Growth and physiology of containerized spruce seedlings : studies in progress at Forestry Canada, Quebec Region

Andre L. D'AousT
Forestry Canada, Quebec Region
SAINTE-FOY, Quebec
G1V 4C7

Paper read at the Northeastern State, Federal and Provincial Nurserymen's Conference, Montreal, Quebec, July 24 to July 27, 1990.

Abstract

Studies of containerized seedlings revealed that greenhouse conditions allow some control over nutrition and irrigation, but not fine adjustment of the growing degree-days over several months. These conditions, and particularly the latter, modified the type of seedling produced. Drought resistance of spruce seedlings of different productions was evaluated over one growing season. Stomatal conductance showed large variations, but reaction to drought stress improved as the growing seascn progressed. Acclimation of black spruce seedlings, prior to overwintering, is possible by applying short-day treatment which is preceded by cessation of nitrogen fertilization and followed by lowered temperatures. Short-day conditioning in August resulted in an earlier dehardening and budbreak the following spring. The performance of the jack pine seedlings in the field was modified by the volume of the container and by the growth period before planting. A significant reduction of height growth was measured, and excavated root systems showed a smaller number cf plunging roots. Field testing showed a much higher mortality rate associated with fall planting as compared to spring plantations and a greater sensitivity with black spruce as compared to jack pine. Seedling mortality was generally caused by freezing damage on boreal sites, while on southern sites, it was mainly due to vegetative competition and animal damage. Height growth of jack pine was between two and three times higher than in black spruce after six to seven years under the same field conditions. Attempts to relate black spruce seedling characteristics to field performance showed that field conditions imposed a larger constraint than the physiology of the seedling to be planted.

Résumé

***Croissance et physiologie des semis d'epinette en contenant : etudes en cours** a Forets **Canada, Region de** Quebec.*

Des etudes de semis en conteneurs ont revele que les conditions en serre permettent un contrOle particulier sur la nutrition et /'irrigation; mais l'ajustement des degres-jours de croissance s'avere moins constant. Toutes ces conditions, et notamment cette demiére, medifient le type de semis produits. La resistance a la secheresse a etc§ evaluee pour des plants d'epinettes, de clifferents lots, au cours dune saison de croissance. La conductance stomatique est tres variable, mais la tolerance au stress hydrique s'ameliore au cours de la saison. L'acclimatation de semis d'epinette noire avant l'hivernage est realisable a l'ètape des productions. Deux semaines de traitement jour-court, en aotit, precede d'un arrêt de fertilisation et suivi de temperatures froides augmentent la tolerance au gel des semis a l'automne. Ce traitement provoque un ciebourrement et un desendurcissement plus tot au printemps. La performance des plants de pin gris sur le terrain est modifiee par le volume du conteneur et par la periode de croissance avant la mise en terre. La reduction de la croissance en hauteur est tres significative et dans les systemes de racines extraits du sot, i1 y a moins de racines plongeantes. Les essais sur le terrain montrent un taux de mortalite plus &eve pour la plantation d'automne que pour celle du printemps; de plus, l'apinette noire est plus sensible que le pin gris. En region boreale, la mortalite est causee par le gel, tandis qu'au sud, la competition vegetale et les animaux en sont responsables. Apres six a sept ans sous les mernes conditions, la croissance en hauteur du pin gris est de deux a trois fois superieure a cette de l'epinette noire. Les tentatives pour relier les caracteristiques initiates des semis d'epinette noire a la performance des plants sur le terrain revélent que la condition de terrain impose une contrainte superieure au developpement du plant, que celle apportee par la physiologie du semis au moment de la mise en terre.

Introduction

Our research on containerized seedlings has been active for over a decade. The *Ministere de l'Energie et des Ressources (Foréts)* had requested the collaboration of Forestry Canada in using containers in plant production. Plant physiologists and a greenhouse facility oriented our activity to the biology of the material being cultivated. We first studied the growth of black spruce seedlings under greenhouse conditions (D'AOUST 1980; GIROUARD 1982; GONZALEZ 1982; HATCHER 1982). Since, the provincial government has reoriented seedling production favoring the use of plastic covered greenhouses (locally called tunnels). Another change has been the adoption of a multipot container with a volume cf 50 cm' for one year production and 110 cm^3 for a two year schedule *(Rigi-pots 67-50* and *45-110* from *IPL Products Limited,* St. Damien, Quebec GOR 2Y0). Also, at the beginning of our studies, the type of biological material intended for outplanting was 15-week-old jack pine and 20 to 25-week-old black spruce seedlings. The plantation period for these seedlings was anticipated to be the complete vegetative period, but early results showed that only the spring and early summer were reliable. The last major modification was that larger plant material is not only desired, but a ratio of height to diameter with a mean value less than 100 is favored, it is even suggested that this value be reduced to 80 for dormant seedlings.

The general problem of what sort of biological material to produce in containers for outplanting remains. Also, can we modify at will the type of material being cultivated and how ?

Results and discussion

Preliminary trials had indicated that we could greatly improve the material produced by choosing proper growing conditions : nutrition, more sustained light regime, larger size of containers and even a substrate with a better water holding capacity (Fig. 1). Over four years, in a series of rearing periods, we annually produced over 25 000 black spruce seedlings to be used in early field evaluation and also to characterize the material produced.

This material originated from a single provenance (Roberval), and during these rearing periods, we measured several climatic and physiological variables. For example, when we measured the biomass accumulation as a function of growing degree-days, for one hundred days of growth, for

Table 1. Effect of nutrient concentrations **and water** levels, in the **peatmoss substrate, on growth of containerized** black spruce seedlings

Treatments Fertilizer[1] (mg)	Water level(%)	ppm N[3]	Twenty weeks of growth height (cm)	diam. (mm)	shoot d.w.	root d.w.
150	30	1 250	19,9 d	2,31 cd	0.68 bc	0,16 a
	45	833	19,6 cd	2,56 cd	0,78 cd	0,20 ab
	60	625	22,0 de	2,75 d	0,91 de	0,24 b
	30-60	937	23,6 e	2,73 d	1,00 e	0,23 b
50	30	417	11,3 a	1,81 a	0,34 a	0,15 a
	45	279	16,8 b	2,41 bc	0,67 cb	0,21 ab
	60	208	16,8 bc	2,21 b	0,57 b	0,21 b
	30-60	312	17,0 bc	2,27 b	0,65 cb	0,24 b

1. A water soluble fertilizer (20-20-20) added.
2. Water level as a percentage of water saturation of the substrate.
3. ppm N estimated equivalent to hydroponic solution (mg N/l).
4. Values followed by the same letter are not significantly different.

eight successive periods (4 years x 2 seasons), we observed that the biomass accumulated was more uniform with our summer production than under the spring conditions (Fig. 2A). We also observed that the sturdiness coefficient (H/D) had a significant pattern in relation to the growing degree-days under our conditions of growth (Fig. 2B). Unfortunately, not all conditions were strictly uniform over these periods. As we just observed, growing degree-days varied, and we had to irrigate accordingly. Mineral analysis of the seedlings showed an increase in nitrogen and phosphorus concentrations in the above-ground tissue as compared to the root material as growing degree-days increased (Fig. 3).

These early results showed that we could modify the size of the seedlings produced and the internal concentration of mineral elements (GONZALEZ and D'ACUST 1988). In another type of experiment, we were interested in the nutrition aspect with a different irrigation regime. Two quantities of a soluble fertilizer (20-20-20 from *Plant Products Co. Ltd.,* Port Credit, Ontario) were injected in the peat moss substrate (110 cm'), 50 and 150 mg of the fertilizer per cavity. Four levels of watering regime were tested: 30, 45, and 60% of water saturation of the medium and a fourth regime fluctuating between 30 and 60% of the peat water saturation level. After twenty weeks in a growth chamber (25/20 ^{0}C day-night temperatures and a 16-hour photoperiod with 200 moles.m^{-2}.s'^{1} of PAR radiations), height, diameter, and biomass showed significant differences (Table 1). The largest seedlings obtained were those with the higher quantity of fertilizer, equivalent to an hydroponic solution of 800 ppm N. For the morphological variables, there was a significant interaction between the water regime and the fertilizer added. Mineral analysis of the tissues indicated that the nutrient concentration had significant effects on the mineral content, but that the water regime had none (Fig. 4). The water relation parameters were also measured cn these seedlings and in general showed the treatments' significant effects.

As anticipated, because of the more rigid greenhouse culture conditions, we were able to modify not only the morphology but also the physiology of containerized seedlings.

We have also been assessing plantation shock by studying the water relations of the materials. Soil conditions may appear relatively humid at plantation, however, there may be a time lapse before the root system becomes functional in its new environment and this will cause drought stress. In a trial to evaluate the drought resistance of different materials, plants were exposed to a fixed drying cycle and their stomatal conductance measured during the three weeks following. This material was also evaluated visually. This sequence was repeated at three different times over the growing season for the same material and for different lots of plants. The results showed a large variation in the stomatal conductance (Fig. 5); the coefficients of variation centered around 40%. Individual plants, however, kept their relative rank over the duration of the test (Fig. 6). The level of visible damage was higher in the smaller container as compared with the larger size; this was probably associated with a larger reservoir of water in the peat substrate in the latter (Fig. 7). The stage of development of the spruce seedlings also had an influence on the level of damage, which was less as the season progressed (Fig. 8). One could reason that earlier in the season stomatal control is not well established. However, last spring, verification of this hypothesis did not give a simple answer: stomatal resistance, on a surface area basis, between newly emerged needles and one-year-old foliage did not appear significantly different. Early susceptibility to damage by water stress could simply be related to the sudden increase in leaf surface area following bud burst with a non-acclimatized organ. We are continuing research for another interpretation of these phenomena and pursuing ecophysiological field experiments.

Frost hardening, or freezing tolerance, is another concern with this fast-growing material. It was soon realized that the natural conditioning of short-days and low temperatures was effective as an acclimation procedure (D'ACUST and CAMERON 1982). Recently, we have closely followed the acclimation process, imposing even lower temperatures during acclimation to correspond to WEISER'S (1970) phase of hardening (Fig. 9). Short-days followed by cold temperatures further increased the frost tolerance of our seedlings (BIGRAS and D'ACUST 1989).

In Quebec, we are not using cold storage facilities to overwinter the material, but several nurseries have started to use short-day conditioning to acclimatize seedlings (particularly spruce) prior to moving their stock out of the tunnels for the winter. As an example, in the fall of 1989, seedlings were brought into our laboratory at the end of October. This material had been under acclimation since late summer, the medium was water soaked to remove fertilizer, which was followed by two weeks of short-day conditioning with relatively high daytime temperatures and forced air ventilation at night to reduce the temperature (COLOMBO *et al.* 1984). This same material was treated in a freezing test, with a gradual lowering of temperature (2°C/h), then at set intervals some seedlings were removed and placed in a greenhouse bench for observation. Three weeks later, visual evaluation showed that the freezing tolerance had been reduced to –24°C. Only one seedling, out of thirteen, showed shoot freezing damage at this temperature. An additional evaluation, following regrowth of this same material, showed a growth reduction for the seedlings subjected to freezing temperatures below –16°C as a result of root damage. A safety margin between 0 and –15°C following operational acclimation procedures is feasible.

