EFFECTS OF COMPETITION ON MICROCLIMATE AND SURVIVAL OF PLANTED SUGAR MAPLE (*ACER SACCHARUM* MARSH.) SEEDLINGS IN SOUTHERN ONTARIO

D. PAUL WEBB

GREAT LAKES FOREST RESEARCH CENTRE

SAULT STE. MARIE, ONTARIO

INFORMATION REPORT O-X-209

CANADIAN FORESTRY SERVICE

DEPARTMENT OF THE ENVIRONMENT

AUGUST 1974

Copies of this report may be obtained from

Director,
Great Lakes Forest Research Centre,
Canadian Forestry Service,
Department of the Environment,
Box 490, Sault Ste. Marie, Ontario
P6A 5M7

INTRODUCTION

Past attempts to establish hardwoods on old fields of abandoned agricultural land in southern Ontario have met with little success (von Althen 1970). However, with the identification of the proper planting site and intensive site preparation, species such as black walnut (*Juglans nigra* L.), white ash (*Fraxinus americana* L.), black cherry (*Prunus serotina* Ehrh.), black locust (*Robina pseudoacacia* L.), red oak (*Quercus rubra* L.), basswood (*Tilia americana* L.), and some *Populus* species can be successfully planted (von Althen 1972). Sugar maple (*Acer saccharum* Marsh.), one of the principal components of the original forest cover on most upland sites, has proven the most difficult to establish.

On old fields, sugar maple usually enters a state of reduced growth or "check" soon after it is planted. The crown becomes flattened and takes on a rosette form which develops slowly. A similar condition has been reported for some conifers and in many cases has been attributed to heavy weed competition (White 1960, 1962). In southern Ontario removal of competing vegetation is a prerequisite to successful establishment of hardwood plantations (von Althen 1964). Similarly, Wallihan (1949) and Zarger (1956) have suggested that the effect of weeds and other competing vegetation is a major factor contributing to the failure of hardwood plantations. It is not surprising, therefore, that improved survival and growth resulting from site treatments have been attributed to reduced competition (MacArthur 1964, von Althen 1971).

Several species of herbaceous vegetation have been shown to exhibit an allelopathic relationship with woody plants (Pickering 1917). Apart from the effects of inhibitors or toxins liberated by some species, the physical competition for nutrients, light and moisture may have marked effects on plant growth (Kramer and Kozlowski 1960).

The ability of some plants to suppress less vigorous plants demonstrates their greater physiological activity under environmental stress (Kramer and Kozlowski 1960). The advantages of planting a seedling with a vigorous and rapidly developing root system surrounded by undisturbed soil have been shown by Huuri (1966). Planting of potted seedlings has the principal advantage of reducing the transplanting shock and, on severe sites, survival is generally better for potted than for bare-rooted seedlings (Hermann 1969). Water loss is usually higher from soil supporting vegetation than from bare soil of the same type (Geiger 1966). In areas where moisture may become limiting the increased loss of moisture from areas with competing vegetation may be the principal factor in reduced survival and growth.

The present study was undertaken to examine the effects of competition on the survival of potted and bare-rooted seedlings of sugar maple on an open field site in southern Ontario.

MATERIALS AND METHODS

The Chatman area is located on lot 6, concession XI, 0.5 mile (0.8 km) north in Lobo Township, Middlesex County, Ontario. This 100-acre (40.5-ha) property has approximately 70 acres (28.3 ha) of woodlot, 10 acres (4.1 ha) of "edge condition" woods and 20 acres (8.1 ha) of open land which was purchased in 1957 by the Ontario Department of Lands and Forests (now the Ontario Ministry of Natural Resources). The woodlot supports a very productive stand consisting of sugar maple, beech (*Fagus grandifolia* Ehrh.), basswood, silver maple (*Acer saccharinum* L.), white ash and hickory (*Carya cordiformis* [Wang.] K. Koch) with a high percentage of white elm (*Ulmus americana* L.), and probably reflects the original productivity of the open land before it was cleared.

The open land was pastured until about 15 years ago. A large portion of the area was planted in conifers - mainly white pine (*Pinus strobus* L.) and Norway spruce (*Picea abies* [L.] Karst.) - between 1958 and 1965. In addition white ash and red oak were planted in 1961 and 1962.

The topography of the Chatman area is gently undulating. The soil is described as a Huron silt loam. The area has a high water table in early spring which falls off sharply in early summer. Approximately 90% of the area is sufficiently well drained to grow excellent ash and basswood. Sugar maple, although it does not reach its maximum development in the woodlot, is excellent in quality. The topographically lower 10% supports primarily elm and silver maple. At present the woodlot shows excellent regeneration of sugar maple and white ash. The ash is beginning to encroach upon the open field adjacent to the woodlot.

