DIFFERENCES IN POST-PLANTING SOIL-MOISTURE RELATIONS OF CONTAINER-GROWN TUBE AND PLUG STOCK AFFECT THE FIELD SURVIVAL AND GROWTH OF BLACK SPRUCE 1/

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Abstract.--The water relations, survival and growth of four types of black spruce container stock were monitored after planting in sandy loam soil. Weekly sampling of the moisture content of the root-ball and adjacent field soil indicated that the water relations of the various containers affected survival and growth. The Tube Types of stock (container retained) maintained root-ball moisture better than the Plug Types (container removed) which rapidly reached an equilibrium with the field soil. The seedlings in the Ontario Tube suffered least from drought induced mortality, those in the Ontario and Ferdinand Plugs most. The seedlings in the Sealed Ontario Tube appear to have suffered from lack of aeration even though their root-ball moisture remained high. Plug stock should only be established in moist periods or on moist sites, tubed stock may be established on temporarily dry sites. A container must be designed that incorporates both the advantages of tubes and plugs, moisture retention and free root egress.

INTRODUCTION

The objective of this study was to compare the post-planting water relations, survival and growth of black spruce (*Picea mariana* (Mill.) B. S.P.) tubed and plug stock after planting in the field in a sandy loam of the Rosslyn Land Type (Hills and Morwick 1944) near Thunder Bay, Ontario.

This study was designed to retest and amplify the results of Day and Scoupy's (1971) laboratory work on "moisture storage capacity and post-planting patterns of moisture movement from seedling containers" in the field. During the 1972 growing season the soil moisture content (SMC) of the peat root-balls of the four types of container stock listed below was monitored and compared, and related to the SMC of the sandy loam field soil.

Tubes

a) Ontario tubed seedling stock planted with the 3/4 x 3-inch (1.9 x 7.6 cm) cylindrical styrene container on.

b) Ontario tubed seedling stock (as above) planted after sealing the top of the styrene cylinder to prevent evaporation.

Plugs

c) Ontario tubed seedling stock planted after removal of the styrene cylinder.

d) Snencer-Lemaire Ferdinand plug stock.

Weekly evaluation and comparison of the SMC of the peat root-balls, and their comparison with the SMC of the adjacent sandy loam field soil provided data for the interpretation of survival and growth of black spruce grown in the various types of container.

Literature on the water relations of container stock is rare, considering the vast bibliography that may be assembled on container stock planting (Cayford 1972). Literature on the water relations of container stock after it

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has been planted in the field is very rare indeed! Day and Scoupy (1971) alone appear to have examined the problem and their work was confined to laboratory studies.

METHODS

In April 1972, 4,500 3/4 x 3-inch (1.9 x 7.6 cm) Ontario tubes (Ontario 1968) and 250 Spencer-Lemaire Ferdinand fold-ups (Spencer 1972) were arranged in flats and were filled with black screened (1.0 cm) peat. After filling the Ontario tubes were found to contain 3.5 g of peat (oven dry) and the Spencer-Lemaire Ferdinands 7.6 g. The tubes and fold-ups were then sown to black spruce of Site Region 3W origin (Hills 1952) and placed in a greenhouse at the Ontario, Ministry of Natural Resources, Thunder Bay Forest Station. The seeded flats were placed on greenhouse benches fitted with very high output wide-spectrum fluorescent lamps which provided 15 watts per square foot of supplementary illumination for a 20-hour daily photoperiod. 'Armalizer' liquid fertilizer 3/ (365 ppm N, 1495 ppm P and 1170 ppm K) was applied at a rate of 5 gallons per 30 square feet (24.5 1 per 3 square m) of flats every 21 days. The seedlings were grown in the greenhouse for a period of 60 days until June 5 and were then transferred to a lath house for 21 days of hardening off. Before planting the seedlings were graded by height and only seedlings in the 10-15 cm height class were planted.

On June 26, a total of 3,600 seedlings were planted in sod in the sandy loam soil of the Rosslyn Land Type (Hills and Morwick 1944) on a flat grassy clearing near the Thunder Bay Forest Station. The planting proceedure for all stock types was to scalp off the sod and to plant in mineral soil with a dibble.

The seedlings were heavily watered before planting so that root-ball moisture would be equal and at a maximum. After watering, one third of the Ontario tubed stock were top sealed with Dow Corning Silastic RTV silicone rubber. Nine hundred of each of the following types of black spruce container stock were planted a) Ontario Tube, b) Sealed Ontario Tube (top sealed with silicone rubber), c) Ontario Plug (styrene cylinder removed) and d) Ferdinand Plug (fig. 1).