Studying a complete cycle from hardening to dehardening in another experiment, we noticed a certain limitation to short-day acclimation (Fig. 9), that is an activation of the dehardening process as compared to the control (long-day); also, a small but significantly earlier budbreak followed short-day treatment (Fig. 10). We are pursuing this type of study so as to refine the timing and conditioning procedure to obtain a safer margin of operation. Also, in collaboration with private nurseries, we are testing other means to prepare or protect the container stocks for overwintering under climatic conditions in Quebec.

The root development of jack pine *(Pines banksiana* Lamb.) in containers has also been studied. After two and three years of growth in two types of containers (50 crn° as compared to the more standard 110 cm^3) under shadehouse conditions, seedlings were smaller with the small volume container (Table 2). Outplanting on abandoned farm land (with a silty fine sand) resulted in a reduction of survival following a three-year rearing period as compared to a two-year period and particularly in the material from the smaller container; height growth was even more affected, with an increase of three times the original size for the younger material at plantation time and only a doubling in size for the older containerized material.

Natural seedlings, or trees, have some superficial roots and a plunging root system just below the soil surface; in the latter, some plants, like jack pine, have a well developed taproot. Seedlings grown in containers equipped with grooves cr ribs frequently have long lateral roots directed downward (orthogeotropic deformation) which are air pruned at the drainage hole (FRANCLET and NAJAR 1978). When these trees were outplanted and then excavated to examine their root systems, we observed many lateral roots

Table **2. Characteristics of Jack** pine seedlings before outplanting and after three years in the field

Containers				Field	
Type	Years	Height (cm)	Diam. (mm)	Survival (%)	Height (cm)
67-50	2	23.0	4.0	97	70.5
	3	36.0	4.3	86	68.9
45-110	2	27.9	4.3	98	81.4
	3	39.6	–	96	80.4

bending downward and uniting to form a chignon. At the base of the plug roots and originating from the remnant air pruned taproots, some replacement roots were present and plunged deeper into the soil (Fig. 11). A look at the root system from above reveals roots extending in two or more quadrants. Analysis of the root morphology of excavated root systems indicated that about two thirds of the plants showed root egress originating from the top and middle zone of the original plug root, and all trees analyzed showed roots plunging from the bottom or what used to be drainage hole of the container. Both increasing the rearing period from two to three years and reducing the volume of the container resulted in a reduction in the number of plunging roots (Fig. 12). Two thirds of these originated from the remnant of the taproot inside the plug.

Our observations of jack pine and under these experimental conditions showed that the rearing period and the volume of the container have a definite influence on the juvenile growth of outplanted material. Although a typical tap root is absent following containerization, some replacement roots are generally present and form an important part of the descending or vertical root system (GIROUARD 1989).

Several plantations were carried out with some of the plants that had been cultivated earlier. We had no local data concerning our containerized material, particularly on how it would perform in the field. But observations by our western colleagues (ARNOTT 1974; JOHNSON 1974; and SCARRATT 1974) indicated that this new type of biological material looked promising. As indicated earlier, we believed that we could modify the physiology of the plant to be cultivated and anticipated a major increase in the number of seedlings to be outplanted, raising the question : could we extend the planting period ? Among the objectives of early field trials was to evaluate spring and fall planting seasons with our containerized material.

Four species were considered : jack pine *(Pinus banksiana* Lamb.); Scots pine *(Pinus sylvestris L.);* black spruce *[Picea mariana* (Mill.) B.S.P.], and white spruce *[Picea glauca* (Moench) Voss]. Three of the plantation sites were at a latitude of 49° North and were typical of boreal forest, while five other sites were located in the so-called St. Lawrence-Great Lakes forest region (RowE 1972). With the exception of two boreal sites where the area had burned and in one southern site, where the vegetation was cut prior to plantation, all sites had some scarification (barrels and chains, *Bracke,* or disk trencher). The spring planting was carried out in May and the fall planting, in September. The seedlings had not received proper acclimation, but only from one to six weeks of shadehouse transition following seventeen weeks of greenhouse culture. Seedlings were planted manually with either a *Pottiputki* or a dibble. With the exception of one site where the vegetative competition was mowed around individual plants for three successive years, all other sites essentially had no released treatment following plantation.

The experimental designs included four cr five replications within one site, in the majority of cases (15) they used randomized blocks; in four situations, we had a completely randomized design.

Different containers were tried, but none outperformed the others although some minor differences were encountered. Therefore, I will concentrate on plant mortality, with its causes and the juvenile growth. I will also limit the presentation to two typical situations : one in the north and another in the south.

The Grand'Mere plantation is a southern site on abandoned farmland. The soil has a fine sand texture. The site was regenerated with white spruce in the 1930s and logged in 1980, then scarified with a *Bracke* in 1981. Black spruce seedlings were planted in 1981 and 1982 (2 800 seedlings) using four containers. For pines, only two species and two containers were used, but seedlings were planted for three successive years (a total of 23 230 plants). The summary of the mortality rate for the black spruce experiments indicate that it changes with time in the field and also with the planting season (Fig. 13), the major causes being vegetative competition, animal damage (mainly hare in this particular situation), and some waterlogging. Cumulative results for both species of pines in the same locality showed similar patterns to those of black spruce, but the level of mortality for the pines was generally lower (Fig. 14). Looking at height growth, one observes a more dynamic height growth performance among pines as compared to the black spruce for our outplanted species at Grand'Mare (Fig. 15).

Lake Bean, a northern site, burned in 1981. This site consisted of a thin layer of moraine, where drainage is rapid. Black spruce and jack pine, the two main species, were produced in three containers (total 3 940 seedlings) and outplanted during two seasons in 1982. The mortality rate for black spruce increased during the first two years following plantation and the fall planting had a higher mortality rate (Fig. 16). Freezing stress is encountered early in the fall on this bo real site and is a major cause of mortality to the just planted seedlings. Freezing damage, however, is only marginally noticed with the spring plantation material. The results were similar for jack pine but with a much lower rate of mortality (Fig. 17). Looking at height growth for this site, again, the more rapid recovery of jack pine as compared to black spruce is noticeable (Fig. 18).

All attempts to correlate the field results with early characteristics of seedlings (height, sturdiness coefficient, biomass, and mineral content) were unproductive. However, in general, the field conditions probably imposed far more restrictions on the seedlings than their physiological make-up at the time of outplanting.

Acknowledgments

It is difficult to individually recognize everyone that has participated in this project, but by naming my scientific colleagues, I would like to acknowledge also their technical assistants and students : Dr. F. BIGRAS, Dr. P.Y. BERMER; Mr. C. DELISLE; Dr. R.M. GIROUARD; Dr. A. GONZALEZ, and Mr. R. HATCHER.

Literature cited

ARNOTT, J.T. 1974. *Performance in British Columbia.* Pages 283-290 *in* R.W. Tinus, W.J. Stein, and W.E. Balmer, editors. Proc. N. Amer. Containerized For. Tree Seedling Symp. August 26-29, 1974, Denver, CO. Great Plains Agric. Counc. Publ. no. 68.

BIGRAS, F. and A.L. D'Aousr. 1989. *Dehardening of white spruce as influenced by hardening conditions.* Suppl. Plant Physiol., Joint meeting Am. Soc. Plant Physiol. and Can. Soc. Plant Physic'. July 30-August 3, 1989, Toronto, Ont. Abstract 151.

COLOMBO, S.J., D.Q. WEBB and C. GLERUM. 1984. *Frost hardiness testing: An operational manual for use with Extended Greenhouse Culture.* Ont. Min. Nat. Resourc. For. Res. Rep. 110. 14 p.

D'AcuST, A.L. 1980. *La culture proprement dite. In* Cent. rech. for. Laurentides, Que. Minist. Energ. Ressour., Ordre Ing. for. Cue, editors. *Atelier de travail sur la culture des semis en recipients,* March 18-20, 1980, Quebec, Que.

D'Aous-r, A.L. and S.J. CAMERON. 1982. *The effect of dormancy induction, low temperatures and moisture stress on cold hardening of containerized black spruce seedlings.* Pages 153-161 *in* J.B. Scarratt, C. Glerum and C.A. Plexman, editors. Proc. Can. Containerized Tree Seedling Symp, Sept. 14-16, 1981, Toronto, Ont. Environ. Can. Can. For. Serv. COJFRC Symp. Proc. 0-P-10.

FRANCLET, A. and M. NAJAR. 1978. *Consequences differees des deformations racinaires chez le pin maritime.* Ann. rech. sylvicol. AFOCEL Tome I : 179-202.

GIROUARD, R.M. 1982. *Jack pine seedlings grown in Quebec tubes and other containers.* Page 444 *in* J.B. Scarratt, C. Glerum and C.A. Plexman, editors. Proc. Can. Containerized Tree Seedling Symp. September 14-16, 1981, Toronto, Ont. Environ. Can., Can. For. Serv. COJFRC Symp. Proc. 0-P-10.

GIRCUARD, R.M. 1989. *Root development after outplanting of jack pine seedlings grown in Quebec, multipots. In* G.K. M. Smith and D. Bates, cochairmen. Forestry Research Marketplace : results. March 21-23, 1989, Toronto, Ont. For. Can. Ontario Reg., Sault St. Marie, Ont. OFRC Symp. Proc. 0-P-18.

GONZALEZ, A. 1982. *Some aspects of fertilization using containerized white spruce seedlings.* Page 432 *in* J.B. Scarratt, C. Glerum and C.A. Plexman, editors. Proc. Can. Containerized Tree Seedling Symp. September 14-16, 1981, Toronto, Ont. Environ. Can., Can. For. Serv. COJFRC Symp. Proc. 0-P-10.

GONZALEZ, A. and A.L. D'AOUST. 1988. *Observations and measurements of containerized black spruce seedlings growing in a greenhouse.* Can. For. Serv. Laurentian For. Cent., Inf. Rep. LAU-X-79E.

GONZALEZ, A. and A.L. D'ACuST. 1990. *Le regime hydrique et la nature du substrat dans la culture des semis en conteneurs. In* Que. Minist. Energ. Ressour. (Forets), editor. Troisieme atelier québecois sur la culture des plants forestiers en recipients. November 9-10, 1988, Chicoutimi, Que. MER 5350-6.

HATCHER, R. 1982. *Survival and growth of some paperpot seedling plantations in Quebec.* Pages 367-371 *in* J.B. Scarratt, C. Glerum and C.A. Plexman, editors. Proc. Can. Containerized Tree Seedling Symp. September 14-16, 1981, Toronto, Ont. Environ. Can., Can. For. Serv. COJFRC Symp. Proc. 0-P-10.

JOHNSON, H.J. 1974. *Canadian Forestry Service Container Planting Trials in Alberta, Saskatchewan and Manitoba.* Pages 298-305 *in* R.W. Tinus, W.J. Stein, and W.E. Balmer, editors. Proc. N. Amer. Containerized For. Tree Seedling Symp. August 26-29, 1974, Denver, CO. Great Plains Agric. Counc. Publ. no. 68.

ROWE, J.S. 1972. *Forest Regions of Canada.* Environ. Can., Can. For. Serv.; Information Canada No. Fo47-1300F, Ottawa.

SCARRATT, J.B. 1974. *Performance of tubed seedlings in Ontario.* Pages 310-320 *in* R.W. Tinus, W.J. Stein, and W.E. Balmer, editors. Proc. N. Amer. Containerized For. Tree Seedling Symp. August 26-29, 1974, Denver, CO. Great Plains Agric. Counc. Publ. no. 68.

WEISER, C.J. 1970. *Cold resistance and injury in woody plants.* Science 169: 1269-1278.

