Table 2. Effectiveness of different temp in stimulating growth of excised 'Spartan Banner' onion shoots after 96 hr of exposure. Shoots planted in moist sand in dark at 20°C for 96 hr after temp treatment.

	Growth (% of initial length)[z]					
	Temperature °C					
Expt.	Control	0	5.0	7.5	12.5	20.0
1	27.2a	49.3b	62.5c	–	67.3c	22.4a
2	14.3a	–	–	40.2b	42.0b	19.3a

[z]Mean separation by Duncan's multiple range test, 5% level.

Table 3. Induction of secondary dormancy in 'Spartan Banner' onion shoots by high temp (30° C) and its reversal by subsequent low temp treatments (10°).

Temp treatment				Growth (% increase over initial length)		
				Expt.[z]		
10°	20°	30°	10°			
(Hr at indicated sequence of temp)				1	2	3
Control – not chilled				20.15a	20.35a	24.23a
96	–	–	–	39.78b	44.92b	45.49bc
96	–	24	–	16.25a	–	–
96	24	–	–	55.20c	–	–
96	–	24	48	–	38.47b	–
–	96	–	–	–	–	18.36a
48	–	–	–	–	–	39.15b
48	24	–	48	–	–	51.27c

[z]Mean separation within experiments by Duncan's multiple range test, 5% level.

increases the level of growth inhibitors in the tissue. This response to high temp of excised onion shoots is similar to effects of high temp on peach bud dormancy (2, 10, 11) and lettuce seed dormancy (9) often referred to as "secondary" dormancy. The promotive effect of 30° could be reversed by following the 30° treatment with another 10° treatment. Exposure of the excised apices to 20° following the low temp treatment was promotive (Table 3). These results are similar to those of Boswell (4) who showed that alternating 0° and 10° caused more rapid sprouting of intact onions than continuous storage at either 0° or 10°. Borden (3) also found that alternating temp promoted germination of dormant *Eucalyptus pauciflora* seeds and Erez and Lavee (5) found similar results in releasing of peach buds from dormancy.

Because of the similarity in response of excised onion shoots and intact bulbs to temp, we conclude that the excised shoot system may be used to provide further information concerning onion rest and dormancy.

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Effects of Cold Storage Duration on Bud Dormancy and Root Regeneration of White Ash (*Fraxinus americana* L.) Seedlings[1]

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Additional index words. regeneration, potential, rest

Abstract. **Root regeneration and time to first budbreak of two-year white ash (*Fraxinus americana* L.) seedlings were strongly correlated with the number of hours of chilling. Physiological dormancy of the buds was removed after approx 2500 hours of storage at 5°C and this coincided with the beginning of increased root regeneration potential. Increased periods of chilling enhanced the rate at which growth was resumed after transfer of seedlings to environmental conditions adequate for growth. The present study indicates that fall-harvested white ash seedlings can be stored at 5° at least until May without any apparent detrimental effects on root regeneration potential or seedling condition.**

Successful establishment and growth of a transplanted seedling are dependent on its ability to initiate and develop new roots rapidly at time of planting (12). Root regeneration capacity has been used as a measure for assessing effects of various cultural and storage techniques on the physiological condition of nursery stock and is correlated with field survival and ease of transplanting (4, 6, 11, 12).

Unlike buds of temperate zone hardwoods, which show a period of dormancy or rest that can be removed by chilling (14), roots do not appear to exhibit a period of innate dormancy (9, 13). Root growth appears to be dependent on environmental parameters such as soil temperature, especially during spring and fall (7, 8). However, the endogenous control of root initiation in hardwoods apparently resides in the shoot (2, 5, 9). According to Richardson (9), silver maple (*Acer saccharinum* L.) seedlings require a physiologically nondormant bud to produce and export growth factors necessary for root initiation. Thus, in this species, root initiation is dependent on the state of dormancy of the buds which, in turn, is dependent on the amount of chilling received as the plant overwinters.

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Artificial chilling or cold storage of nursery stock is commonly practised by many nurseries to insure availability for planting in the spring and to extend the planting season beyond the normal harvesting period. However, much of the work to date has involved conifer seedlings that differ from hardwoods in their control of root regeneration (2, 9).

The present paper outlines the effects of cold storage on bud dormancy and root regeneration of white ash seedlings.

Two-year white ash seedlings were obtained from the Ontario Ministry of Natural Resources, St. Williams Nursery, St. Williams, Ontario in the spring of 1973. The seedlings were planted into transplant beds on St. Joseph Island approx 50 km (30 miles) SE of Sault Ste. Marie, Ontario on April 28, 1973. No nutritional treatments were applied. The seedlings were harvested on Oct. 27 and placed in 5°C storage and approx 65% relative humidity. At time of harvesting all seedlings had abscissed their leaves and were dormant. They were stored in the dark with their roots surrounded by damp peat moss. At monthly intervals from Nov. 1, 1973 to May 1, 1974, 12 seedlings were removed from cold storage, examined for new white lateral roots and placed in 20-cm (8-inch) pots in a sterilized mixture of 2 soil:1 sand:2 peat (v/v) in the greenhouse under extended 16-hr photoperiods obtained with Sylvania GroLux WS fluorescent tubes. Greenhouse temp were maintained at approx 18° (night) and 28° (day).