Sugar maple seeds collected from open-grown trees near Harriston, Ontario in 1967 were stratified at 5°C for 60 days and sown in flats in the greenhouse on March 20, 1969. After 3 weeks the seedlings were transplanted to peat pots with a rooting medium of Vigoro[1] potting soil mulched with perlite. At 6-week intervals the seedlings were fertilized with 20:20:20 liquid fertilizer. At time of planting (July 19, 1969) the seedlings each had a sturdy shoot and a vigorous root system. The mean root-to-shoot ratio calculated on a dry weight basis was 0.70.

---

[1] The identification of commercial products is solely for the information of the reader and does not constitute endorsement by the Great Lakes Forest Research Centre.

A randomized block design was used for the experiment with three replications. The seedlings planted in the open field at the Chatman tract were subjected to natural competition or no competition. In the no-competition areas the vegetation was removed by hand hoeing throughout the study. Within each of these areas four treatments were randomly applied. These consisted of (1) seedlings with peat pots intact (2) peat pots removed and soil ball intact (3) peat pots and soil removed (bare roots) and (4) "wildings" (bare roots). The last-named treatment was included since the few successful sugar maple plantations in southern Ontario were initiated from "wilding" planting stock (von Althen 1970). For this treatment, seedlings of approximately the same size as the container-grown seedlings were removed from the adjoining woodlot. The mean root-to-shoot ratio calculated on a dry weight basis was 0.59. Each treatment consisted of three replications of 10 seedlings. The seedlings were planted with 3 ft x 3 ft (0.91 m x 0.91 m) spacing to reduce mutual shading and the soil in the peat pot was kept level with the surrounding soil.

To obtain an estimate of the competition present in the open field planting site, the percentage cover occupied by the different species was estimated visually from 1-sq-m quadrats.

A number of environmental measurements were taken to define the climate at the time of planting and throughout the experiment. Variations in air temperature and relative humidity were measured by means of a sheltered hygrothermograph (Fuess)[2] and standard meteorological minimum and maximum thermometers calibrated by the Canada Department of Transport (now the Atmospheric Environment Service of Canada). A Stevenson screen was erected at an instrument height of 3 ft (0.91 m) above ground level. Readings of minimum and maximum air temperatures and current air temperatures were recorded each day at 9:00 a.m. and 2:00 p.m. EST.

Total air flow and evaporation 3 ft (0.91 m) above the experimental plots were recorded twice daily with a totalizing cup counter anemometer (Casella and Company Ltd., Model W1204-1)[3] and two black porous disc atmometers (Robertson 1961). Rainfall was measured according to the method of Wilm (1946). Randomization of the gauges was performed after each rainfall. Shortwave solar radiation was recorded on a solar radiation recorder (actinograph, Model R-401, Weather Measure Corp.)[4]. Readings of soil temperature at the 1-, 3-, 6- and 12-inch (2.54-, 7.62-, 15.24- and 30.48-cm) depths were taken with a telethermometer (Yellow Springs Instrument Company)[5] at a site adjacent to the experimental plots. Installation of the thermistors was according

---

[2] ibid.

[3] ibid.

[4] ibid.

[5] ibid.

to the method of Fraser (1968) and measurements were taken twice daily at 9:00 a.m. and 2:00 p.m. EST. Readings of minimum and maximum thermometers placed at the soil surface in the experimental plots were recorded twice daily at the above times from three pairs of thermometers using the method of Wilm (1946) for randomization. It is recognized that soil surface temperature measurements present great difficulties. However, it was felt that the use of unshielded standard minimum and maximum thermometers placed at the soil surface might give some indication of the relative temperature differences between areas with and without competition to which the seedling shoots were exposed. Daily determinations of gravimetric soil moisture from a 1-in. (2.54-cm)- diameter core centered at the 3-in. (7.6-cm) depth were recorded on a dry weight basis. Samples were taken from a site adjacent to the plots and from the competition and no-competition areas as mentioned under RESULTS.

RESULTS

In the open areas the most conspicuous woody species were hawthorn (*Crataegus* spp.) and wild apple (*Pyrus* spp.). The herbaceous vegetation consisted mainly of quack grass (*Agropyron repens* [L.] Beauv.) occupying approximately 70% of the total cover, with some timothy (*Phleum pratense* L.). Wild carrot (*Daucus carota* L.) occupied approximately 15% and golden rod (*Solidago canadensis* L.) approximately 5%. Other species such as wild parsnip (*Pastinaca sativa* L.), yarrow (*Achillea lanulosa* Nutt.), teasel (*Dipsacus sylvestris* Huds.), buttercup (*Ranunculus repens* L.), St. John's wort (*Hypericum perforatum* L.), ribgrass (*Plantago lanceolata* L.), and some sedges occupied the remaining 10%. Moss (species unknown) completely covered the mineral soil.