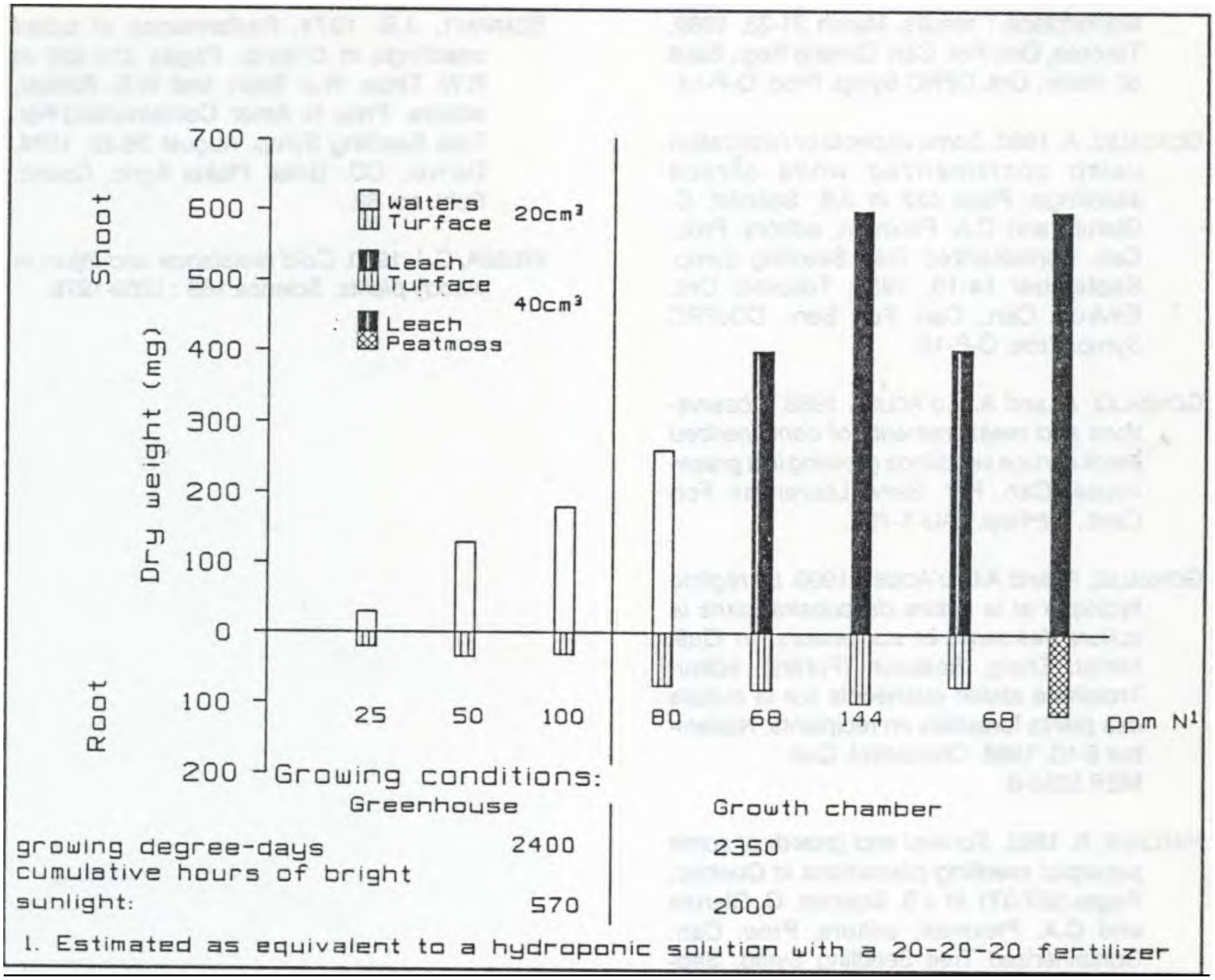

Figure 1. Variation of biomass with black spruce seedlings as a function of growing conditions.

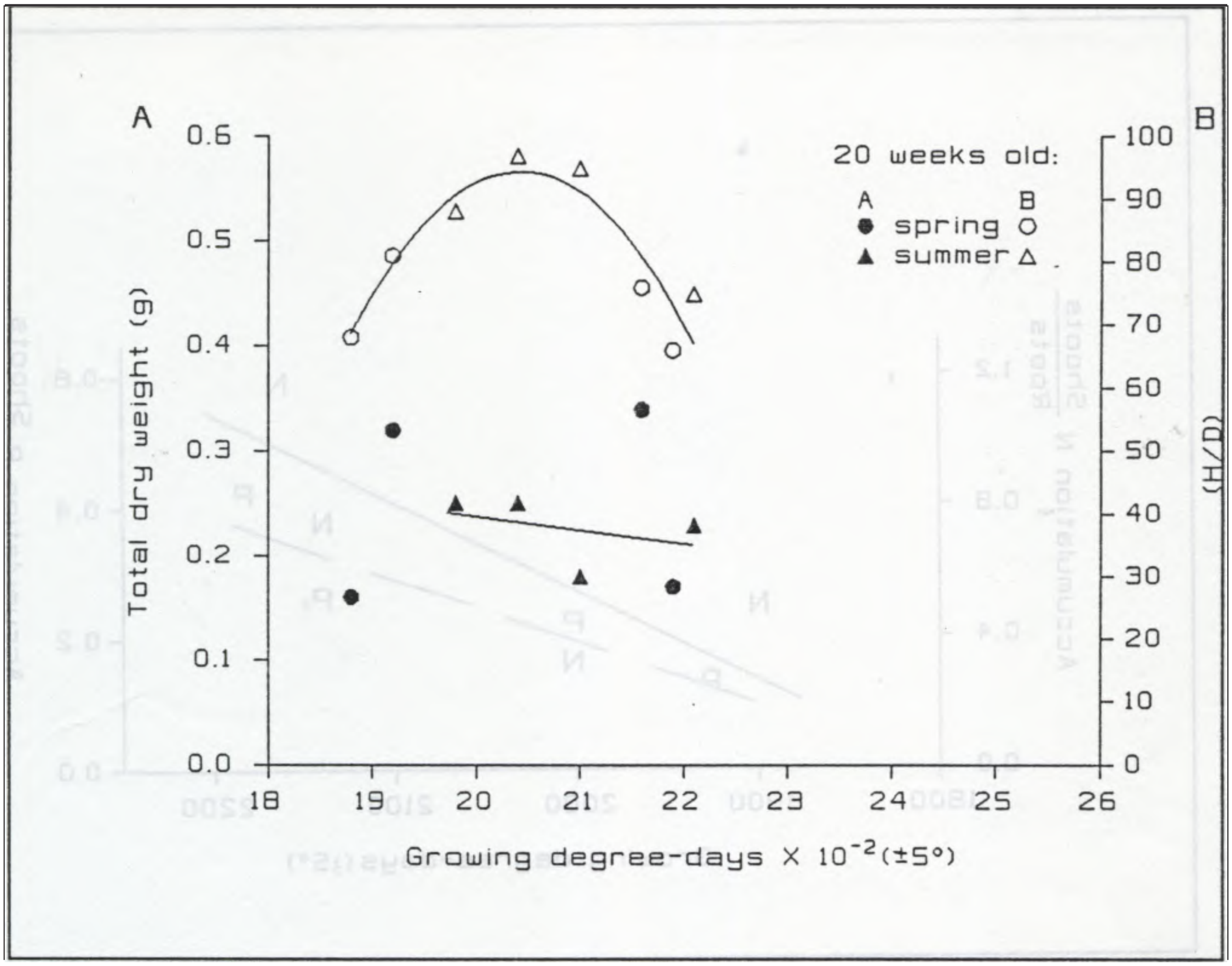

Figure 2. Growth of black spruce seedlings in the greenhouse as a function of growing degree-days: A, biomass B, sturdiness coefficient.

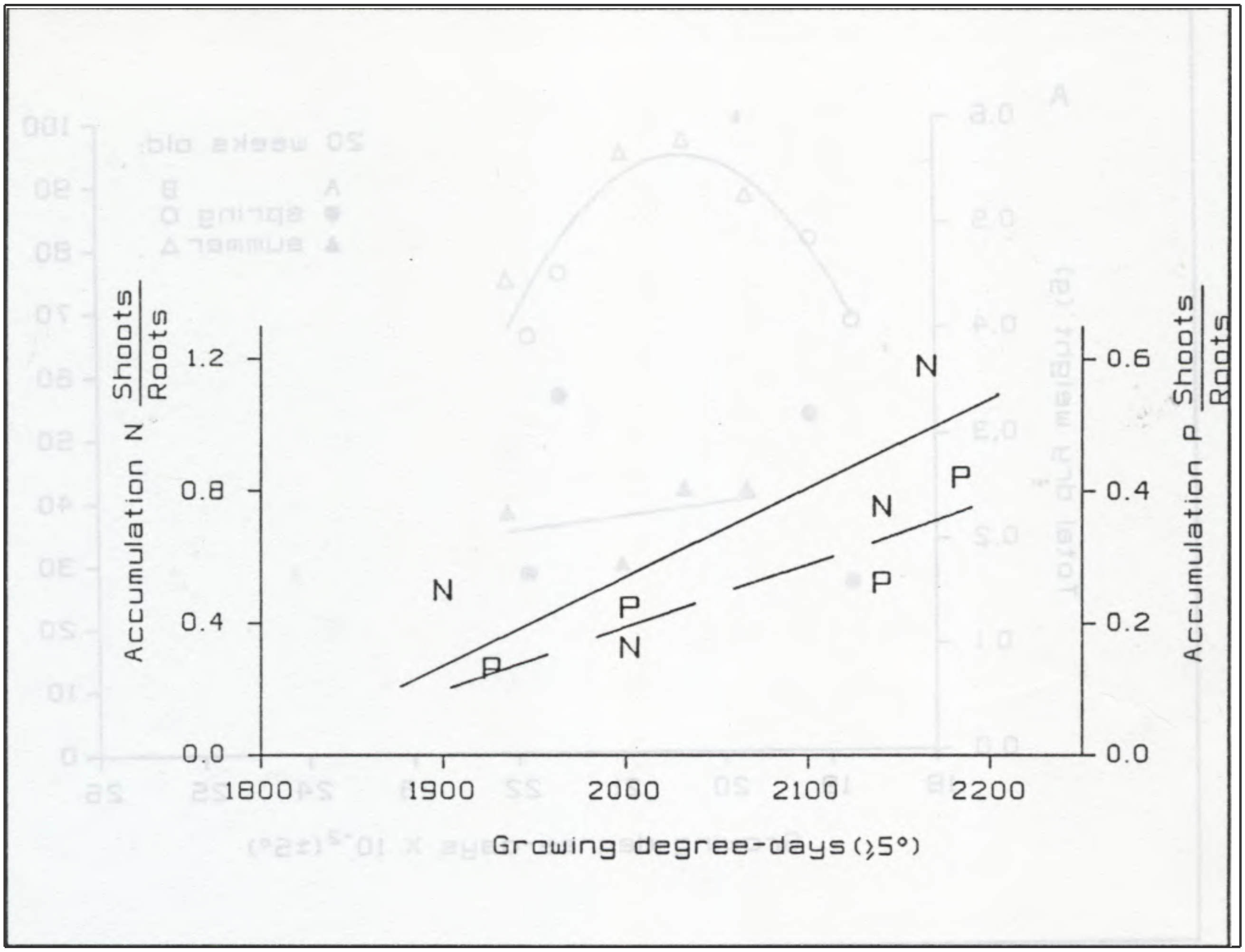

Figure 3. Effect of growing degree-days on the accumulation of nutrients by fifteen-week-old black spruce seedlings.