After 30 days, the seedlings were removed from the pots and the soil was carefully washed from the roots with water to minimize damage. The new white lateral roots produced during this period were counted and the plants were repotted. The time required for first budbreak was also recorded. Seedlings planted on Nov. 1 remained in the greenhouse throughout the experiment and were the unchilled controls. Seedlings were considered to have broken physiological dormancy or rest when all seedlings lifted at a particular sampling time broke bud within a 3-week period.

The data were subjected to linear regression and in the case of the root regeneration data after a $\log_e$ transformation.

All seedlings remained healthy in storage at 5°C and no detrimental fungal growth was observed. No bud or root growth was noted in storage at any of the sampling dates.

Only 58.3% of the seedlings removed from storage on Nov. 1, 1973 and hence exposed to only a short period of chilling in storage and in the nursery prior to harvesting broke bud after 220 days in the greenhouse environment. With chilling, a greater proportion of the seedlings broke dormancy, 83.3% in Dec. and 100% from Jan. to May.

The time required for first budbreak is shown in Fig. 1. A strong negative correlation ($r = -0.98$ at $P = 0.005$) was found between the time required for first budbreak and the hours of chilling in storage at 5°C. Approx 2500 hr of chilling at 5° were required for removal of physiological dormancy.

Increased no. of new white roots initiated during the 30-day growth period in the greenhouse were observed with increased periods of storage at 5°C (Fig. 2). During Dec. and Jan., low root regeneration potentials were obtained. These potentials increased rapidly beginning in Feb. and reached their highest levels in April and May. There was a strong positive correlation ($r = 0.96$ at $P = 0.005$) between the no. of new white roots initiated and hours of chilling at 5°.

Since both root regeneration potential and time to first budbreak were strongly correlated with the no. of hours of chilling at 5°C, it is possible that they themselves were correlated. An examination revealed a strong

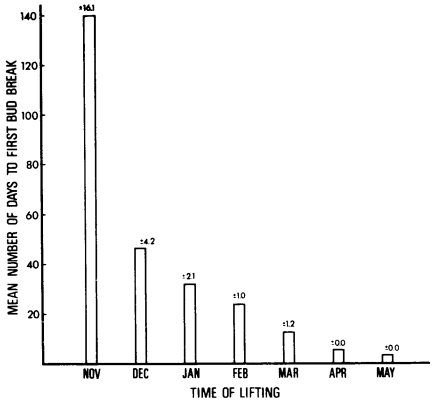

Fig. 1. The mean number of days required for first budbreak in seedlings brought into the greenhouse after various periods of storage at 5 C. Figures on histograms represent one standard error.

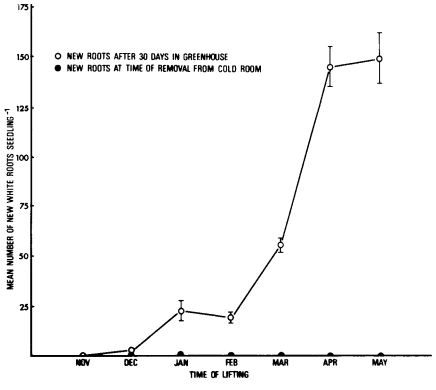

Fig. 2. Mean number of new white lateral roots per seedling brought into the greenhouse after various periods of storage at 5 C ± one standard error.

negative correlation ($r = -0.98$ at $P = 0.005$) between root regeneration potential and time required for first budbreak.

Correlations similar to the above have been obtained with other hardwood species, notably sugar maple (*Acer saccharum* Marsh.) and silver maple (Webb, unpublished data).

Cold storage of dormant, fall-lifted white ash seedlings appears useful as a method for storing nursery stock to be transplanted in the spring. Unlike other hardwoods, such as sugar maple and silver maple, that show bud swelling and new root formation in storage at 5°C (Webb, unpublished data), and hence possible utilization of essential food reserves necessary for growth when transplanted (3), no shoot or root growth was obtained in white ash during storage at 5°. Although physiological dormancy of the buds was removed after a short period of chilling prior to lifting in the nursery, followed by storage at 5° for approx 2500 hr, the seedlings were maintained in a state of imposed dormancy during storage until the end of the experiment in May. This temp was below the minimum requirement for growth and was sufficient to inhibit bud and shoot growth as well as root growth.

As expected from previously reported work (10), a strong correlation between the time required for budbreak of white ash and hours of chilling at 5°C was obtained. Similarly, results of work with sugar maple, yellow birch (*Betula alleghaniensis* Britt.) and balsam fir (*Abies balsamea* [L.] Mill.) demonstrated a positive correlation between length of cold storage and the speed at which growth commenced after transfer to greenhouse conditions (1).

