	38
" 3	30	38
" 7	30	36
" 12	32	37
" 15	32	38
" 17	32	38
" 22	32	38
" 27	32	39
May 1	32	42
" 3	32	42
" 7	32	41
" 10	32	41
" 13	32	42

TABLE III

TEMPERATURE RANGES FOR COOLER SET AT 36-44° F.
MINIMUM AND MAXIMUM TEMPERATURES
REACHED BETWEEN DATES RECORDED

Date	Minimum	Maximum
February 12	36	43
" 14	36	44
" 18	36	44
" 22	36	44
" 26	36	45
" 28	36	45
March 3	34	44
" 7	34	44
" 11	32	44
" 15	35	44
" 19	35	46
" 23	34	44
" 27	35	44
April 1	35	44
" 3	34	44
" 7	34	43
" 12	34	44
" 15	34	43
" 17	34	44
" 22	36	44
" 27	36	44
May 1	36	44
" 3	38	44
" 7	34	44
" 10	34	44
" 13	35	43

CHAPTER IV

RESULTS

The rooted cuttings of Burford Holly, Ilex cornuta clon Burford, remained in storage from February 12, 1957 until May 6, 1957, a total of 83 days. On May 6 the cuttings were removed from storage and planted in an outdoor bed. The group of cuttings that were maintained in the propagation benches were removed and planted in the bed with the stored cuttings. A light shade for both groups was provided with cheesecloth.

All holly cuttings packed in boxes, with various materials around the roots and those bare root half wrapped stored at 32-36 degrees F. with a relative humidity of 50-60 per cent were desiccated, very brittle, and showed a loss of color. Therefore, they were considered dead and discarded.

Figures 3, 4 and 5 show the condition of the holly cuttings immediately after they were taken out of storage.

As shown in Table IV, the holly cuttings that were full wrapped had a much higher percentage of survival than did those in other type of wraps.

Holly cuttings half wrapped and boxed stored at 36-44 degrees F. showed more color and were not as dry as the cuttings stored at 32-36 degrees F. Tables IV and V show the cuttings stored at 32-36 and 36-44 degrees F. The highest percentage of survival was obtained from cuttings



Figure 3. Holly cuttings stored in a box packed with sphagnum for 83 days at, left, 36-44 and right, 32-36 degrees F.



Figure 4. Holly cuttings stored bare root for 83 days at, left, 36-44 and, right, 32-36 degrees F.



Figure 5. Holly cuttings stored full wrapped packed with perlite for 83 days at, left, 32-36 degrees, right, 36-44 degrees F.

TABLE IV

PERCENT SURVIVAL OF BURFORD HOLLIES STORED AT 32-36 DEGREES F. FOR 83 DAYS

Packing material	Method of wrap	Weeks after planting: 2	4	6	8
		Percent survival			
Sphagnum	Full wrap	40	36	36	34[a]
	Half wrap	4	0	0	0
	Box	0	0	0	0
Perlite	Full wrap	10	10	10	10
	Half wrap	10	10	10	10
	Box	0	0	0	0
Bare root	Full wrap	48	48	48	48[a]
	Half wrap	0	0	0	0
	Box	0	0	0	0
Maintained in propagation bench		98	98	98	98

[a]Sphagnum and bare root were significant over perlite.

For values to be significant at the 5 per cent level, in most cases the values must differ by 20 percentage points.

TABLE V

PERCENT SURVIVAL OF BURFORD HOLLIES STORED AT 36-44 DEGREES F. FOR 83 DAYS

Packing material	Method of wrap	Weeks after planting: 2	4	6	8
		Percent survival			
Sphagnum	Full wrap	92	92	90	88[a]
	Half wrap	80	72	72	72
	Box	66	62	60	56
Perlite	Full wrap	72	70	68	68[b]
	Half wrap	50	40	38	36
	Box	24	24	24	24
Bare root	Full wrap	84	76	74	74
	Half wrap	98	94	94	94[c]
	Box	80	74	74	74
Maintained in propagation bench		98	98	98	98

[a]Full wrap was significant over box.

[b]Full wrap was significant over half wrap and box.

[c]Half wrap was significant over box and full wrap.

For values to be significant at the 5 per cent level, in most cases the values must differ by 20 percentage points.

stored bare root and half wrapped.

The holly cuttings that were half wrapped and packed with sphagnum moss showed new root growth when taken from storage. New root growth in the other packages was not apparent.

Top growth measurements taken 8 weeks after planting showed no consistent difference in growth. Stored cuttings showed as much new growth as the group that was maintained in the propagation bench.