The seedlings were planted in a randomized block design with 4 (stock types) x 10 (sampling times) x 3 (replications) x 30 (seedlings) = 3600

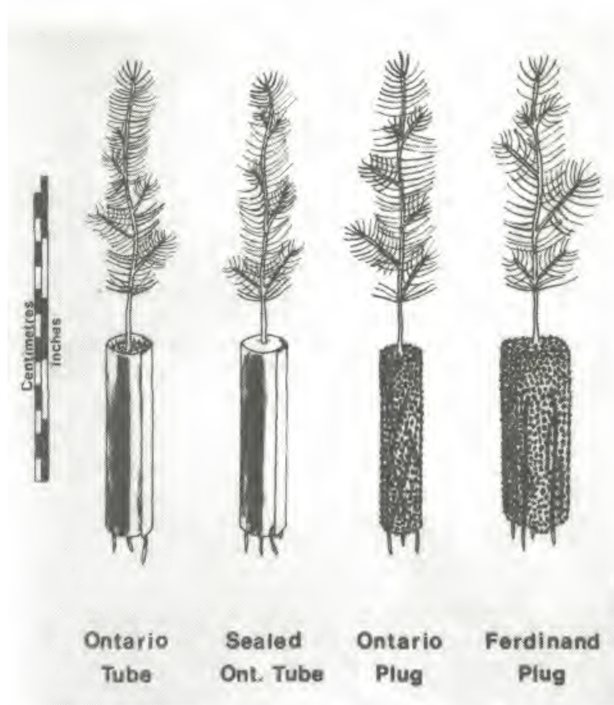


Figure 1.--The four types of container stock.

seedlings total. This two-way classification permitted comparison of the root-ball and field soil SMC's of the four types of stock at various times in 1972. It also permitted comparison of the soil moisture environment with survival and growth.

The first samples for determination of the SMC of the root-ball were taken before planting on June 26. Samples of both the root-balls and their adjacent field soils were taken weekly after planting for a period of 10 weeks. Every third seedling was lifted from the plot to be sampled on a specified date and composite samples of both the seedling root-balls and the field soil immediately beneath the root-ball were collected for SMC determination.

An attempt was made to determine soil moisture retention curves for both the sandy loam field soil and the root-ball peat in a ceramic plate apparatus. Although a satisfactory retention curve was derived for the loam and both field capacity (1/10 bar) and wilting coefficient (15 bar) were established, it was not possible to derive a retention curve for the peat. The field capacity of the peat was determined after saturating it and allowing it to drain, wilting coefficient was determined by bioassay with sunflowers (*Helianthus* spp.).

The survival of the four types of container stock was recorded in the autumn in 1972 and 1973. Height growth was measured in 1973.

3/'Armalizer', a fertilizer devised by Prof. K. A. Armson, Faculty of Forestry, Univ. of Toronto for small container stock.

Analysis of variance was used to show the significance of differences between mean root-ball SMC, mean field soil S C, survival, and growth. Linear regression was used to show the relationships between field and root-ball SMC.

RESULTS

Table 1 shows the change in per cent SMC of the root-balls from time of planting to one week after planting. At time of planting, all root-balls were at or above field capacity (1/10 bar). Seven days later the amount of the initial soil moisture that remained was 26% in the Sealed Ontario Tube, 16% in the Ontario Tube, 13% in the Ferdinand Plug, and 10% in the Ontario Plug. Within a week of planting the mean SC of the root-balls of the two plugs had dropped close to the wilting coefficient of 40% SMC in the peat!

Table 1.--Per cent SMC of the root-balls of container stock at time of planting (June 26) and one week after planting (July 3).

	Per cent SMC		Per cent water remaining
	Time of planting	7-days later	
Sealed Ont. Tube	390	100	26
Ontario Tube	376	62	16
Ontario Plug	384	37	10
Ferdinand Plug	280	36	13

Figure 2 shows the mean per cent SMC of the root-balls of the four types of container-grown stock and of the field soil from June 26 (planting date) to September 4 in 1972 (a ten-week period). The field capacity and permanent wilting coefficients of both the root-ball peat and the sandy loam field soil are given in figure 2 to indicate the obvious periods of abundant soil moisture supply and drought in 1972.

Table 2 shows that the Sealed Ontario Tube stock had a higher mean root-ball SMC during the 1072 growing season than any of the other types of container-grown stock (differences significant). The mean root-ball SC of the Ontario Tube stock which was second best was 12% SMC lower than the Sealed Ontario Tube stock, but was considerably higher than either the Ontario or Ferdinand Plug stock (differences significant). The mean root-hall SMC's of the

Table 2.--Mean per cent SMC of the root-balls and adjacent field soil from 7-days after planting (July 3) until final sampling in the 10th week (September 4).