Differences in percentage mortality of seedlings in areas with and without competition were highly significant ($P>.001$) (Fig. 1 and 2). Wildings from the adjoining woodlot were not successful in either of the competition or no-competition areas and were significantly different from the container-grown seedlings regardless of the treatment. However, at the termination of the experiment, 20% of the seedlings taken from the woodlot and planted in the no-competition areas were still alive, whereas no seedlings remained in the competition areas. In all cases where mortality occurred, the foliage lost its healthy green color, turned brown and finally abscissed. Desiccation of the stem and terminal bud was also evident.

Treatments with the container-grown seedlings showed no significant differences in the competition areas at the end of the experiment. Approximately 100% mortality was recorded in each treatment. However, seedlings with their peat pots intact initially showed the lowest rate of mortality, as compared with the other treatments, until approximately 26 days from planting (Fig. 2). In the no-competition areas, all three treatments with the container-grown seedlings were significantly different ($P= 0.05$) from each other (Fig. 1). Unexpectedly, seedlings with their peat pots removed and soil ball intact, and the bare-rooted,

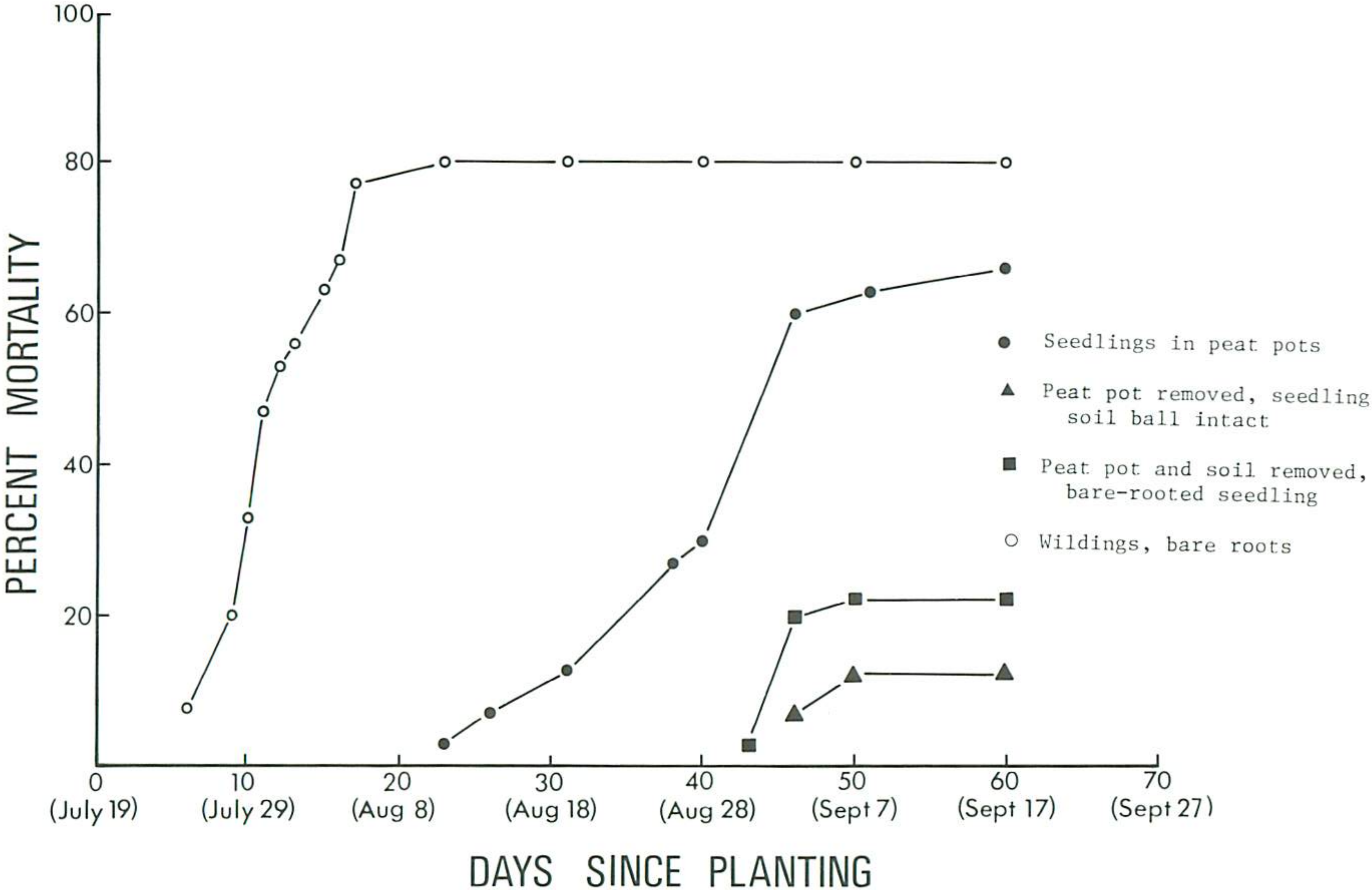

Figure 1. Sugar maple seedling mortality in areas where competing vegetation had been removed.