The arborvitae cuttings were placed in storage on February 12, 1957 and taken out May 13, a total of 90 days in storage. They were potted in 2½ inch Jiffy pots made of pressed peat and placed in greenhouse benches. The cuttings that were maintained in the propagation bench was removed and potted in the same type pots.

Arborvitae cuttings half wrapped and those packed in boxes with various materials around the roots stored at 32-36 degrees F. were found to show desiccation and a loss of color. The foliage and stems were brittle and the cuttings were considered to be dead, therefore, they were discarded.

Figures 6 and 7 show the condition of the arborvitae cuttings when removed from storage.

Tables VI and VII indicate the percentage of survival of Thuja occidentalis under the two conditions of temperature and humidity. Only those fully wrapped survived at 32-36 degrees F.



Figure 6. Arborvitae cuttings stored for 90 days at 36-44 degrees F. Left to right, half wrap, box and full wrap.



Figure 7. Arborvitae cuttings stored half wrap for 90 days at, left, 36-44, right, 32-36 degrees F.

TABLE VI

PERCENT SURVIVAL OF THUJA OCCIDENTALIS STORED AT 32-36 DEGREES F. FOR 90 DAYS

Packing material	Method of wrap	Weeks after planting: 2	4	6	8
		Percent survival			
Sphagnum	Full wrap	54	30	26	24[a]
	Half wrap	0	0	0	0
	Box	0	0	0	0
Perlite	Full wrap	44	30	28	28[a]
	Half wrap	0	0	0	0
	Box	0	0	0	0
Bare root	Full wrap	42	34	32	28[a]
	Half wrap	0	0	0	0
	Box	0	0	0	0
Maintained in propagation bench		100	100	100	100

[a]Full wrap was significant over other wraps.

For values to be significant at the 5 per cent level, in most cases the values must differ by 20 percentage points.

TABLE VII

PERCENT SURVIVAL OF THUJA OCCIDENTALIS STORED AT 36-44 DEGREES F. FOR 90 DAYS

Packing material	Method of wrap	Weeks after planting: 2	4	6	8
		Percent survival			
Sphagnum	Full wrap	26	20	20	18
	Half wrap	38	34	20	14
	Box	84	60	52	52[a]
Perlite	Full wrap	14	12	8	8
	Half wrap	68	58	46	38[c]
	Box	90	78	74	66[a]
Bare root	Full wrap	22	18	18	16
	Half wrap	82	72	64	62[b]
	Box	88	60	32	22
Maintained in propagation bench		100	100	100	100

[a]Box was significant over half and full wrap.

[b]Half wrap was significant over full wrap and box.

[c]Half wrap was significant over full wrap.

For values to be significant at the 5 per cent level, in most cases the values must differ by 20 percentage points.

Stem and leaf tissue breakdown was found on full wrapped cuttings stored at both temperatures. However, more rot was found on those stored at 36-44 degrees F. and a relative humidity of 90-100 per cent. A higher percentage of survival was obtained from full wrapped cuttings at 32-36 degrees F. than at 36-44 degrees F. The full wrapped cuttings stored at 36-44 degrees F. had more mold and foliage rot than did cuttings stored at the lower temperature.

Growth measurements of the arborvitae showed that the group maintained in the propagation bench made much more new growth than any of the stored groups.

Higher percentages of survival were obtained from the 36-44 degrees F. storage with a relative humidity of 90-100 percent.

A statistical analysis of the data shown in Tables VIII and IX based on percentage of survival showed the following relationships between packing media and between types of wraps for each of the two storage conditions.

Holly cuttings stored at 32-36 degrees F.

1. Cuttings with a full wrap were significantly better than those packaged by other methods, except in the case of perlite medium with the half wrap.
2. Cuttings packaged in a full wrap with various media showed those packaged with sphagnum and with roots bare to be significantly better than those packaged with perlite.

TABLE VIII

STORAGE CONDITIONS AND PERCENT SURVIVAL OF HOLLIES AFTER EIGHT WEEKS

Media	32-36° F.			36-44° F.		
	Full wrap	Half wrap	Box	Full wrap	Half wrap	Box
Sphagnum	34	0	0	88	72	56
Perlite	10	10	0	68	36	24
Bare root	48	0	0	74	94	74

For values to be significant at the 5 per cent level, in most cases the values must differ by 20 percentage points.