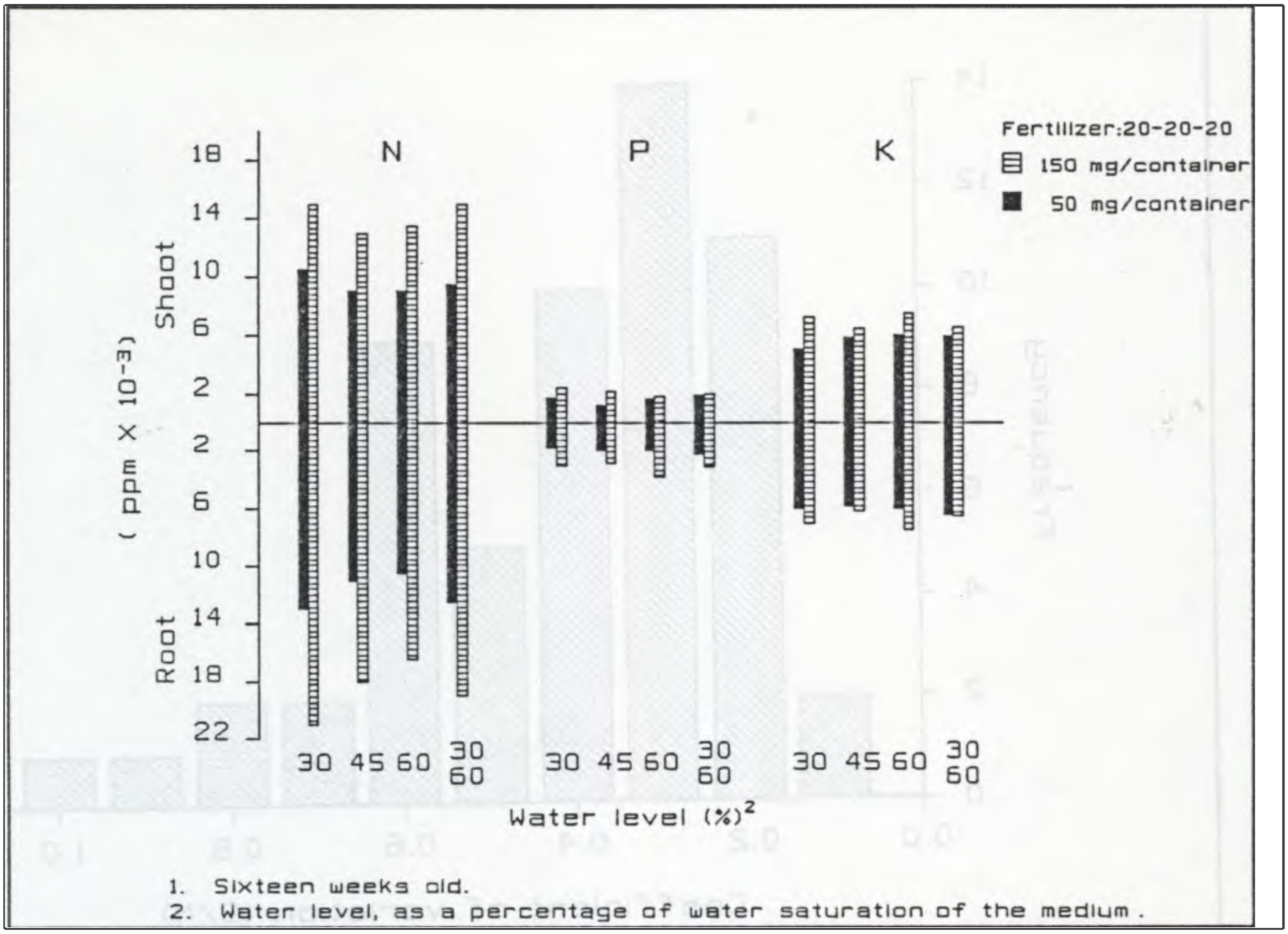

Figure 4. Effect of nutrient concentrations and water levels on the N,P,K concentrations of black spruce seedlings.

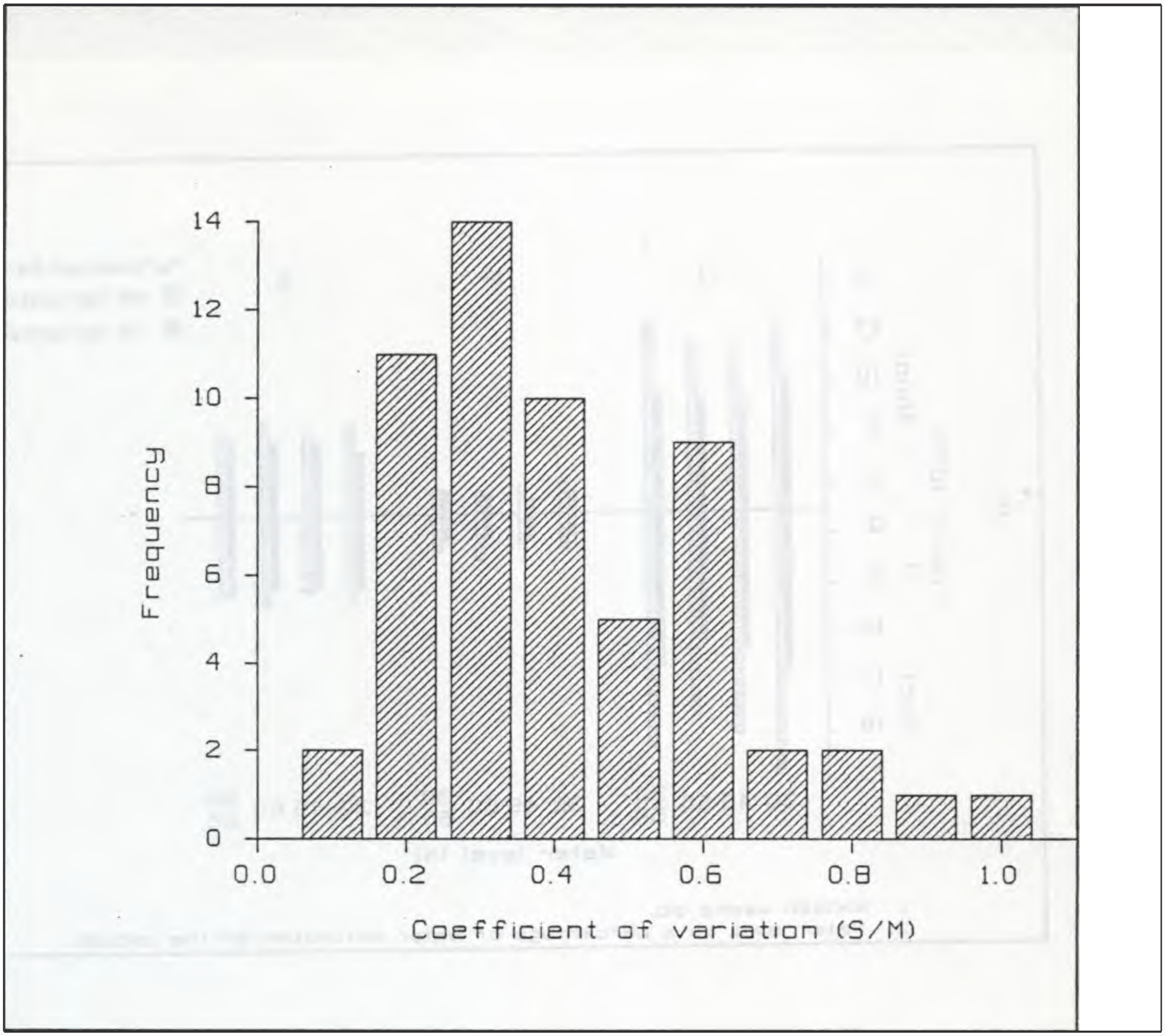

Figure 5. Coefficients of variation of stomata) conductance over a three-week-period for black spruce seedlings.

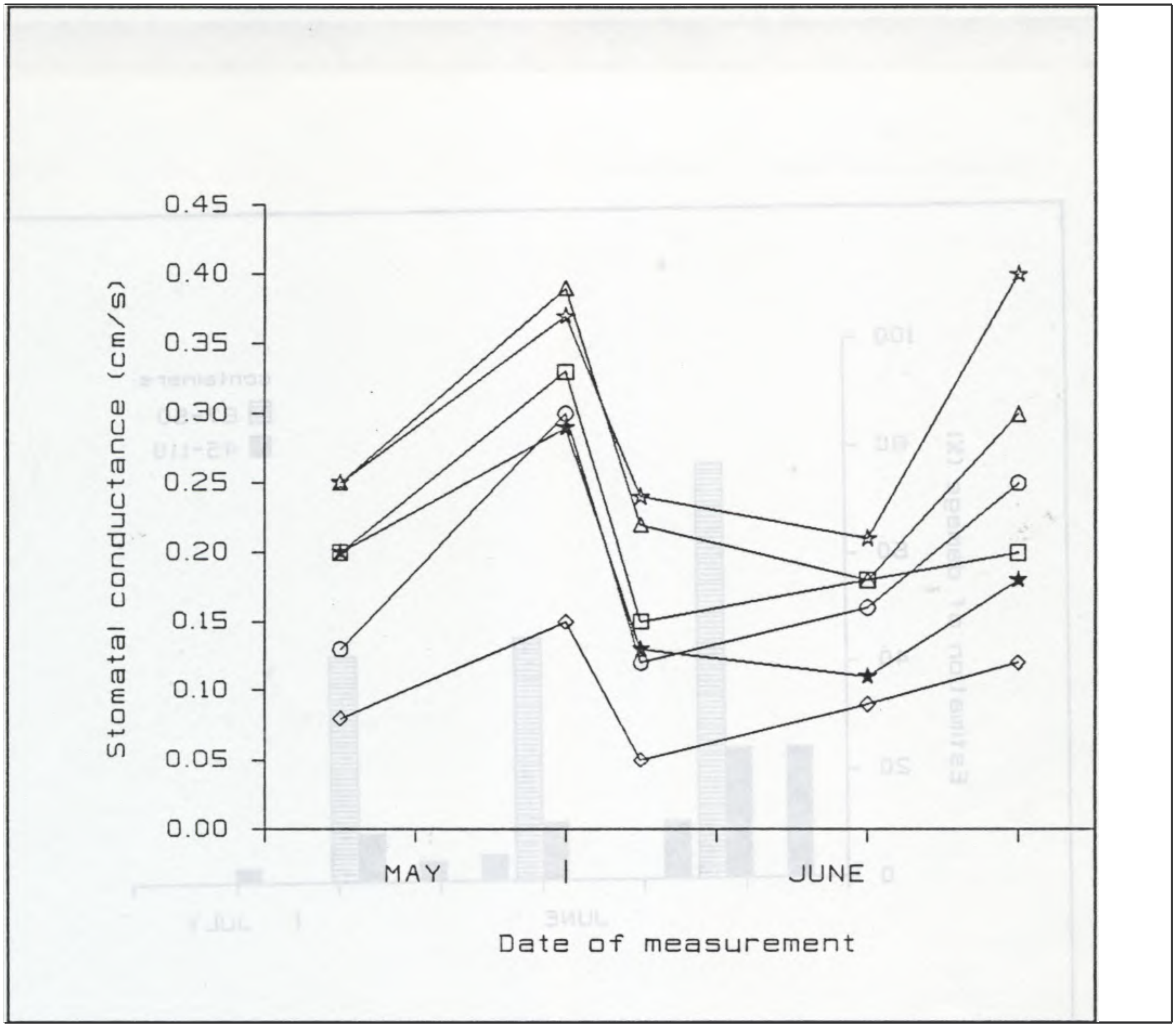

Figure 6. Stomata) conductance of individual seedlings from a single provenance of black spruce.

