RECOMMENDATIONS FOR SPECIES SELECTION AND MANAGEMENT IN THE AMENITY PLANTATIONS OF SOUTHERN SASKATCHEWAN

BY

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INFORMATION REPORT NOR-X-181
APRIL 1977

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Johnson, J. D. and G. L. Lesko. 1977. Recommendations for species selection and management in the amenity plantations of southern Saskatchewan. Environ. Can., Can. For. Serv., North. For. Res. Cent. Edmonton, Alberta Inf. Rep. NOR-X-181.

ABSTRACT

Condition surveys, soil moisture studies, and trials of cultural practices were conducted on the amenity plantations in three southern Saskatchewan Provincial Parks in 1972 and 1973. Results show that water-conserving techniques must be applied every year to conserve adequate soil moisture for tree growth. In drought years cultivation is necessary for the safe maintenance of tree plantations, but low mowing of weeds is adequate in normal years.

The results of spacing estimates for various tree heights suggest that spacing in existing plantations may be too dense.

Colorado spruce, Manchurian elm, and green ash were the best-performing tree species, with 87-100% healthy. Hybrid poplars showed the greatest mortality. Manchurian elm, green ash, American elm, and Manitoba maple are more suitable trees for plantations than are hybrid poplars in areas without irrigation.

RESUME

On a effectué des relevés sur l'état des sols, sur leur teneur en humidité et fait des essais sylvicoles en des plantations d'agrément dans trois parcs provinciaux de la Saskatchewan en 1972 et 1973. Les résultats de l'étude indiquent qu'il est nécessaire d'appliquer des méthodes de conservation de l'eau chaque année pour maintenir un degré d'humidité suffisant pour la croissance des arbres. Au cours des années de sécheresse, des soins culturaux sont requis si l'on veut assurer le maintien des plantations d'arbres mais au cours des années normales, une tonte rase des mauvaises herbes est indiquée. L'espacement des arbres dans les plantations existantes est peut-être insuffisant.

Les espèces qui donnèrent le meilleur rendement furent l'Epinette du Colorado, l'Orme chinois et le Frêne vert avec 87 à 100% d'arbres sains. Les Peupliers hybrides subirent la plus forte mortalité. L'Orme chinois, le

Frêne vert, l'Orme d'Amérique et l'Erable négondo conviennent mieux que les Peupliers hybrides dans les zones non irriguées.

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INTRODUCTION

Approximately 2500 ha of amenity plantations (trees and shrubs) were established in southern Saskatchewan between 1947 and 1972 to provide shade and shelter for campers and picnickers in a prairie environment. The most important silvicultural problems related to these plantations were species selection, site selection, and proper maintenance after establishment. Species utilized in the plantations include coniferous trees such as white spruce (*Picea glauca* (Moench) Voss), Colorado spruce (*P. pungens* Engelm.), lodgepole pine (*Pinus contorta* Loudon var. *latifolia* Engelm.), Scots pine (*P. sylvestris* L.), and Siberian larch (*Larix sibirica* Ledeb.); deciduous trees such as hybrid poplars (*Populus* X *balsamifera* L. cv. 'Wheeler #4'), green ash (*Fraxinus pensylvanica* Marsh.), American elm (*Ulmus americana* L.), Manchurian elm (*U. pumila* L.), Manitoba maple (*Acer negundo* L. var. *interius* (Britt.) Sarg.), Amur maple (*A. ginnala* Maxim.), and crab apple (*Malus* spp.), and 15 varieties of shrubs.

The need for soil moisture conservation in the amenity plantations of southern Saskatchewan was recognized by Kagis (1963, 1965-1968). He recommended annual soil cultivation in the established plantations to eliminate competing weeds. Park managers introduced mowing in 1969 as a cheaper method of weed control, but the effectiveness of this method was not proven. In a study of the effects of six maintenance treatments on the growth of Wheeler poplars at Danielson Park (Lesko and Soos 1976) shallow cultivation gave the best results, followed by deep cultivation and chemical weed control. Nil treatment produced the poorest results, and high mowing was only slightly better. The value of low mowing was not clear, because in the early years of the experiment it gave better results than deep cultivation or herbicide treatment, but fell behind these in the last 2 years of the experiment. The study of soil moisture did not clarify this uncertainty, because the growing trees lowered the soil moisture content to the same level in each treatment.