In the present study a good correlation was also found between hours of storage at 5°C and root regeneration potential. The phenology of root regeneration potential in cold storage of white ash seedlings was similar to the seasonal pattern of root regeneration potential of nursery-harvested pin oak (*Quercus palustris* Muenchh.) and scarlet oak (*Q. coccinea* Muenchh.) (6). Root regeneration potential increased with increasing periods of storage and reached a maximum during April and May, a time when physiological dormancy of the buds had been removed. Similarly, a strong correlation was also found between root regeneration potential and time to first budbreak. Bud dormancy was removed after approx 2500 hr of chilling and this coincided with the beginning of increased root regeneration. Unlike root initiation in silver maple (9), root regeneration in white ash can take place at a time when buds are strongly dormant, i.e., in Dec. and Jan. These results are similar to those found in northern red oak (*Q. rubra* L.) (2) and sugar maple (13).

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Root regeneration potentials usually show a peak and then decline with increased time in storage or in the nursery (6, 11). The highest levels of root regeneration in white ash were obtained in April and May. Whether root regeneration potentials will decrease or be maintained at these levels with increased storage at 5°C remains to be determined. The present work demonstrates that increased periods of cold storage enhanced the rate at which growth of white ash seedlings was resumed after transfer to environmental conditions adequate for growth and that seedlings can be stored at 5° at least until May, a time when most sites are available for planting, without any apparent detrimental effects on root regeneration potential and seedling condition.

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Growth of Chrysanthemums Fertilized with Liquid Sewage Sludge[1]

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Additional index words. Chrysanthemum morifolium, inorganic fertilizer, soil, sand, peat, flower diameter

Abstract. **Chrysanthemum plants (*Chrysanthemum morifolium* Ramat. cv. Bright Golden Anne) were grown for 84 days in plastic pots containing 6 different media treated with inorganic fertilizers or liquid digested sewage sludge at 50, 100, and 200 ml/week. Plants grown in 1 soil:1 sand:1 peat, 1 soil:1 sand, and 1 soil:1 peat were similar to each other in size, and larger than plants grown in 1 sand:1 peat, all sand, or all peat. Peat-grown plants were smallest. Plant size and flower diameter decreased with increasing rates of sludge application. Plants fertilized with inorganic sources of fertilizer looked the same as those grown with 50 ml/week sludge (6 mm), except the sludge-treated plants were shorter and had a smaller dry weight. Plants treated with 50 ml/week sludge had flowers with a diameter and dry weight equal to those of flowers grown with liquid or pelletized inorganic fertilizer.**

Liquid digested domestic sewage sludge has been used to fertilize field crops for decades. It is an inexpensive fertilizer, often available free from sewage treatment plants. In 1965 sewage sludge was suggested as a good fertilizer not only for field plants, but also for horticultural and greenhouse crops (1). But no experiments had been done to prove this. A few years ago, Kiplinger[3] found that various greenhouse potted plants could be grown with sludge. However, because the problem of waste disposal was not urgent then, the research was not published.

Composted municipal refuse, which sometimes is treated with sludge, has been used to grow ornamentals (3, 5). Only 2 reports (2, 6) appear to have been published on the use of sludge, without municipal refuse, in greenhouse media to grow ornamental plants. In these studies, dried sludge was incorporated into the media before planting. Sludge was not applied in the liquid form to the growing potted plants.

Chrysanthemum plants (rooted cuttings) with 10 cm top growth were planted in 10 cm diam plastic pots, 1 plant per pot, on Dec. 10, 1974 (Day 1). Six different media, mixed on a volume basis, were tested: 1 soil:1 sand:1 peat; 1 sand:1 peat; 1 soil:1 sand; 1 soil:1 peat; all sand; and all peat. A Hadley very fine sandy loam (4), sphagnum peat moss from New Brunswick, Canada, and coarse, builder's sand were used to formulate the media.

Six fertilizer treatments were used during a 12-wk period (Table 1). Digested secondary liquid sewage sludge was obtained from the Amherst, Massachusetts, Sewage Treatment Plant. (Secondary treatment of wastewater involves the screening and settling processes of primary treatment plus biological activities designed to reduce the quantity of suspended and dissolved organic solids. Digestion is the process in which organic or volatile matter in sludge is gasified, liquefied, mineralized, or converted into more stable organic matter, through the activities of living organisms.) Fifty ml (or about 6 mm) of sludge added weekly to each pot for 12 wk at 2% solids corresponded to a yearly application rate of 15.5 metric tons/ha. Weekly additions of water,

Table 1. Fertilizer treatment of 'Bright Golden Anne' chrysanthemums.

Treatment	Application rate
No sludge or inorganic fertilizer	100 ml tap water per week
A 2600-ppm solution of an inorganic fertilizer (20% N, 9% P, 17% K)	100 ml per week (standard amount added by commercial greenhouse growers)
Plastic-encapsulated and pelletized inorganic fertilizer (trade name: Osmocote; 14% N, 6% P, 12% K)	5 grams per pot, mixed in media before planting (standard amount added by growers); pots then received 100 ml tap water per week
Liquid sewage sludge	50 ml per week
Liquid sewage sludge	100 ml per week
Liquid sewage sludge	200 ml per week

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