TABLE IX

STORAGE CONDITIONS AND PERCENT SURVIVAL OF ARBORVITAES AFTER EIGHT WEEKS

Media	32-36° F.			36-44° F.		
	Full wrap	Half wrap	Box	Full wrap	Half wrap	Box
Sphagnum	24	0	0	18	14	52
Perlite	28	0	0	8	38	66
Bare root	28	0	0	16	62	22

For values to be significant at the 5 per cent level, in most cases the values must differ by 20 percentage points.

Holly cuttings stored at 36-44 degrees F.

1. Cuttings stored under these conditions showed those full wrapped and packed with sphagnum to be significantly better than cuttings packed in a box with sphagnum.
2. Full wrapped cuttings packed with perlite showed a significant difference over cuttings packed with perlite in boxes and half wraps.
3. Cuttings stored bare root in a box showed a significant difference over those packed in a box with sphagnum and perlite and those packaged in sphagnum were significantly better than those in perlite.
4. Cuttings packaged in a full wrap with various media showed those with sphagnum to be significantly better than those with perlite.
5. Cuttings packaged bare root in a half wrap showed a significant difference over half wrapped cuttings packed with sphagnum and perlite and those packaged with sphagnum were significantly better than those with perlite.
6. Cuttings half wrapped and packed with roots bare showed a significant difference over cuttings stored bare root in full wraps and boxes.

Arborvitae cuttings stored at 32-36 degrees F.

1. Arborvitae cuttings stored under these conditions when analysed statistically showed that all full wrapped cuttings were significantly better than those in other type of wraps.

Arborvitae cuttings stored at 36-44 degrees F.

1. Cuttings packed in a box with various media showed those with sphagnum and perlite to be significantly better than those with the same media in full and half wraps.
2. Cuttings half wrapped with roots bare showed a significant difference over cuttings packed with roots bare in full wraps and boxes.
3. Half wrapped cuttings packed in perlite and with roots bare showed a significant difference over cuttings half wrapped with sphagnum and those with roots bare were significantly better than those in perlite.

The statistical analysis of the data given in Tables VIII and IX was determined by the method used by Pearson and Bennett (10) for testing the significant difference between percentages at the 5 per cent level.

CHAPTER V

SUMMARY

The survival of cuttings stored at 36-44 degrees F. was much greater than those stored at 32-36 degrees F. This difference is thought to have been due to the high humidity maintained by the cooling unit set at 36-44 degrees F.

Holly cuttings half wrapped and stored bare root at 36-44 degrees F. showed a significant difference in survival over half wrapped cuttings packed with sphagnum and perlite.

Full wrapped holly cuttings packed with sphagnum showed a significant difference in survival over those packed in perlite when stored at 36-44 degrees F.

Half wrapped arborvitae cuttings stored bare root at 36-44 degrees F. showed a significant difference in survival over cuttings stored half wrapped and packed with sphagnum and perlite.

Burford cuttings half wrapped and stored bare root at 36-44 degrees F. had the highest percentage survival of any group of stored holly cuttings and nearly equal to those left in the bench, but survival of those stored at 32-36 degrees F. was only about 50 per cent of those in the bench.

The arborvitae cuttings packed in a box with perlite and stored at 36-44 degrees F. had the highest percentage survival of any stored arborvitae group, but not equal to

those left in the bench. Sixty-six percent survived as compared with 100 per cent for those in the bench, but at 32-36 degrees F. only 28 per cent survived.

Eight weeks after planting, the holly cuttings that had been stored showed no consistent difference in new top growth as compared to that of the group that was maintained in the propagation bench. However, the arborvitae cuttings that were maintained in the propagation bench showed much more new growth than did the cuttings that were stored.

CRANES CREST

BIBLIOGRAPHY

BIBLIOGRAPHY

1. American Nurserymen, "Cold Storage Improves Nursery Operation, Increases Profit", Dec. 1, 1953, p. 10.

2. _____. "Researchers Report on Tests With Polyethylene Packaging", Aug. 1, 1954, p. 12.

3. _____. "Storage of Cuttings", Dec. 15, 1956, p. 45.

4. Bird, J. J. "Growing Strawberries", Tennessee Publication 344, 1953.

5. Bonner, J. and Galston, A. W. Principles of Plant Physiology, San Francisco, W. H. Freeman and Company, 1952, p. 466.

6. Curtis, O. F. and Clark, D. G. An Introduction to Plant Physiology, 1st Ed., New York, McGraw-Hill Book Co., 1950, pp. 275-295.