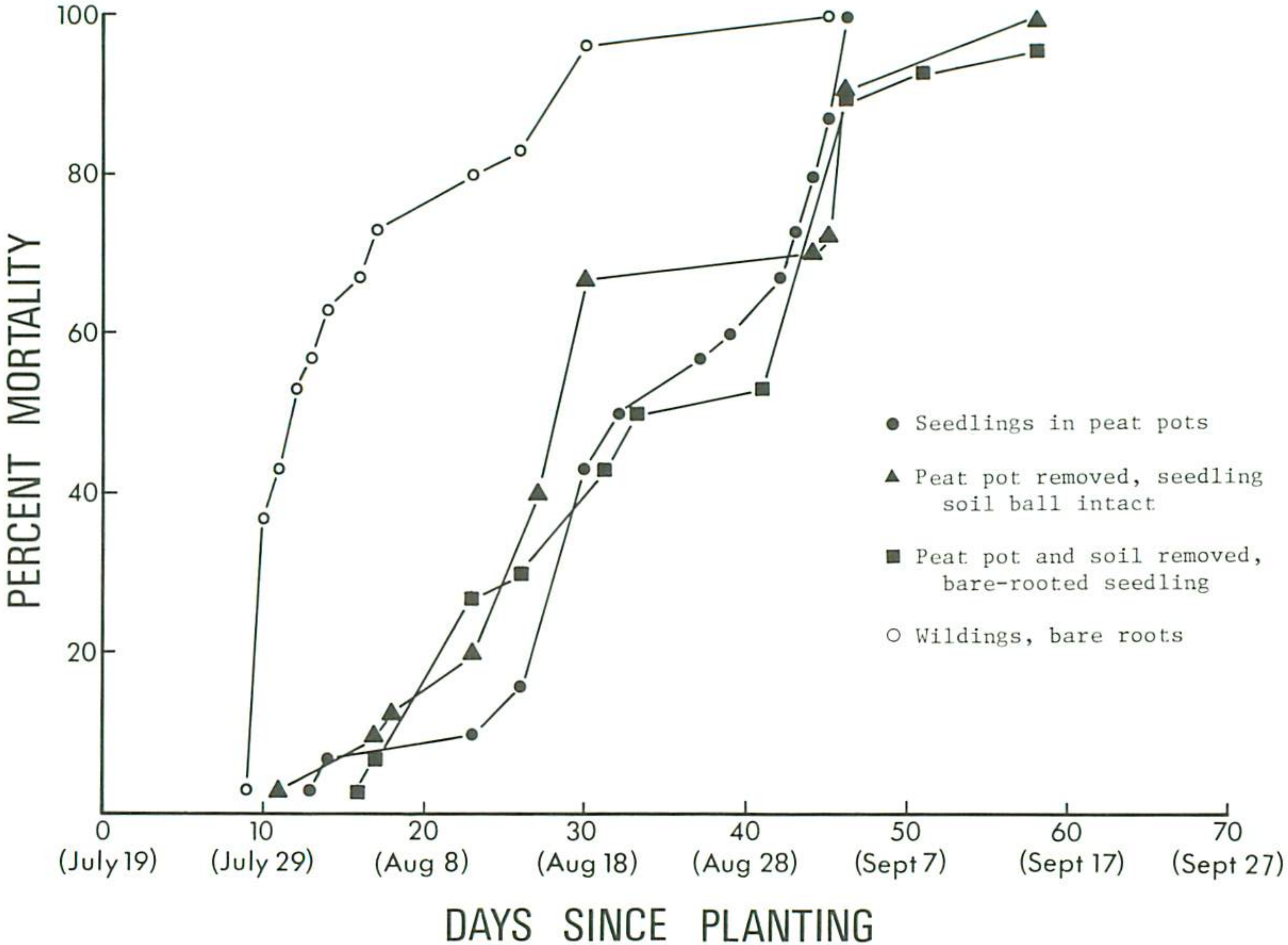

Figure 2. Sugar maple seedling mortality in areas with competing vegetation.

container-grown seedlings were more successful than the seedlings with their peat pots intact. In the latter treatment mortality began 23 days after planting and reached 67% at day 61. Bare-rooted seedlings, however, did not succumb until day 43 and reached only 23% mortality at day 50. Seedlings with their peat pots removed and soil ball intact were the most successful. First mortality occurred at day 46 and reached only 13% at day 50 (Fig. 1).

Data were recorded for the first year only; however, the majority of the seedlings that survived in the no-competition areas succumbed to competition in the succeeding year (removal of competition was maintained only for the first year) and after 3 years only three seedlings remained. These seedlings showed typical symptoms of "check" with no discernible growth evident.