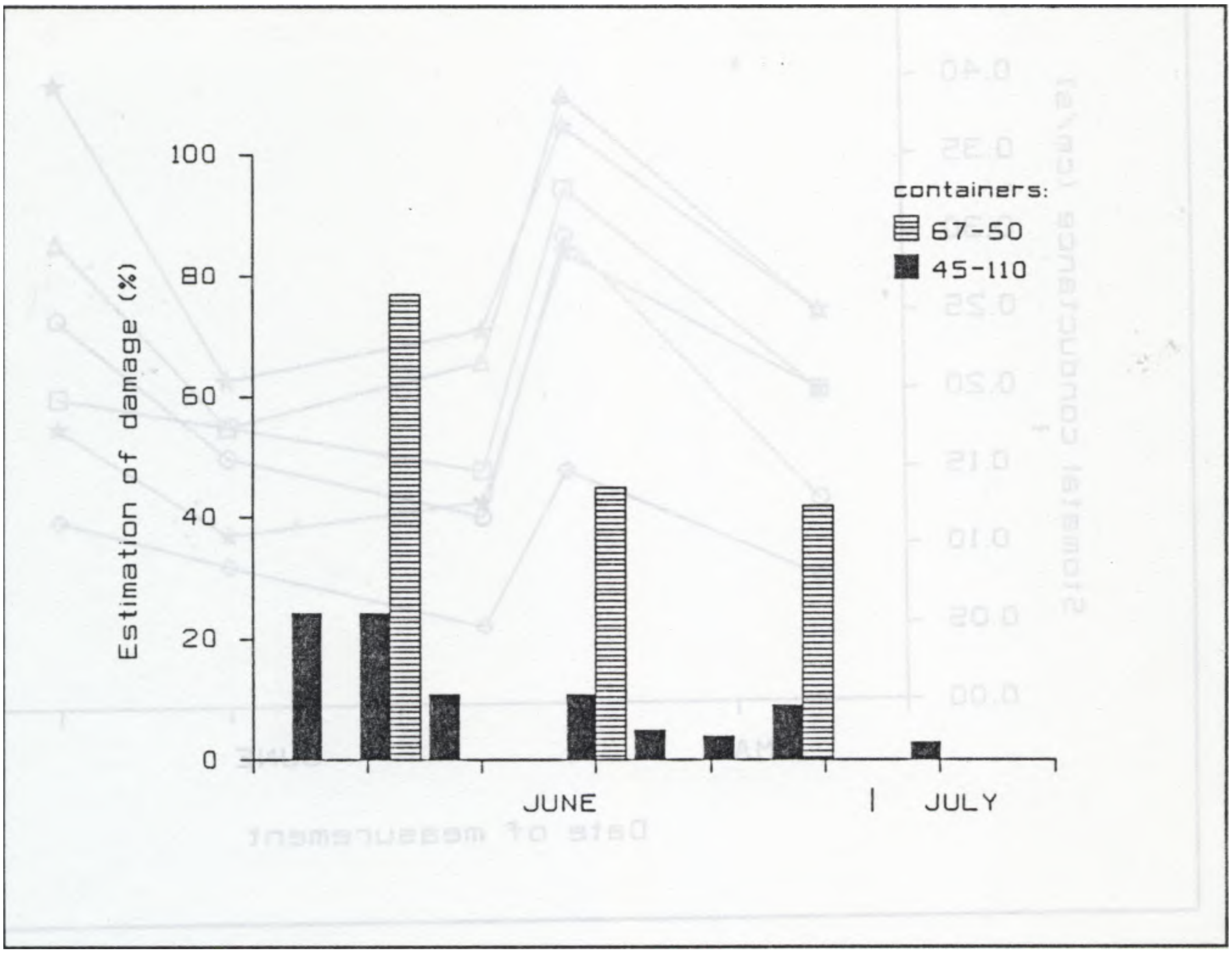

Figure 7. Visual evaluation of damage for two sizes of containers following a single drought stress.

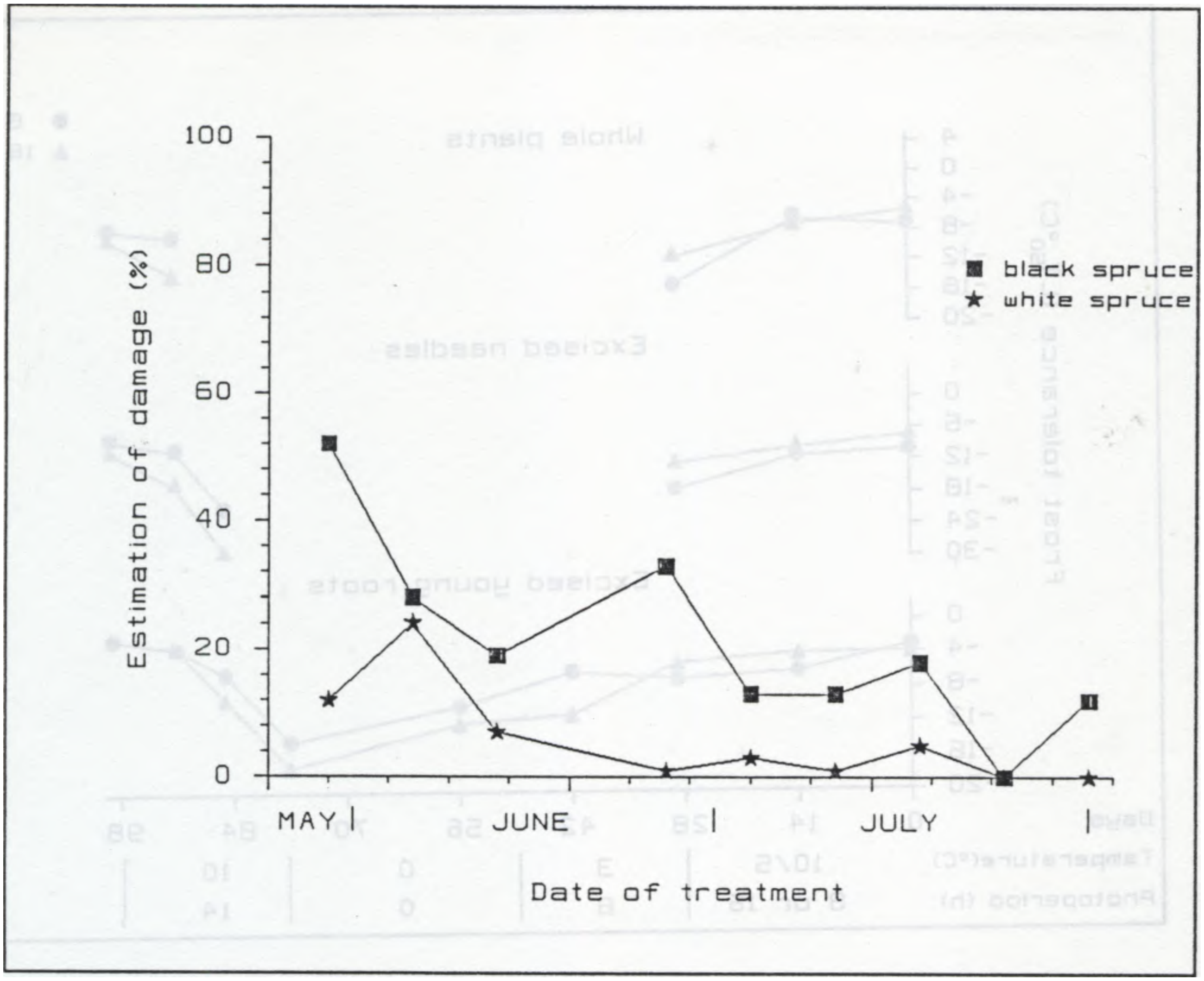

Figure 8. A summary of visible damage on black and white spruce seedling shoots after a three-week-period in the greenhouse following a single drought stress.

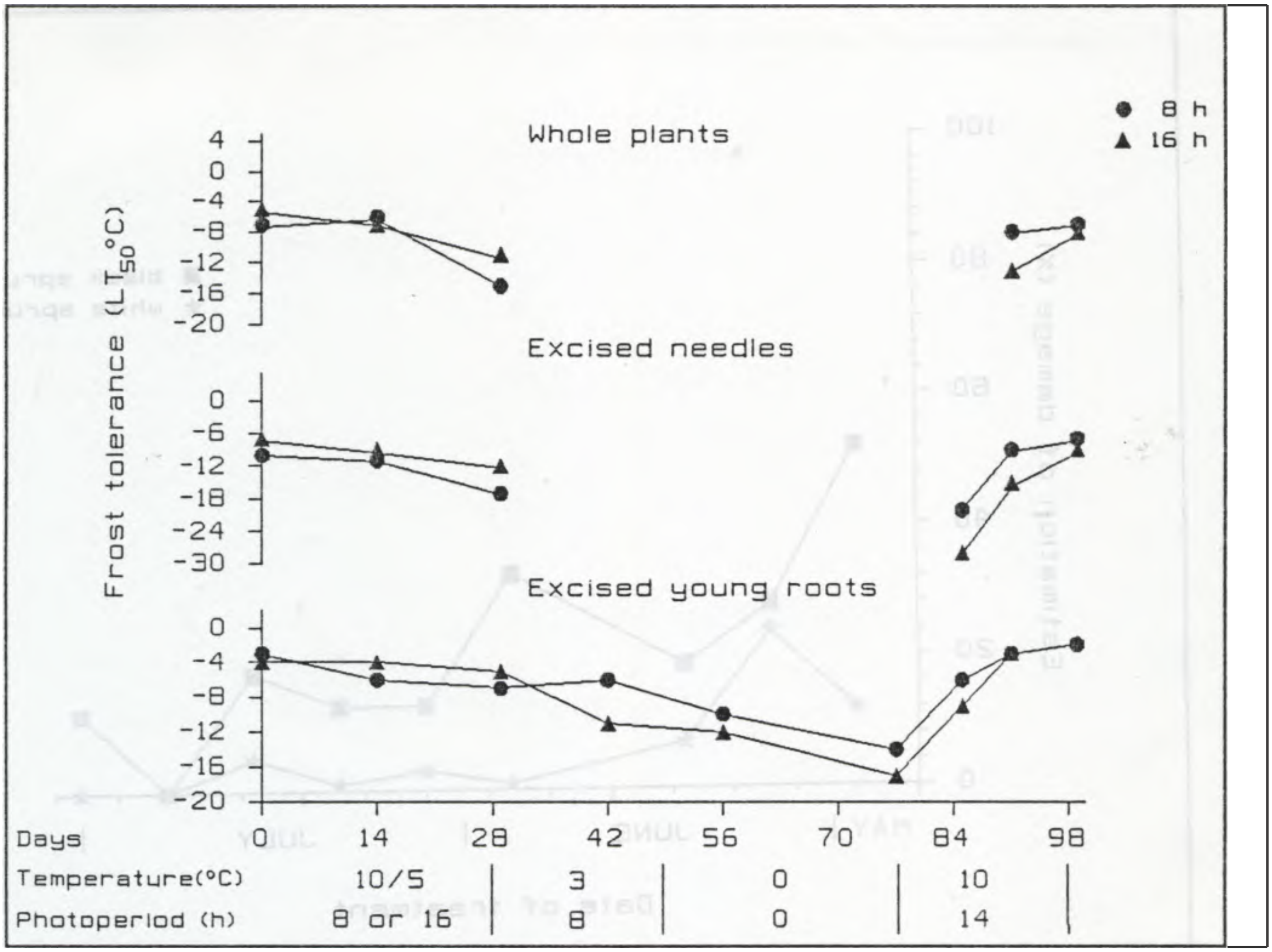

Figure 9. Hardening of seventeen-week-old white spruce seedlings and dehardening after one month of cold storage.