	Per cent SMC	
	Root-ball	Field soil
Sealed Ont. Tube	109	14
	*	NS
Ontario Tube	97	13
	*	NS
Ontario Plug	79 *	14
	NS	NS
Ferdinand Plug	77	14

1/ * = difference significant, NS = difference non-significant.

two plugs were similar, and were 187 and 20% lower than the Ontario Tube stock.

Table 3 shows that the Ontario Tube stock had the best survival in both 1972 and 1973 (differences significant) even though it's mean height growth in 1973 was 27% less than Ontario Plug stock and 37% less than Ferdinand Plug stock (Differences significant). The survival of the Ontario Plug stock and Ferdinand Plug stock which was the next best was similar (differences non-significant) in 1972 and 1973. The survival of the sealed Ontario Tube stock was the worst in both 1972 and 1973 (differences significant) and it's mean height growth in 1973 was 13% less than Ontario Tube stock, 36% less than Ontario Plug stock and 41% less than the Ferdinand Plug stock (differences significant).

Table 3.--Per cent survival of container stock in 1972 and 1973, height growth in 1973

	Per cent survival		Mean height growth cm
	1972	1973	1973
Ontario Tube	92	89	6.2
	*	*	*
Ontario Plug	85 *	79 *	8.4 *
	NS	NS	NS
Ferdinand Plug	85 *	76 *	9.1 *
	*	*	*
Sealed Ont. Tube	73	65	5.4
Mean	84	77	7.3

1/ * = difference significant, NS difference non-significant.

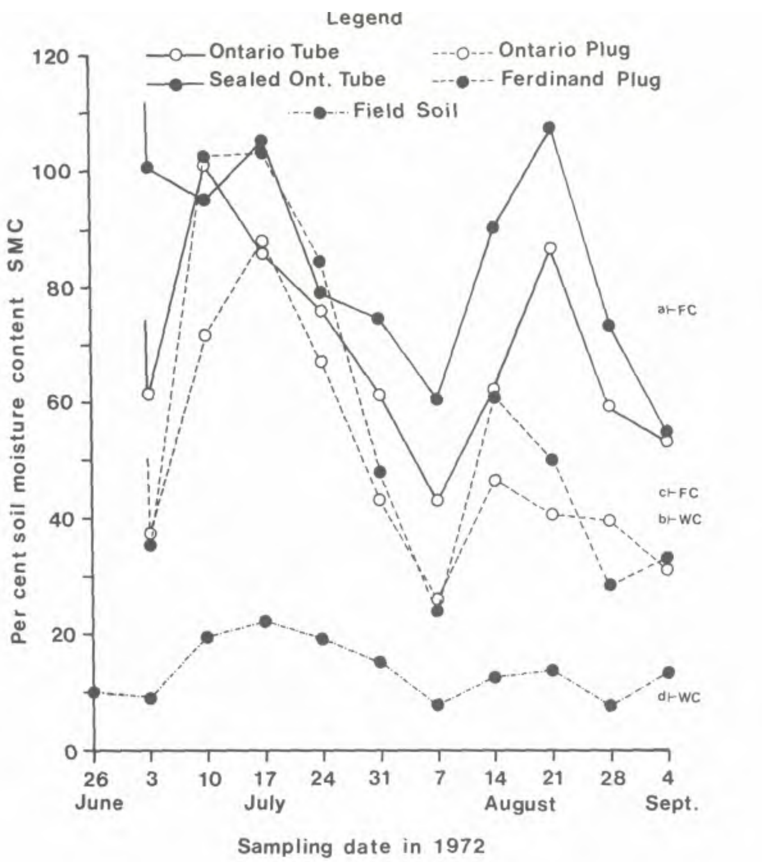


Figure 2.--Mean soil moisture content of the root balls and the field soil at weekly intervals in 1972. Note:

a = field capacity, and
b = wilting coefficient of the root ball peat;

c = field capacity, and
d = wilting coefficient of the field soil.