A weekly summary of the climatic data recorded throughout the experimental period is show in Table 1. During this period a general decrease in total weekly precipitation was observed. No rainfall was recorded during the period from August 25 to September 15. Correspondingly, a high rate of latent evaporation, measured from black porous disc atmometers (Robertson 1961), was recorded during this period. Pelton and Korven (1969) have shown that this instrument can be used to estimate evapotranspiration. Thus it appears that the transplanted seedlings were subjected to an increasing moisture stress. Correlated with the decreased precipitation and high potential evapotranspiration was a decrease in weekly mean soil moisture which reached a low of 11.3% w/w for the week of September 8-15 for the competition sites. The mean -0.33 bar percentage and -15 bar percentage moisture levels for Huron silt loam soil are 26.3% and 13.9% w/w, respectively (D.A. Tel, personal communication). Those data suggest that the soil at this time would be at or below the wilting point.

Gravimetric soil moisture was recorded on September 15 at the 3-in. (7.6-cm) depth in the competition and no-competition areas. The areas without competition (bare soil) had a significantly ($P = .05$) higher soil moisture level (15.7% w/w) than the areas where competition was present (9.5% w/w).

Modification of the microclimate by removal of vegetation is also evident in Figures 3a and 3b. Weekly mean maximum and minimum, and weekly mean temperatures recorded from maximum and minimum thermometers placed at the soil surface differed significantly ($P = .01$) between competition and no-competition areas. The competition areas consistently showed a higher maximum and a lower minimum temperature. It is realized that the measured temperatures are probably not correct in the absolute sense, but reflect qualitative differences between the two areas.

The ratio of reflected visible radiation to incident radiation impinging on the study area was determined with Sekonic light meters on August 13 at 2:00 p.m. EST. More than twice as much radiation in the

TABLE 1. Climatic data of the open field

Date	Air temp (°C)			Total rain-fall	Total air flow	Mean	Total latent evap.	Total solar radiat.	Soil temperature (°C) 9:00 a.m. EST, Depth (cm)				Soil temperature (°C) 2:00 p.m. EST, Depth (cm)				Soil mois-ture
	Mean	Min.	Max.	(mm)	(km)	RH(%)	(ml)	(cal cm^{-2})	2.5	7.6	15.2	30.5	2.5	7.6	15.2	30.5	(%)
June 16-23	14.7[a]	8.7	20.7	12	709	65	188	469	16.3	15.9	16.1	16.2	21.0	18.8	16.9	16.0	
June 23-30	21.6	15.4	27.8	6	890	70	249	463	20.5	18.9	17.9	17.0	26.5	22.6	19.3	17.1	
June 30 - July 7	17.9	11.6	24.1	18	684	68	240	492	19.7	18.4	18.1	17.9	25.1	22.3	19.5	17.8	
July 7-14	19.9	13.0	26.9	0	529	54	303	536	19.6	18.6	18.5	18.5	26.1	22.9	20.6	18.6	
July 14-21	22.7	16.3	29.1	9	365	66	238	425	21.4	20.4	19.9	19.6	25.9	23.5	21.4	19.5	18.4
July 21-28	22.1	15.8	28.3	18	553	63	253	477	21.0	20.5	20.3	20.4	27.0	24.3	22.0	20.0	16.7
July 28 - Aug 4	19.8	13.0	26.6	4	432	64	233	454	19.7	18.9	18.8	19.1	25.7	23.2	20.7	19.0	19.1
Aug 4-11	20.6	12.9	28.2	2	572	61	304	471	22.7	19.2	19.3	19.6	26.7	22.9	20.8	19.4	13.0
Aug 11-18	22.6	15.8	29.3	6	573	62	267	426	23.3	20.3	19.8	19.8	28.5	24.9	21.6	19.6	13.4
Aug 18-25	18.6	9.2	27.9	3	403	60	303	497	21.0	18.3	18.5	19.4	31.0	24.7	20.9	19.3	14.0
Aug 25 - Sept 1	22.4	14.1	17.8	0	508	56	351	438	22.0	19.7	19.6	20.1	31.3	25.2	21.4	19.6	14.0
Sept 1-8	21.9	15.0	28.8	0	629	63	237	325	21.2	20.2	20.2	20.6	26.6	23.6	21.4	20.2	11.2
Sept 8-15	16.4	9.3	23.4	0	685	61	244	335									11.3