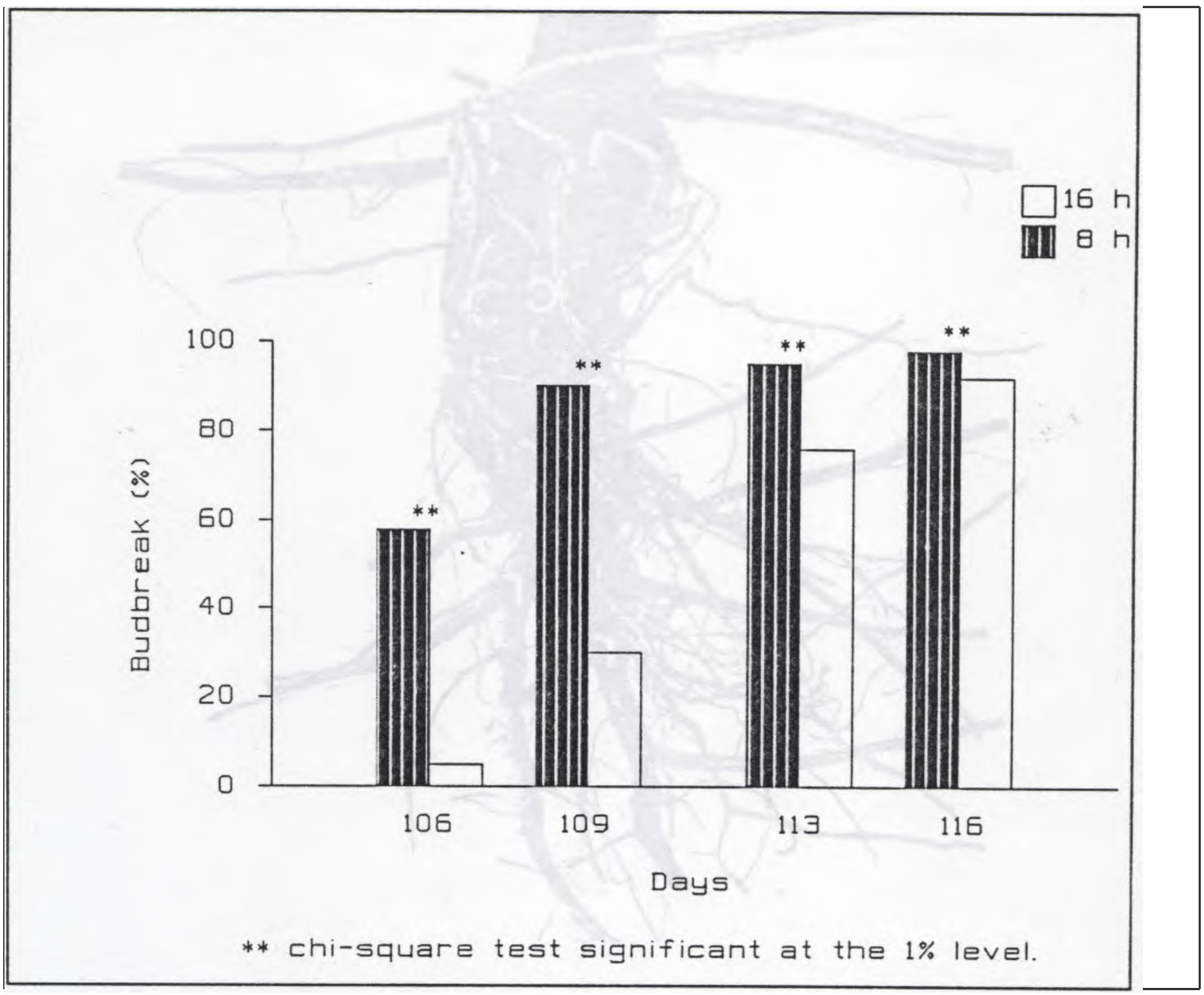

Figure 10. Budbreak following photoperiod treatments during hardening.

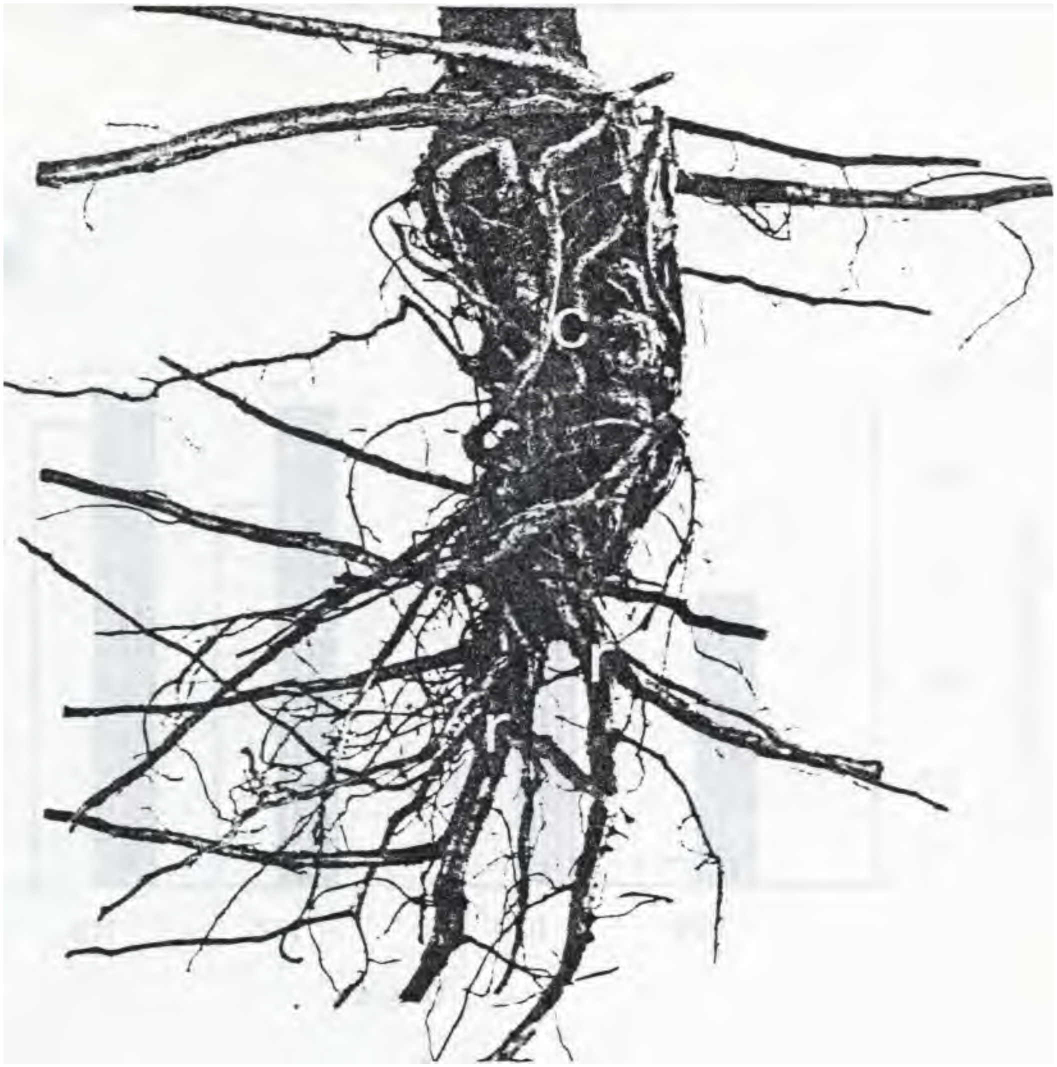

Figure 11. Typical Jack pine root system, excavated three years after outplanting: chignon (c) and replacement roots (r).

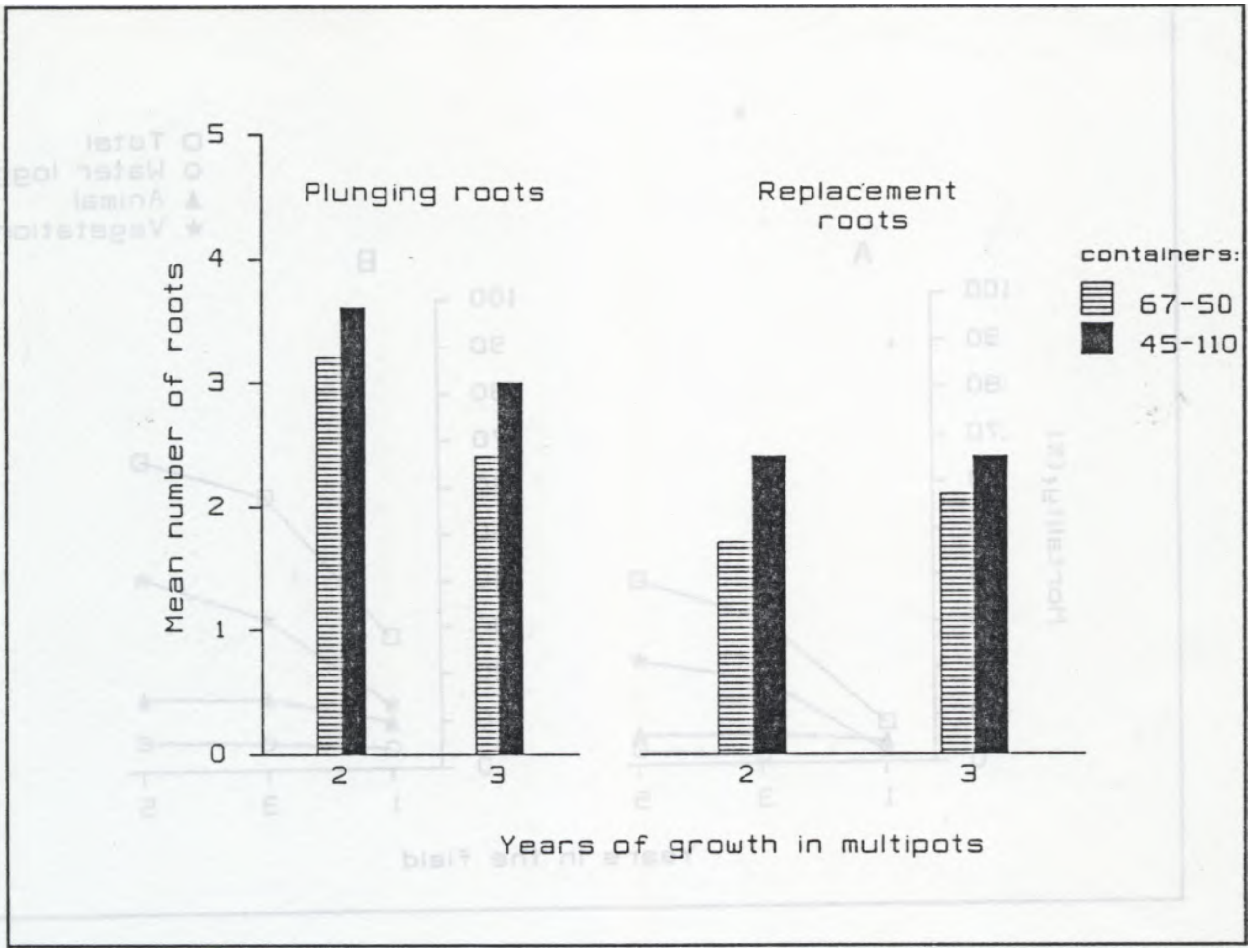

Figure 12. Root characteristics of containerized Jack pine three years after outplanting.