In 1972 and 1973, at the request of the Saskatchewan Department of Natural Resources, a study was carried out to:

1) determine the condition of tree plantations
2) study the effects of rooting habit in hybrid poplars on moisture utilization

3) examine the soil moisture content between two rows of hybrid poplars
4) compare the effectiveness of cultivation and low mowing as water conserving methods, and
5) estimate the minimum spacing requirement of trees on the basis of available soil moisture.

THE STUDY AREA

LOCATION AND SOILS

The locations chosen for this study were the provincial parks at Saskatchewan Landing (50°39'N, 107°58'W) at 540 m elevation, Danielson Park (51°17'N, 106°52'W) at 525 m elevation, and Rowan's Ravine (51°17'N, 105°14'W) at 500 m elevation. Grassland vegetation characterizes all three parks. The first and second objectives of the study were carried out at Danielson Park and Saskatchewan Landing, the third objective at Danielson Park, and the remaining two objectives at all three parks.

The plantations at Saskatchewan Landing are within the Brown Soil Zone in the valley of the South Saskatchewan River, about 90 m lower than the regional topography. Danielson Park and Rowan's Ravine are both in the Dark Brown Soil Zone, but Danielson Park is close to the boundary with the Brown Soil Zone (Richards and Fung 1969).

CLIMATE AND VEGETATION

Saskatchewan Landing is within the Semiarid Climatic Zone with less than 300 mm annual precipitation and short grass prairie vegetation. Danielson Park and Rowan's Ravine are in the Subhumid Continental Climatic Zone with mid-grass prairie vegetation. However, Danielson Park is close to the boundary of the Semiarid Climatic Zone with 300-350 mm annual precipitation, while Rowan's Ravine is nearer to the Humid Continental Climatic Zone with 350-400 mm annual precipitation (Richards and Fung 1969). Small native aspen occur around Rowan's Ravine, indicating moister conditions.

The climate of these regions is characterized by summer precipitation maxima and frequent dry spells during the growing season (Dey 1973). The amount of growing season precipitation is highly variable; there is a drought once in every 6-8 years (Fig. 1). Precipitation data in Fig. 1 were extracted from the climatic records of stations at Pennant, 22 km SW of Saskatchewan Landing; Outlook, 27 km NW of Danielson Park; and Strassburg, 21 km E of Rowan's Ravine (Environment Canada 1943-1974).

METHODS

For the plantation condition survey at Danielson Park and Saskatchewan Landing, the condition of hybrid poplars, green ash, Manitoba maple, American elm, Manchurian elm, and Colorado spruce was classified by census as healthy, poor (dead top), or dead. The age of the surveyed plantations ranged from 7 to 9 years. At both locations the root system of a hybrid poplar with a dead top was excavated and examined. These trees had been planted 8 years prior to excavation and were in areas which had been cultivated. Soil profiles were examined close to the excavated trees. Soil moisture content between two rows of hybrid poplars was examined at the three different depths at one site in Danielson Park on July 19, 1972.

Soil moisture observations were taken on treeless plots established to determine the effectiveness of cultivation and low mowing in the three previously described locations. Treatments, including a control, were replicated three times at each location on heavy and light soils. The experiment was laid out in blocks containing nine 400-m^2 rectangular sample plots. The treatments were applied in the last week of June and in early August 1973, by cultivating the soil to a depth of 10 cm and mowing the weeds to a height of 10 cm. The control plots received no treatment. A view of the different treatments is shown in Fig. 2. Moisture content of the soil was measured at intervals of 3 weeks from May to early October. The measurements were carried out by the gravimetric method on two series of soil samples from each sample plot from the 0 to 13-, 13 to 25-, 25 to 38-, and 38 to 64-cm soil layers. The samples were taken by an auger. All the soil from a layer was thoroughly mixed in a plastic bag before a representative sample was placed into a metal can, sealed, and weighed within about 3 h of the sampling time. The results were analyzed statistically by analysis of variance and Duncan's multiple range test.