[a] All data are weekly means

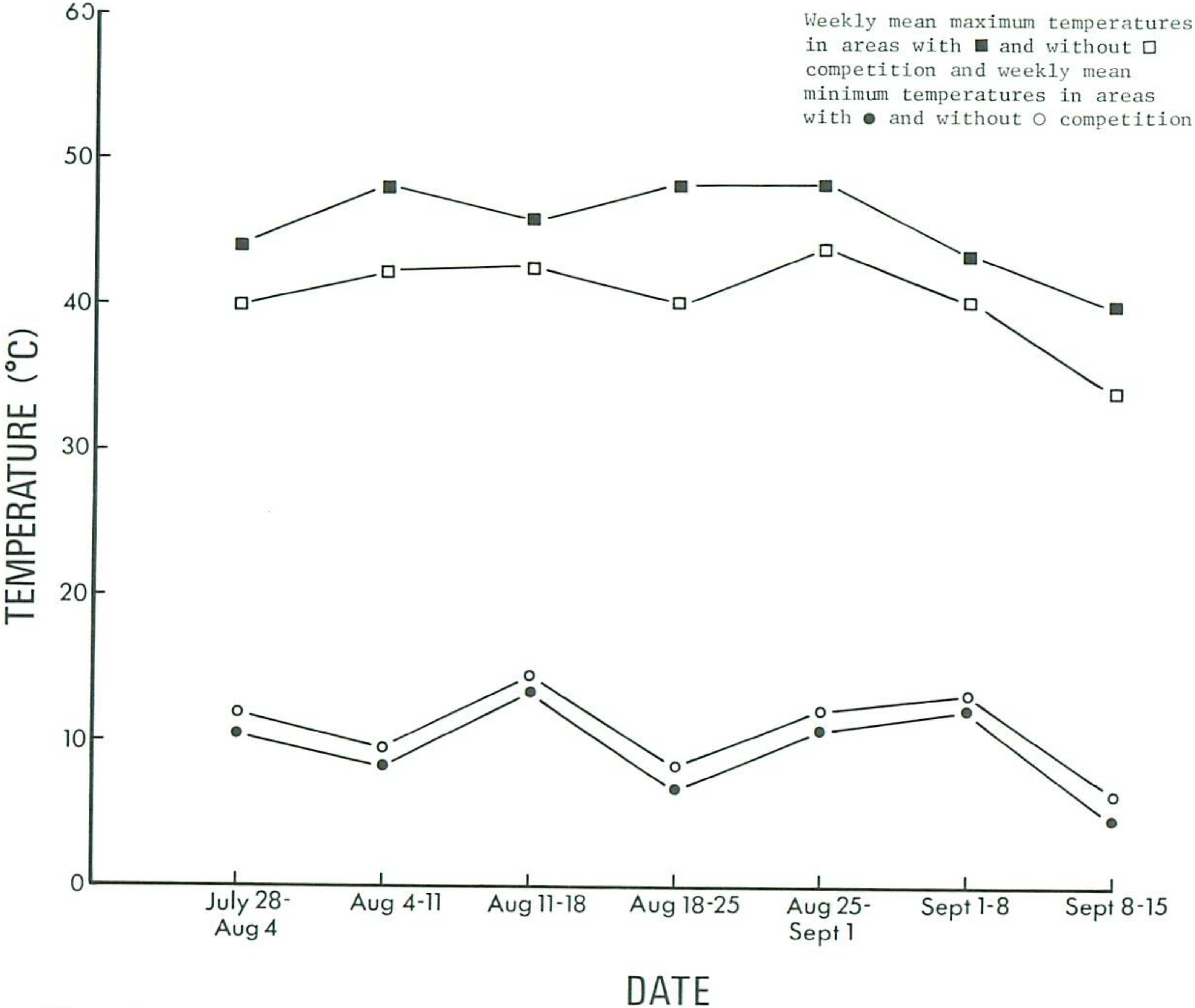

Figure 3a. Temperature readings of standard minimum and maximum thermometers placed at the soil surface.