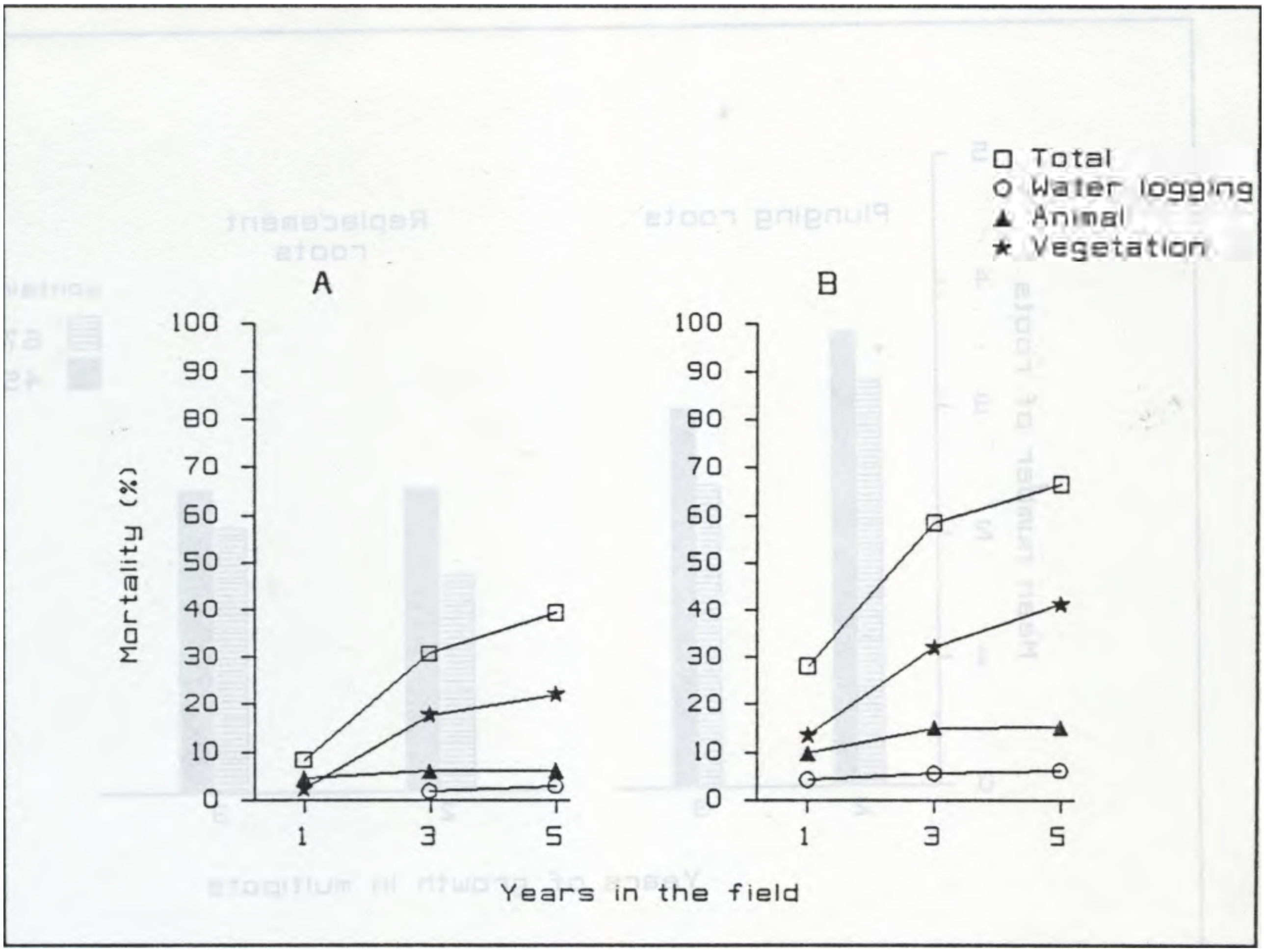

Figure 13. Mortality rates and their causes over time in Grand'Mere plantations from containerized black spruce seedlings (1981-82): spring (A) and fall (B) plantings.

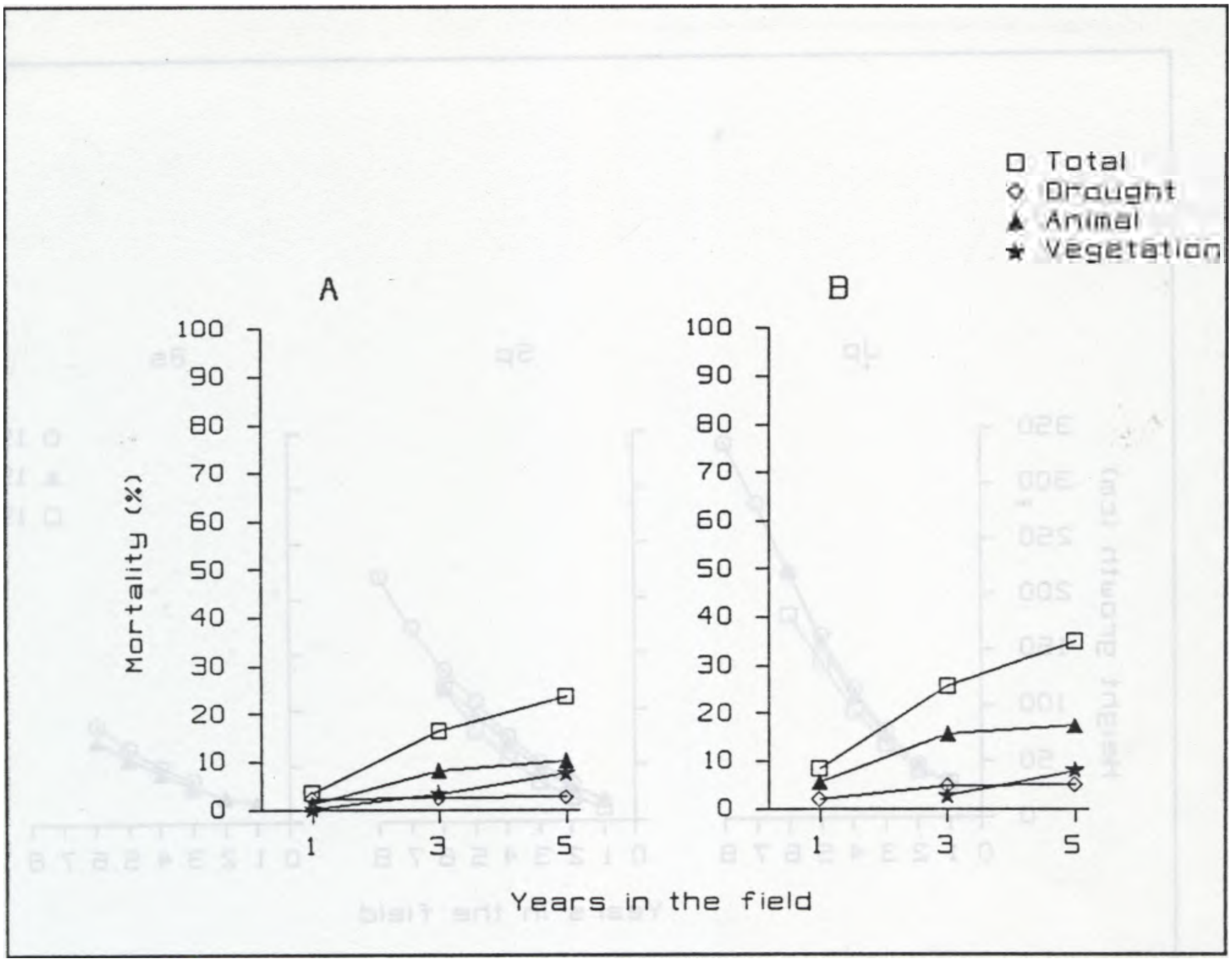

Figure 14. Mortality rates and their causes over time in Grand'Mere plantations
from containerized Jack pine seedlings (1981, 82, 83): spring (A) and fall (B) plantings.

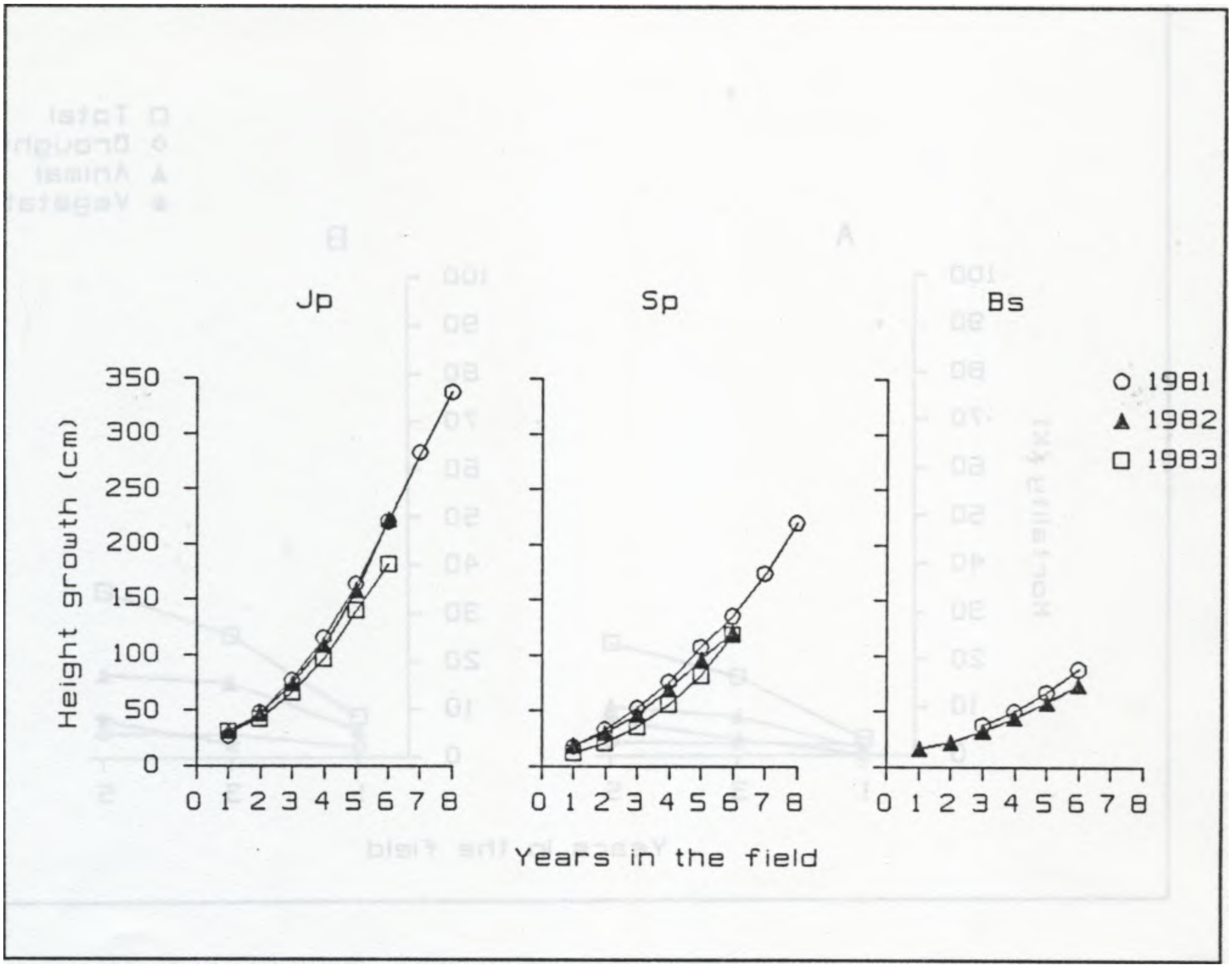

Figure 15. Height growth of Jack pine, Scotch pine and black spruce in Grand'Mêre plantations (1981, 82, 83) from containerized seedlings.