7. Mahlstede, J. P. "Polyethylene Packaging of Ornamental Plants", American Nurserymen, Sept. 1, 1955, p. 9.

8. Meyer, B. S. and Anderson, D. B. Plant Physiology, New York, Van Nostrand Co., 1939 pp. 585-612.

9. _____. Plant Physiology, 2nd Ed., New York, Van Nostrand Co., 1952, p. 619.

10. Pearson, E. S. and Bennett, C. A. Statistical Methods, New York, John Wiley and Sons, 1952, p. 343.

11. Shoemaker, J. S. Small Fruit Culture, 2nd Ed., Philadelphia, The Blakiston Co., 1948, pp. 117-219.

12. _____. Small Fruit Culture, 3rd Ed., New York, McGraw-Hill, 1955, p. 134.

13. Snyder, W. E. and Hess, C. E. "Low Temperature Storage of Rooted Cuttings of Nursery Crops", American Society for Horticultural Science, Vol. 67, 1956, p. 545.

14. Vanderbrook, C. "The Storage of Rooted Cuttings", American Nurserymen, May 15, 1956, p. 10.

CRANES CREST

APPENDIX

TABLE X

COMPARISON OF PACKING MATERIALS ON SURVIVAL OF BURFORD HOLLIES STORED AT 36-44 DEGREES F. FOR 83 DAYS

Packing material	Method of wrap	Weeks after planting: 2	4	6	8
		Percent survival			
Sphagnum	Full wrap	92	92	90	88[a]
Perlite	Full wrap	72	70	68	68
Bare root	Full wrap	84	76	74	74

[a]Sphagnum wrap was significant over perlite.

For values to be significant at the 5 per cent level, in most cases the values must differ by 20 percentage points.

TABLE XI

COMPARISON OF PACKING MATERIALS ON SURVIVAL OF THUJA OCCIDENTALIS STORED AT 36-44 DEGREES F. FOR 90 DAYS

Packing material	Method of wrap	Weeks after planting: 2	4	6	8
		Percent survival			
Sphagnum	Full wrap	26	20	20	18
Perlite	Full wrap	14	12	8	8
Bare root	Full wrap	22	18	18	16

No significant difference.

For values to be significant at the 5 per cent level, in most cases the values must differ by 20 percentage points.

TABLE XII

COMPARISON OF PACKING MATERIALS ON SURVIVAL OF BURFORD HOLLIES STORED AT 36-44 DEGREES F. FOR 83 DAYS

Packing material	Method of wrap	Weeks after planting: 2	4	6	8
		Percent survival			
Sphagnum	Half wrap	80	72	72	72[a]
Perlite	Half wrap	50	40	38	36
Bare root	Half wrap	98	94	94	94[a]

[a]Sphagnum and bare root was significant over perlite and bare root was significant over sphagnum.

For values to be significant at the 5 per cent level, in most cases the values must differ by 20 percentage points.

TABLE XIII

COMPARISON OF PACKING MATERIALS ON SURVIVAL OF THUJA OCCIDENTALIS STORED AT 36-44 DEGREES F. FOR 90 DAYS

Packing material	Method of wrap	Weeks after planting: 2	4	6	8
		Percent survival			
Sphagnum	Half wrap	38	24	20	14
Perlite	Half wrap	68	58	46	38[a]
Bare root	Half wrap	82	72	64	62[a]

[a]Perlite and bare root were significant over sphagnum and bare root was significant over perlite.

For values to be significant at the 5 per cent level, in most cases the values must differ by 20 percentage points.

TABLE XIV

COMPARISON OF PACKING MATERIALS ON SURVIVAL OF BURFORD HOLLIES STORED AT 36-44 DEGREES F. FOR 83 DAYS

Packing material	Method of wrap	Weeks after planting 2	4	6	8
		Percent survival			
Sphagnum	Box	66	62	60	56[a]
Perlite	Box	24	24	24	24
Bare root	Box	80	74	74	74[a]

[a]Sphagnum and bare root were significant over perlite.

TABLE XV

COMPARISON OF PACKING MATERIALS ON SURVIVAL OF THUJA OCCIDENTALIS STORED AT 36-44 DEGREES F. FOR 90 DAYS

Packing material	Method of wrap	Weeks after planting 2	4	6	8
		Percent survival			
Sphagnum	Box	84	60	52	52[a]
Perlite	Box	90	78	74	66[a]
Bare root	Box	88	60	32	22

[a]Perlite and sphagnum were significant over bare root.

For values to be significant at the 5 per cent level, in most cases the values must differ by 20 percentage points.