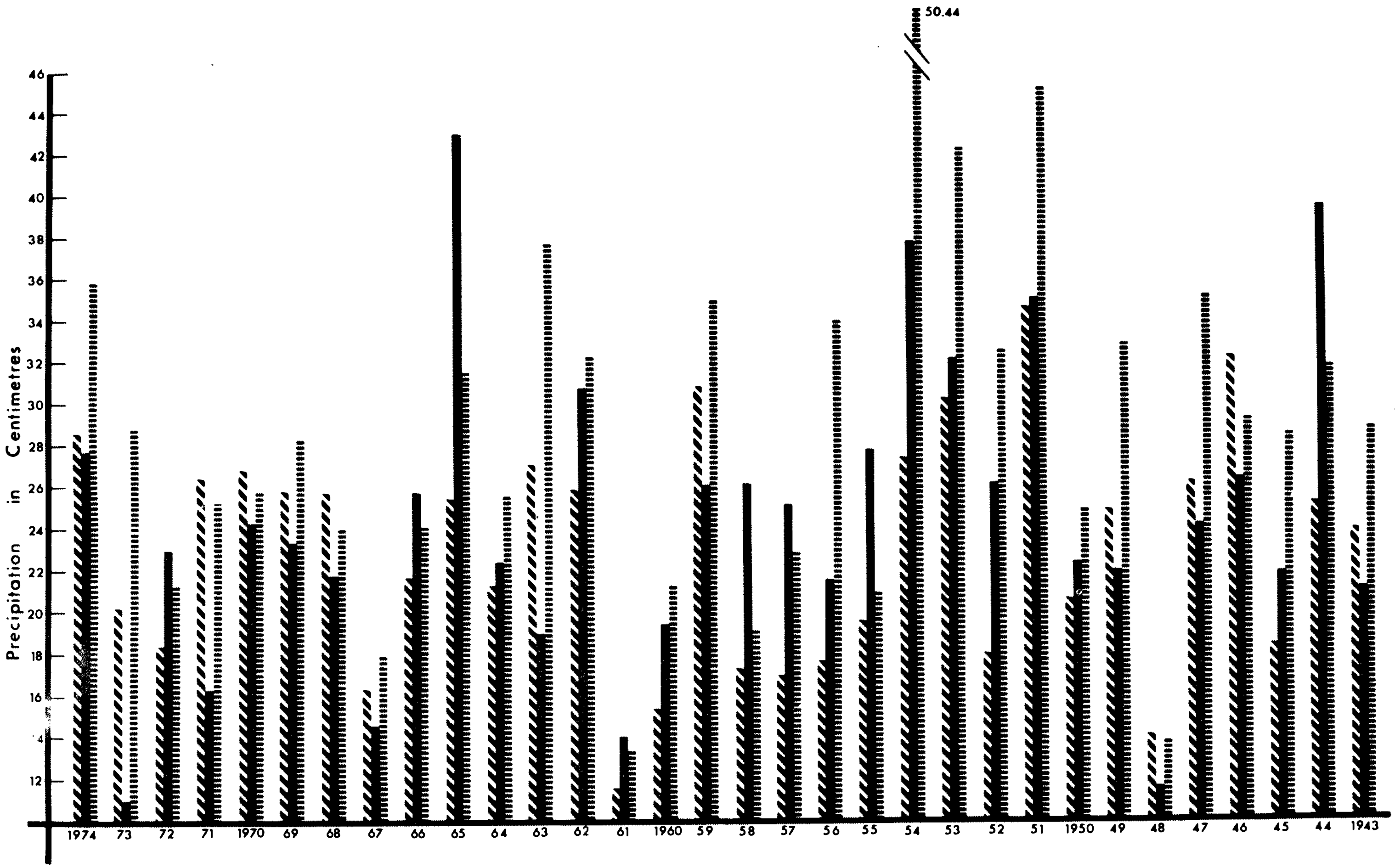

Figure 1. Precipitation totals from May to September inclusive in the years 1943 to 1974 at Outlook (diagonal) Pennant (solid) and Strassburg (horizontal)