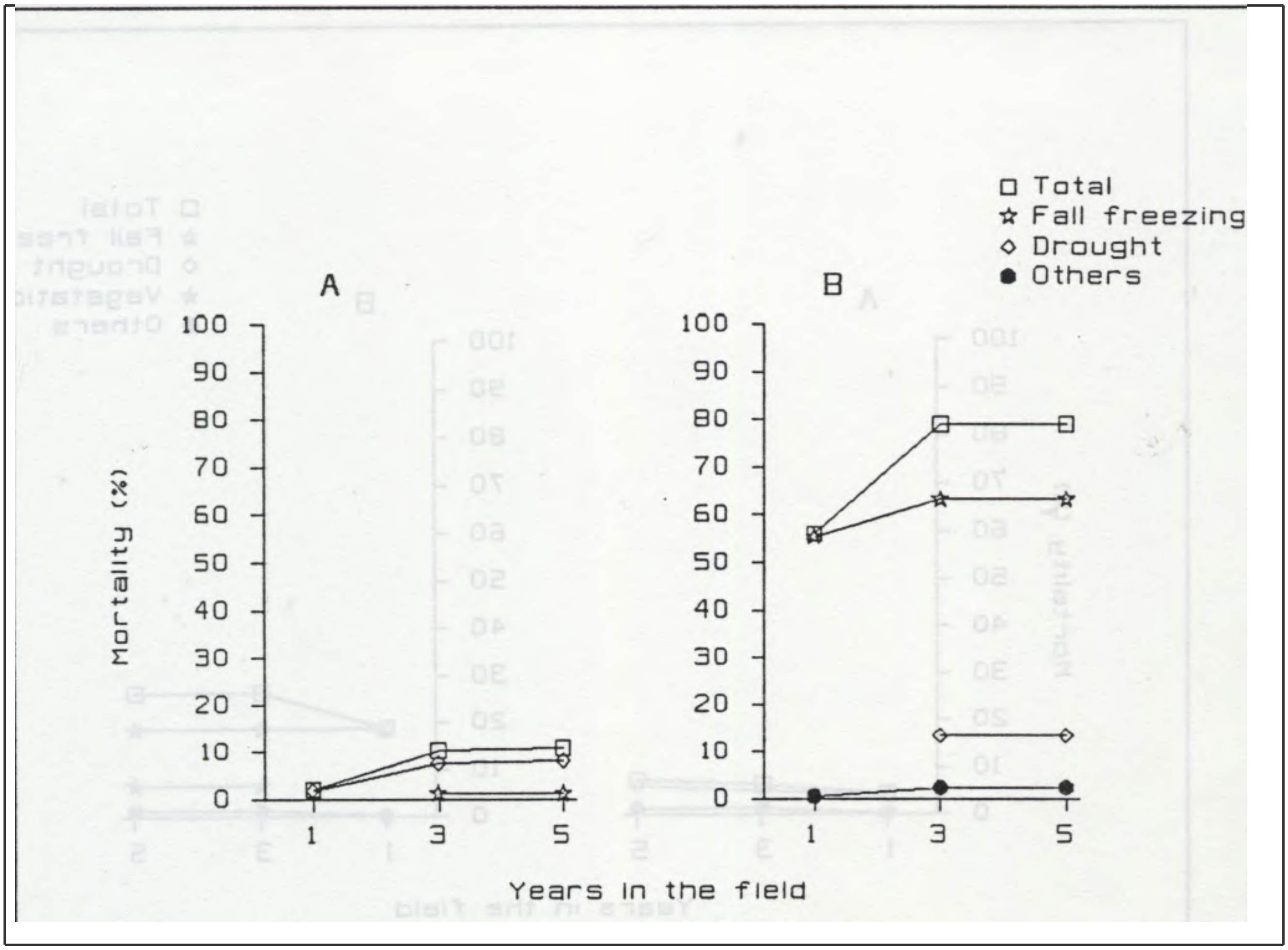

Figure 16. Mortality rates and their causes over time at "Lac Bean" plantations from containerized black spruce seedlings (1982): spring (A) and fall (B) plantings.

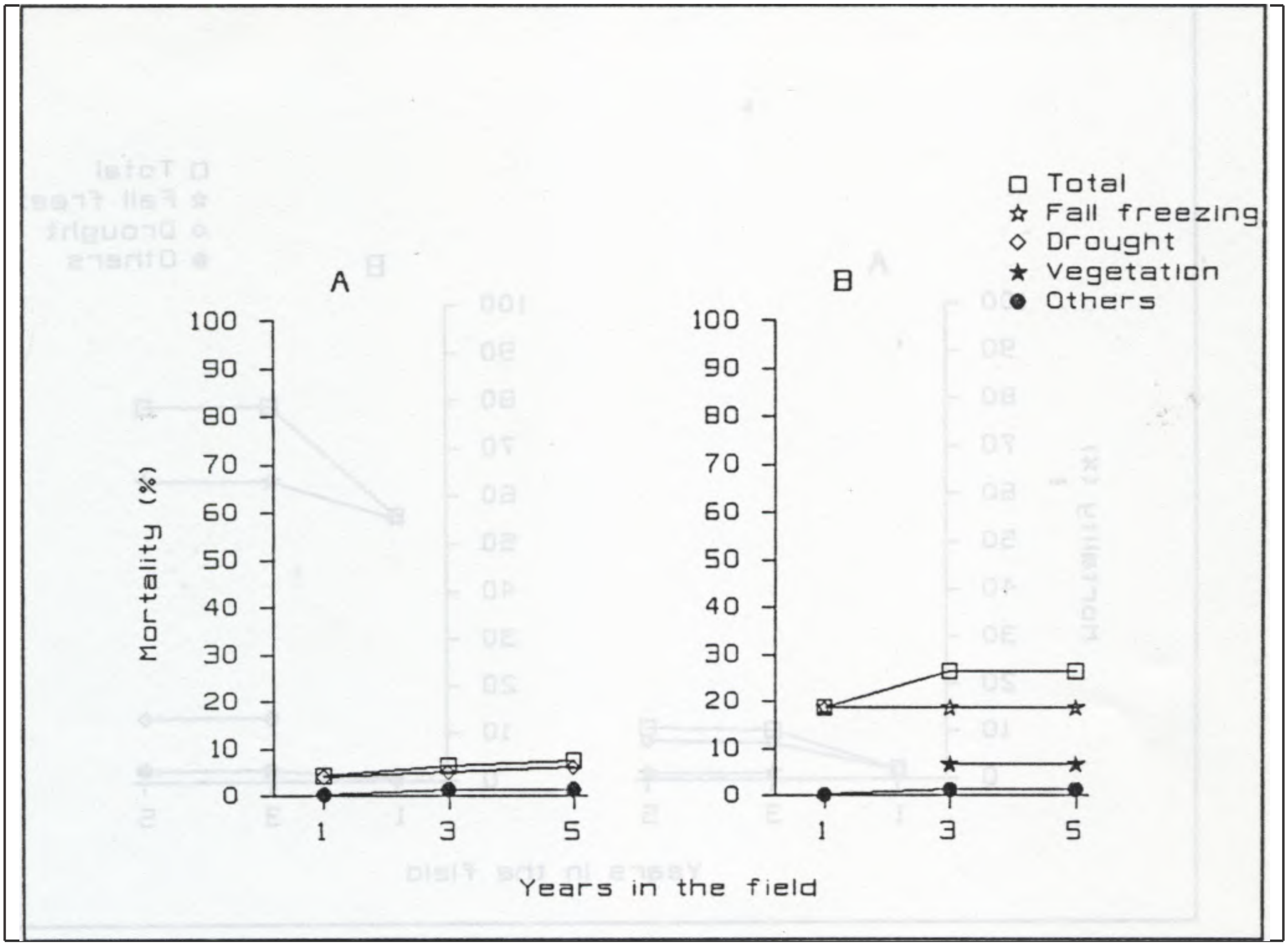

Figure 17. Mortality rates and their causes over time at "Lac Bean" plantations from containerized Jack pine seedlings (1982): spring (A) and fall (B) plantings.

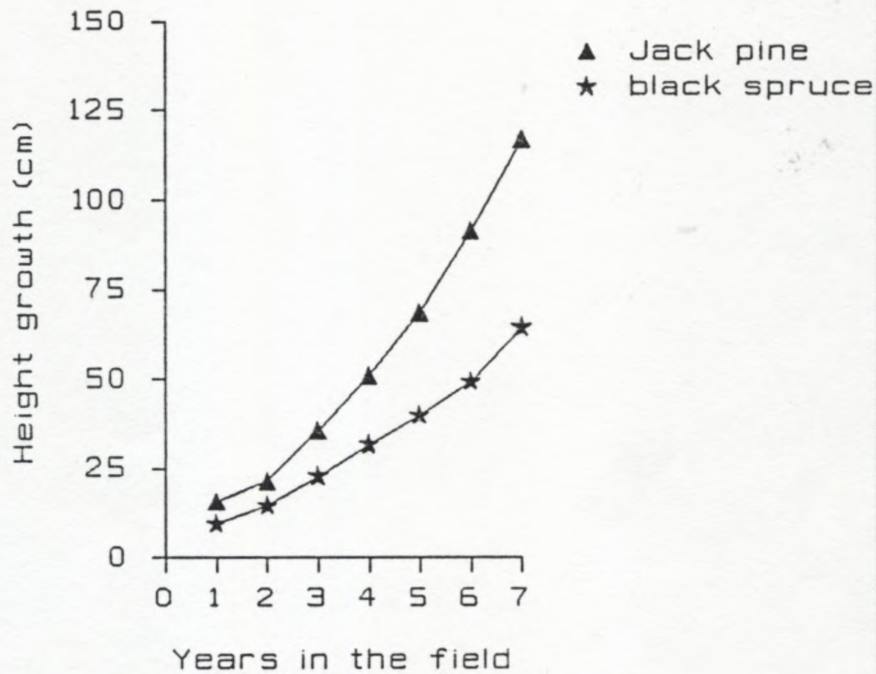

Figure 18. Height growth of Jack pine and black spruce at "Lac Bean" plantations from containerized seedlings.