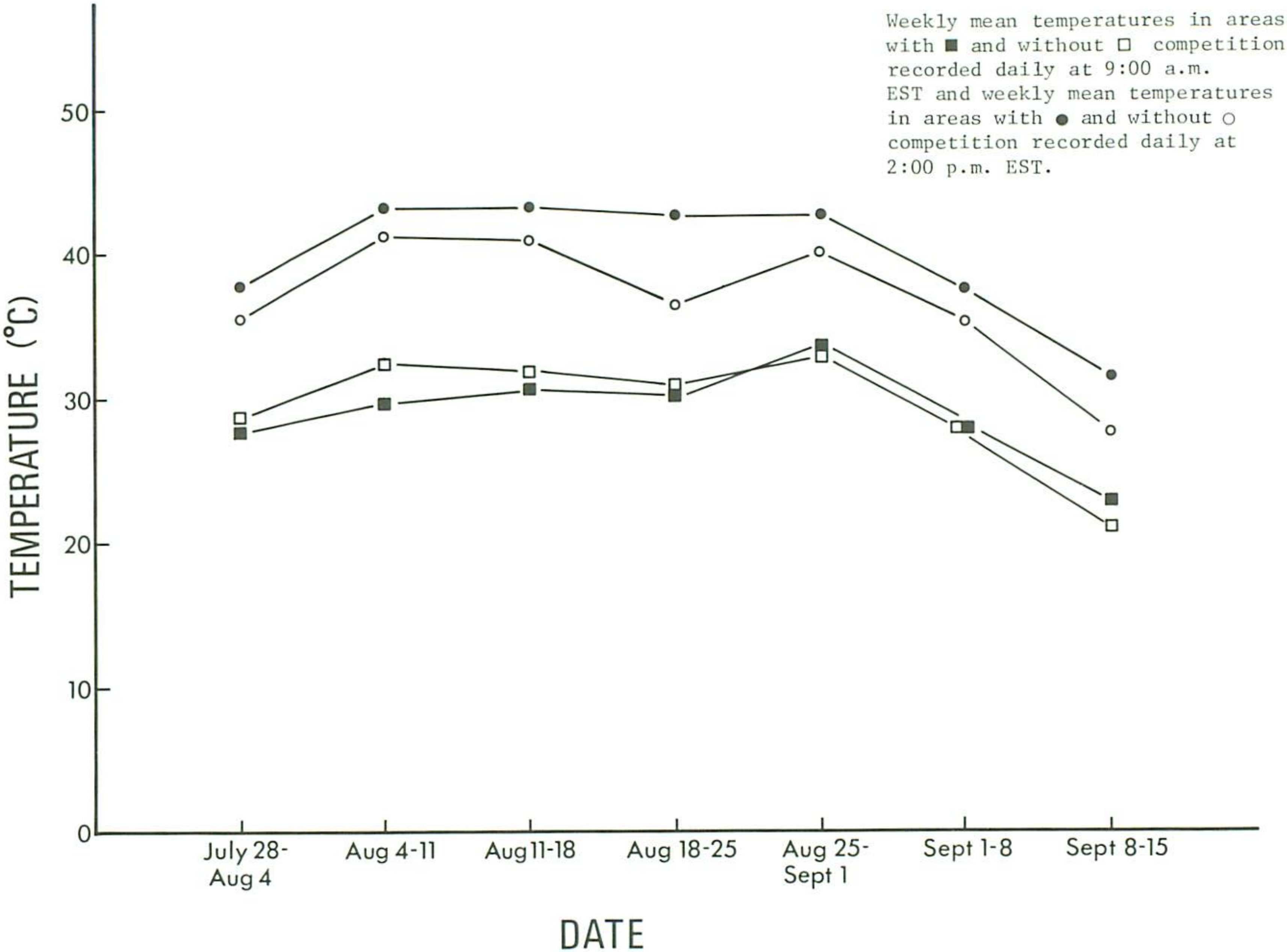

Figure 3b. Temperature readings of standard minimum and maximum thermometers placed at the soil surface.

visible spectrum was reflected from the no-competition areas as from the competition areas. Assuming that the quality of reflected radiation did not differ greatly between the two areas it is possible to calculate the albedos of the two sites as 4.7% and 10.3% for the competition and no-competition areas, respectively. These data correlate with the increased maximum temperatures observed in the competition areas and also with the decrease in soil moisture.

DISCUSSION

The results of the present study indicate that removal of competing vegetation markedly increased sugar maple seedling survival during the initial year. Significant differences in microclimate were observed between areas with and without competition. In the latter, the decreased absorption of solar radiation, the decreased maximum temperatures and the absence of transpiring vegetation resulted in a significant increase in soil moisture. In planting sites where soil moisture levels may become limiting, the increased soil moisture in areas without competition may be highly significant to plant growth and survival. In such a complex system, it is difficult to relate conclusively the increased survival of planted seedlings to any one factor. However, apart from differences in the physical competition for nutrients, light and space which may affect plant growth under certain conditions, differences in microclimate between the competition and no-competition areas were observed. The overall decrease in soil moisture throughout the study and the increased amount present in the no-competition areas lead one to speculate that soil moisture was probably the limiting factor of greatest importance in these studies. However, the possibility that vegetation present in the competition areas and dead and dying roots in the no-competition areas produced substances inhibitory or toxic to the growth of sugar maple seedlings cannot be overlooked.

Several of the most successful sugar maple plantations established earlier in southern Ontario were initiated from wilding planting stock (von Althen 1970). It is also known that sugar maple seedlings planted in hardwood woodlots or in clear cuts in conifer plantations in southern Ontario are successful, whereas in the open field environment they do poorly. If success is a result of a mycorrhizal association with seedling roots obtained through exposure to forest soil it would be expected that wildings taken from the woodlot would show better survival and growth than greenhouse-grown stock that had not been in contact with forest soil. However, in both the competition and no-competition areas wildings showed the greatest percentage mortality of all the treatments. At this time of year, removal of relatively small seedlings from the sheltered woodlot environment to the more severe and exposed open field conditions was detrimental to their survival even in areas where competition was not present. Regardless of the treatment, the container-grown seedlings were more successful than the wildings.