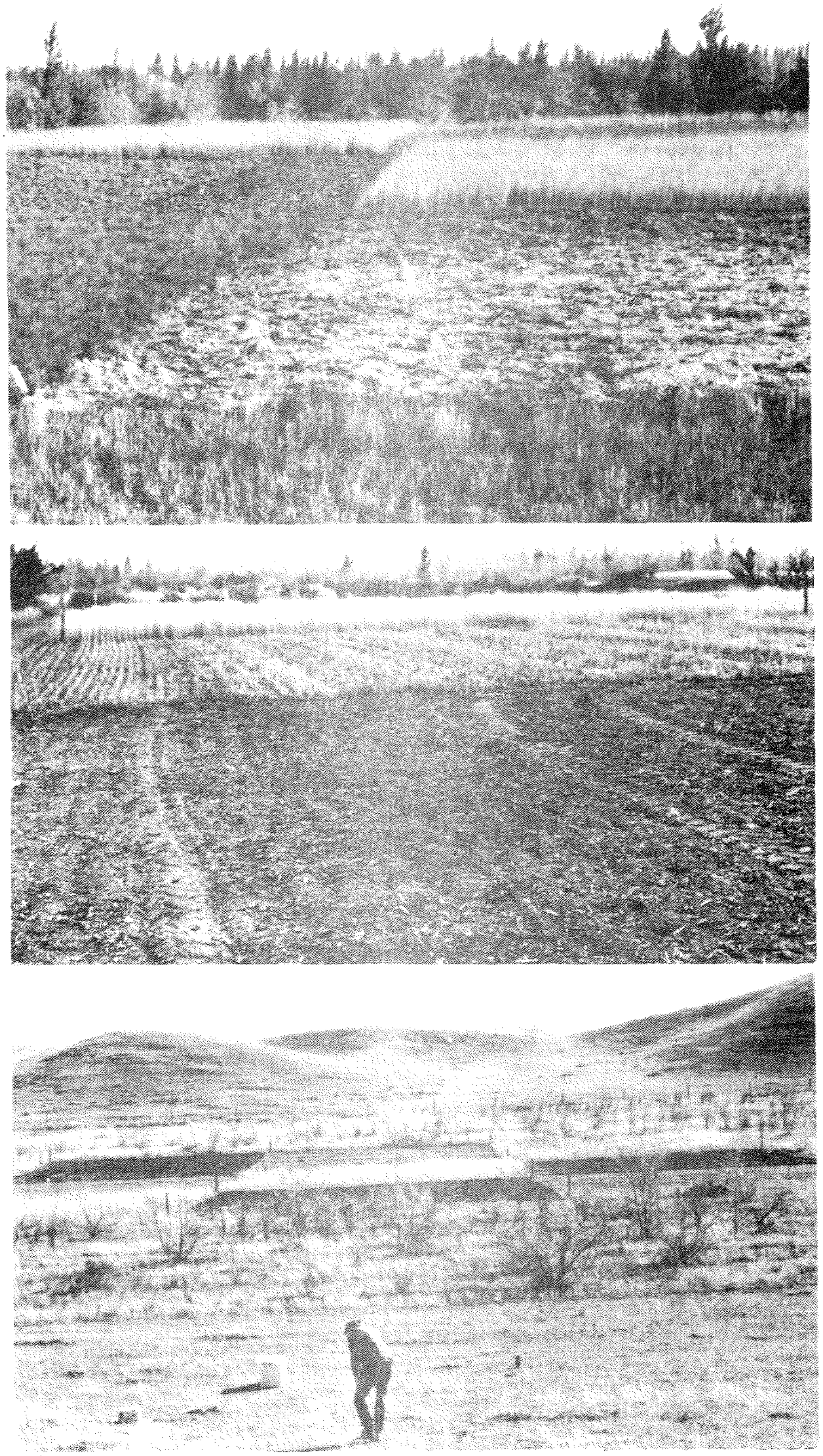

Figure 2. The view of experimental plots in August 1973 at Rowan's Ravine, Danielson Park and Saskatchewan Landing from top to bottom. Note Stevenson screen for temperature sensors, pyrheliograph and rain gauge in foreground of plot at Saskatchewan Landing.

Soils were collected at four points in each block, according to the previously described layers, for the determination of soil moisture curves, exchangeable and water-soluble Na, K, Ca, and Mg, total carbonates, and electrical conductivity. The analyses were performed by the standard methods employed by the Soil Service Laboratory of the Northern Forest Research Centre (Kalra 1971).

Local climatic observations were carried out in the growing season of 1973 at each experimental site. Precipitation, air temperature, relative humidity, and solar radiation were recorded at about 20 cm above ground level (Fig. 2). The recordings were made with standard rain gauges, weekly Fuess hygrothermographs, and weekly Belfort pyrheliographs. Daily observations of precipitation and temperature were made by park personnel.