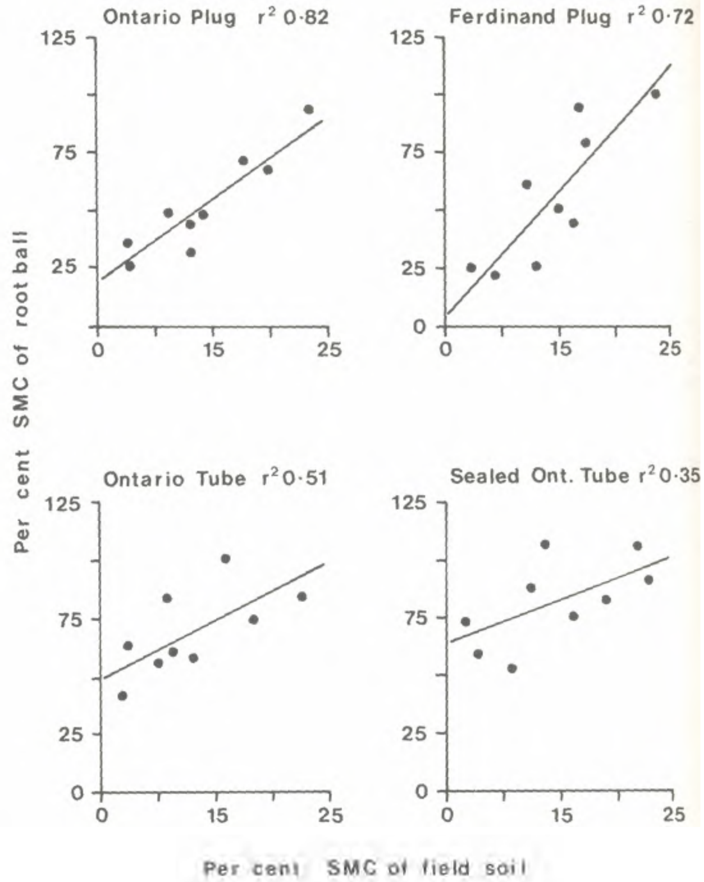
DISCUSSION

The most important result of this study is the difference in soil moisture relations between the tube (container retained) and plug (container removed) types of stock. Figure 2 shows that the root-balls of both Ontario and Ferdinand Plugs lost moisture rapidly after planting and came into equilibrium with the droughty field soil in a week in 1972. In spite of drought, the root-balls of the Ontario Tube and Sealed Ontario Tube stock retained enough moisture to stay above or well above the wilting coefficient during this period. Throughout the remainder of the growing season the pattern of water relations was similar. The root-ball SMCs of the Ontario and Ferdinand Plugs fluctuated with variations in SMC of the field soil, and when the field soil dried to drought levels in early June, in early August and in late August early September, the black spruce stock suffered from soil moisture stress! In contrast, the root-balls of the Ontario Tubes and Sealed Ontario Tubes which were protected from severe moisture loss by the container did not suffer from drought stress in 1972! Correlations of the per cent SMC of of the root-ball with the per cent SMC of the field soil confirm these results (fig. 3).

The correlations suggest that the root-balls of the small Ontario Plug stock (r = 0.82) lost or gained moisture to or from the field soil a little more readily than the larger Ferdinand Plug stock (r = 0.72), but that the root-balls of both plugs readily came into moisture equilibrium with the field soil. The root-balls of the Ontario Tube stock (r^2 = 0.51) and the Sealed Ontario Tube stock (r^2 = 0.35) did not come into moisture equilibrium with the field soil because the styrene cylinder prevented moisture egress, and in the latter case the sealant prevented evaporative loss. Thus in 1972, Ontario Tube stock and Sealed Ontario Tube stock did not fluctuate as much in root-ball SMC and tended to lag behind both the Ontario and Ferdinand Plug stock in wetting and drying.

The survival and growth of the black spruce stock was important but was not the primary objective of this study (table 3). A comparison of the survival of seedlings grown in the four types of container with their water relations in 1972 indicated that survival was commensurate with the amount of moisture retained in the root-ball, except when the upper surface of a container root ball was coated with sealant. Poor survival and height growth after top

Figure 3.--Soil moisture content (SMC) of the root-ball in relation to soil moisture content of the field soil.



sealing appears to be related to the exclusion of air and to a toxic increase in CO_2 concentration. A comparison of the height growth of the seedlings that survived to the autumn of 1973 showed that growth was considerably better in plugs than in tubes! The superior height growth of the plug stock was attributed to freer root egress.

This study confirmed Day and Scoupy's (1971) laboratory results in the field and permitted the following recommendations.

1. Plug stock should only be planted in drought free periods or on drought free sites, because the root-balls of plug stock rapidly come into moisture equilibrium with the potentially droughty field soil.

2. Tubed stock may be planted on sites subject to periodic drought, because their root-balls loose moisture slowly and remain moist for longer periods than plug stock.

3. A seedling container should be designed that incorporates the advantageous features of both tube and plug stock. It must retain moisture during the establishment period yet permit root egress for effective establishment and growth.

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