This may be the result of (1) the increased root-to-shoot ratio of the container-grown stock which would allow more available root surface area for absorption of moisture and nutrients, and/or (2) possible differences in the physiological state of the seedlings at time of transplanting.

Unexpectedly, seedlings with their peat pots intact were less successful in the no-competition areas than seedlings with their peat pots removed. This suggests that the peat pot may have interfered with the rapid penetration of the roots into the surrounding soil or more probably interfered with moisture flow. The latter would be the case especially if planting resulted in poor contact between the pot and the surrounding soil.

Several workers have examined the effects of weed control treatments on survival and growth of 2-0 bare-rooted sugar maple seedlings and obtained contrasting results. Bare-rooted sugar maple seedlings planted in southern Ontario in the spring on former agricultural soil showed unsatisfactory survival and growth under a range of weed-control treatments (von Althen 1971). However, Yawney and Carl (1970) demonstrated in a similar study in Vermont that survival of fall-planted bare-rooted sugar maple seedlings was not affected by competition whereas overall seedling growth was markedly reduced as a result of competition. It is difficult to draw any conclusions from these geographically separated studies since local climatic conditions, site, seedling stock, competition and season of planting vary. However, the results of the present study indicate that removal of competing vegetation markedly increased survival of container-grown sugar maple seedlings during the initial year. On planting sites where soil moisture may become limiting as in the present study, the increased soil moisture in areas without competition may be highly significant to plant growth and survival.

CONCLUSION

In summary, planting of container-grown seedlings with their peat pots removed and soil ball intact in areas where competing vegetation had been eliminated was the most successful treatment. Apart from removal of competition for nutrients, light and growth space, site treatments which result in the removal of vegetation significantly modify the microclimate. Under certain environmental conditions the modification of microclimate may be an important factor in increased seedling survival.

REFERENCES

Fraser, J.W. 1968. A method of constructing and installing thermocouples for measuring soil temperatures. Can. J. Soil Sci. 48: 366-368.

Geiger, R. 1966. The climate near the ground. Harvard Univ. Press, Cambridge, Mass. 611 p.

Hermann, R.K. 1969. Growth of tree seedlings in peat pellets. Tree Plant. Notes 20(1): 8-9.

Huuri, O. 1966. A new investigation result in the use of peat pots for the planting of pine. Finn. Pap. Timber 11: 3-7.

Kramer, P.J. and Kozlowski, T.T. 1960. Physiology of trees. McGraw-Hill Book Co., New York. 642 p.

MacArthur, J.D. 1964. Planting methods to overcome strong competition from dense, herbaceous vegetation. Tree Plant. Notes 66: 25-29.

Pelton, W.L. and Korven, H.C. 1969. Evapotranspiration estimates from atmometers and pans. Can. J. Plant Sci. 49: 615-621.

Pickering, S. 1917. The effect of one plant on another. Ann. Bot. 31: 181-187.

Robertson, G.W. 1961. Evaporation. Proc. Hydrol. Symp. No. 2 (discussion). Nat. Res. Counc. Can. 104 p.

von Althen, F.W. 1964. Hardwood planting problems and possibilities in eastern Canada. Can. Dep. For. Publ. No. 1043. 40 p.

von Althen, F.W. 1970. Hardwood plantations of southern Ontario. Can. For. Serv., Sault Ste. Marie, Ont. Inf. Rep. O-X-2. 34 p.

von Althen, F.W. 1971. Effects of weed control on the survival and growth of planted black walnut, white ash and sugar maple. For. Chron. 47(4): 1-4.

von Althen, F.W. 1972. Preliminary guide to hardwood planting in southern Ontario. Can. For. Serv., Sault Ste. Marie, Ont. Inf. Rep. O-X-167. 12 p.

Wallihan, E.F. 1949. Plantations of northern hardwoods, some factors influencing their success. Cornell Univ. Agric. Exp. Stn., Bull. 853. 31 p.

White, D.P. 1960. Effect of fertilization and weed control on the establishment, survival, and early growth of spruce plantations. Vol. III, Trans. 7th Int. Congr. Soil Sci., Madison, Wis. p. 355-362.

White, D.P. 1962. Don't choke your trees! Control those weeds. Am. For., June.

Wilm, H.G. 1946. The design and analysis of methods for microclimatic factors. J. Am. Stat. Assoc. 41: 221-232.

Yawney, H.W. and Carl, C.M. Jr. 1970. A sugar maple planting study in Vermont. USDA For. Serv., Northeast For. Exp. Stn., Res. Pap. NE-175. 14 p.

Zarger, T.G. 1956. Eight-year survival and height growth of sugar maple seed source planting. Tenn. Val. Auth., Div. For. Rel. Tech. Note 22. 7 p.