The spacing requirements of hybrid poplars, green ash and Manitoba maple were estimated on the basis of the following factors:

1) The amount of available water in the growing season during a drought year under cultivation treatment in the top 64 cm of the soil. These were considered to be 5 cm^3/cm^2 in heavy soil and 2 cm^3/cm^2 in light soil from Danielson Park measurements (Table 1).
2) Transpiration rate of trees as measured by Kagis (1966).
   Poplar--5.72 $cm^3/cm^2/8$ h
   Green ash--1.97 $cm^3/cm^2/8$ h
   Manitoba maple--1.89 $cm^3/cm^2/8$ h
3) Growing season length of 5 mon (May to September) with 14 h per day active transpiration.
4) Estimated leaf surface area of trees by associated tree height taken from measurement of trees at Rowan's Ravine (Fig. 3).

From the above factors the total growing season transpiration per unit leaf area was calculated as:

Poplar $Wn = Tr \times H = 0.00715 \times 2100 \simeq 15\ cm^3/cm^2$

Green ash $Wn = Tr \times H = 0.00246 \times 2100 \simeq 5.2\ cm^3/cm^2$

Manitoba maple $Wn = Tr \times H = 0.00233 \times 2100 \simeq 4.9\ cm^3/cm^2$

Table 1. The total volume of available water in the top 64 cm of the soil under different treatments expressed as cm^3/cm^2 of surface area.

DATE	Saskatchewan Landing						Danielson Park						Rowan's Ravine					
	Heavy Soil			Light Soil			Heavy Soil			Light Soil			Heavy Soil			Light Soil		
	Control	Mow	Cultivate	Control	Mow	Cultivate	Control	Mow	Cultivate	Control	Mow	Cultivate	Control	Mow	Cultivate	Control	Mow	Cultivate
April 13	.98	2.13	2.07				3.81	4.08	5.52	.56	.64	.78						
May 2				3.33	3.46	3.67							9.75	7.93	6.84			
May 24	1.49	1.56	1.81	1.66	1.57	1.28	4.58	3.90	5.23	.51	1.42	3.94	6.76	6.28	6.01	1.71	3.69	3.92
June 13	0.0	0.0	0.0	.28	.27	.15	6.01	4.05	7.65	1.33	1.86	3.01	7.11	6.80	7.32	5.83	3.62	6.03
July 4	0.0	0.0	0.0	0.0	0.0	.41	1.48	.35	5.45	0.0	0.0	2.33	4.78	4.76	4.99	.97	3.55	6.27
July 24	0.0	0.0	0.0	0.0	0.0	.21	.17	1.64	5.92	0.0	0.0	3.23	3.69	3.82	5.54	.62	2.87	4.46
Aug. 14	0.0	0.0	0.0	0.0	0.0	.01	0.0	.83	5.72	0.0	0.0	1.22	3.02	3.50	5.34	.14	2.43	2.11
Sept. 11	0.0	0.0	0.0	0.0	0.0	.22	0.0	.56	6.03	0.0	0.0	2.83	1.37	5.50	5.84	0.0	1.30	3.35
Oct. 2	0.0	0.0	0.0	0.0	0.0	0.0	.27	1.25	5.21	0.0	0.0	3.73	2.87	4.72	6.41	.92	2.83	6.61

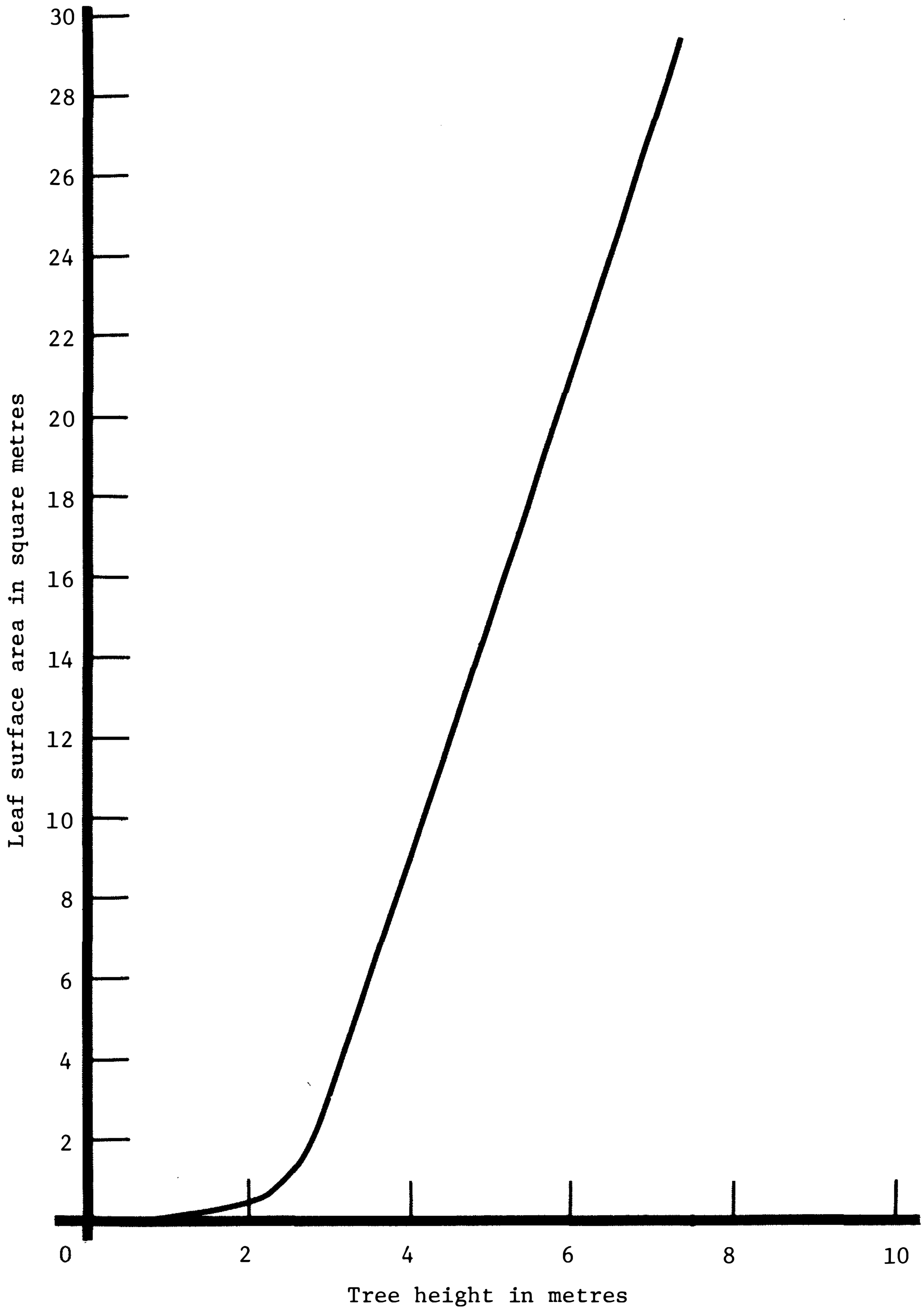

Figure 3. Relationship between hybrid poplar tree height and leaf surface area at Rowan's Ravine

Where Wn = growing season water transpiration per square centimetre of leaf area

Tr = transpiration rate, in cubic centimetres per square centimetre

H = number of hours of transpiration during the growing season

The area requirements of trees were calculated by the following formula:

$$Ar = \frac{Wn \times La}{Aw}$$

Where Ar = area required by a tree

La = total estimated leaf surface area of a tree from Fig. 3

Aw = available water per square centimetre of soil

RESULTS

CLIMATE

The May to October precipitation in 1973 was close to the average at Strassburg but only 84% and 41% of the 32-year mean at Outlook and Pennant respectively. Measurements during the same period at the experimental sites showed only 54% of the Pennant mean precipitation at Saskatchewan Landing, 30% of that in Outlook at Danielson Park, and 83% of the average at Strassburg in Rowan's Ravine. Totals at the experimental sites were therefore even lower than those recorded at the regular climatological stations in 1973.

CONDITION SURVEY

Mortality

Only hybrid poplars were surveyed for mortality in Danielson Park, because damage in other species was negligible. Of the 140 trees examined, 63% were healthy, 36% had dead tops, and 1% were dead. The survey results were grouped according to the topographic position of the examined trees (Table 2). The data show a strong trend towards higher incidence of top dieback in more exposed, drier topographic positions.

All species were included in the mortality survey at Saskatchewan Landing (Table 3). Thirty-two percent of the planted stock was dead or in poor health. The most severely affected species were hybrid poplars followed by Manitoba maple and American elm. The best-performing species were Colorado spruce, Manchurian elm, green ash, and the shrubs, with 87-100% still healthy.

Table 2. Condition of hybrid poplars according to topographic position in Danielson Park

Tree Condition	Topographic Position: Flat	Hill Tops and Upper Slopes	Mid Slopes	Lower Slopes	Depression
Healthy	79%	22%	51%	78%	91%
Dead Top	19%	78%	49%	22%	9%
Dead	2%	0	0	0	0

Table 3. Condition of planted trees at Saskatchewan Landing by species

Species	No. Examined	Tree Condition: Healthy No.	Healthy %	Dead Top No.	Dead Top %	Dead No.	Dead %
Hybrid Poplar	677	258	38	181	27	238	35
Green Ash	656	570	87	66	10	20	3
Manitoba Maple	330	178	54	132	40	20	6
American Elm	149	106	71	39	26	4	3
Manchurian Elm	61	56	92	3	5	2	3
Shrubs	415	377	91	-	-	37	9
Colorado Spruce	18	18	100	0	0	0	0
TOTAL	2306	1563	68	412	18	321	14

Rooting Habit of Hybrid Poplar

Figure 4 shows the root system of a hybrid poplar with a dead top at Danielson Park. The soil profile belongs to the Calcareous Brown subgroup. The top 23 cm of the soil was well mixed by cultivation preceding the establishment of the plantation, as evidenced by the high permeability and low bulk density of this layer. Bulk density increases downward from 10 cm, reaching maximum compaction at 23 cm. Available soil moisture increases with depth from 11 to 14%. The soil reaction is moderately alkaline in the Ap horizon and moderately to strongly alkaline in the B and C horizons. Salinity, expressed as electrical conductivity of the soil extract at field capacity, increases sharply between 48 and 61 cm.

Most surface roots did not penetrate deeper than 25 cm below the soil surface, and about 70% of them showed some evidence of mechanical damage from cultivation or an abrupt change in the direction of growth from vertical to horizontal. Maximum rooting depth was found to be about 50 cm. At that depth, the roots turned sharply horizontal (Fig. 5). All the deeper roots showed a tendency to grow towards the soil surface instead of going deeper (Fig. 6). Figure 6 also shows the horizontal distribution of the roots. The root system occupies a roughly 8 x 9 m elliptical area with the longer axis coinciding with the tree row.

Figure 7 shows the root system of an excavated hybrid poplar at Saskatchewan Landing. The soil profile belongs to the Cumulic Regosol subgroup. The top 46 cm of the profile is a light-textured sandy loam with some organic matter enrichment. Below 46 cm the soil is richer in clay content, but poorer in organic matter. The light-textured soil is friable, well aerated, and easily penetrated by roots. Available soil moisture increases with depth from 8 to 11%. Soil reaction is strongly alkaline, and the carbonate content is moderately high up to the surface of the soil. The salinity of the soil is low. Distribution of extractable cations is uniform throughout the entire profile, indicating very little, if any, leaching or accumulation by soil-forming processes.

Horizontally the roots spread 2.5, 6, 4, and 2 m to the north, east, south, and west directions respectively, covering a 6.5 x 8-m area.

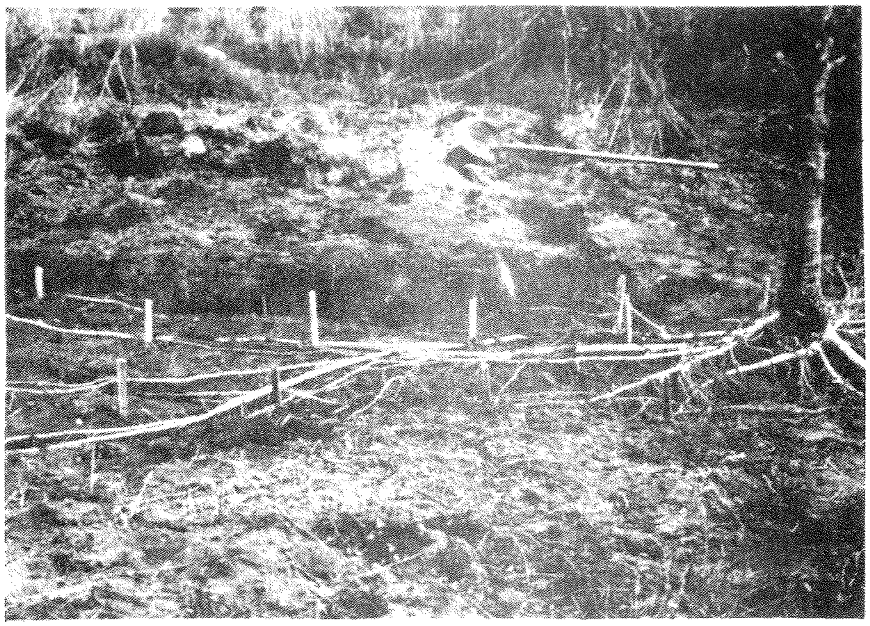

Figure 4. Superficial nature of the root system. Metal stakes are 60 cm apart and their tops were level with the undisturbed soil surface.

Figure 5. Maximum root penetration is about 50 cm, where the downward growing roots turn abruptly horizontal.

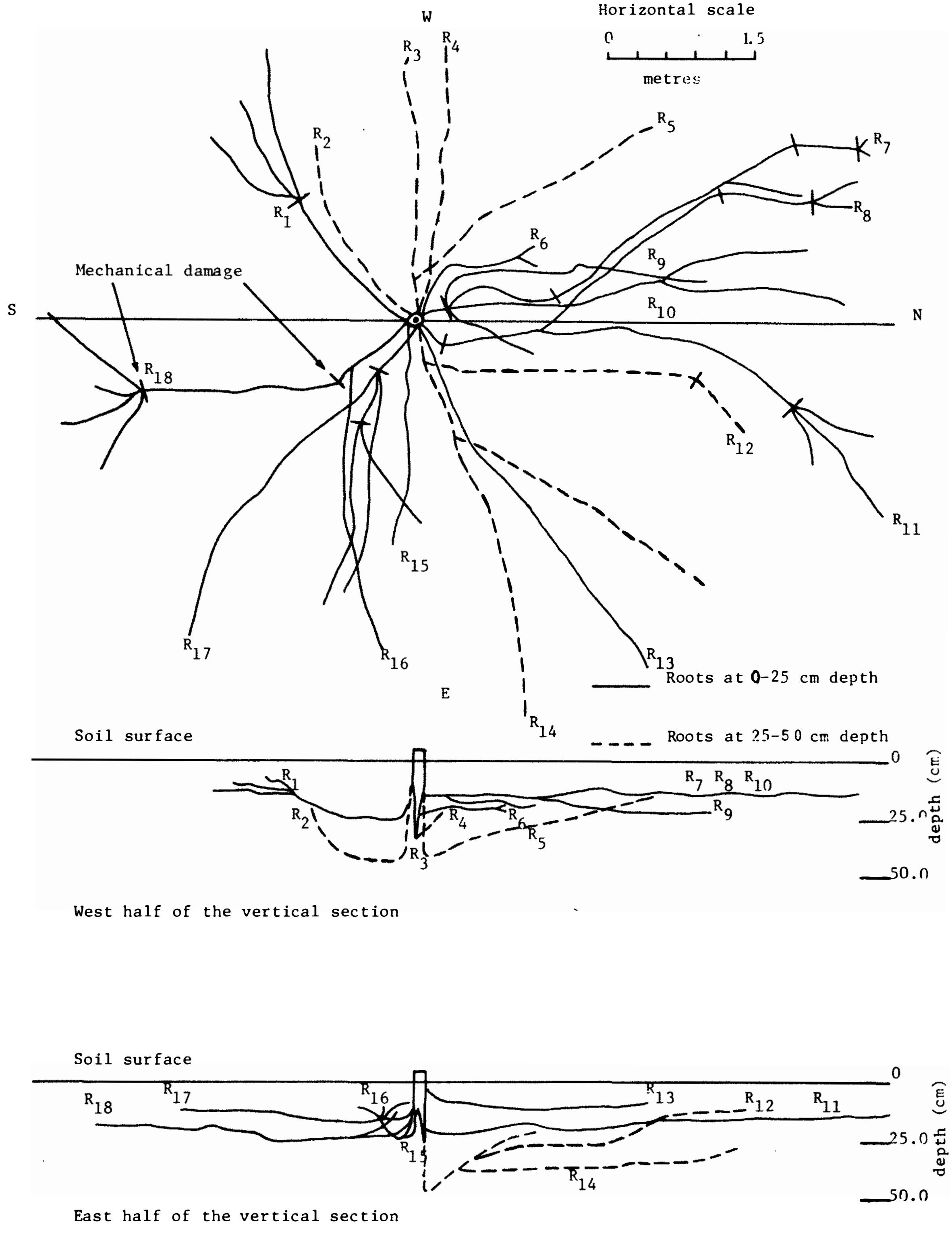

Figure 6. Root distribution of a hybrid poplar with a dead top at Danielson Park

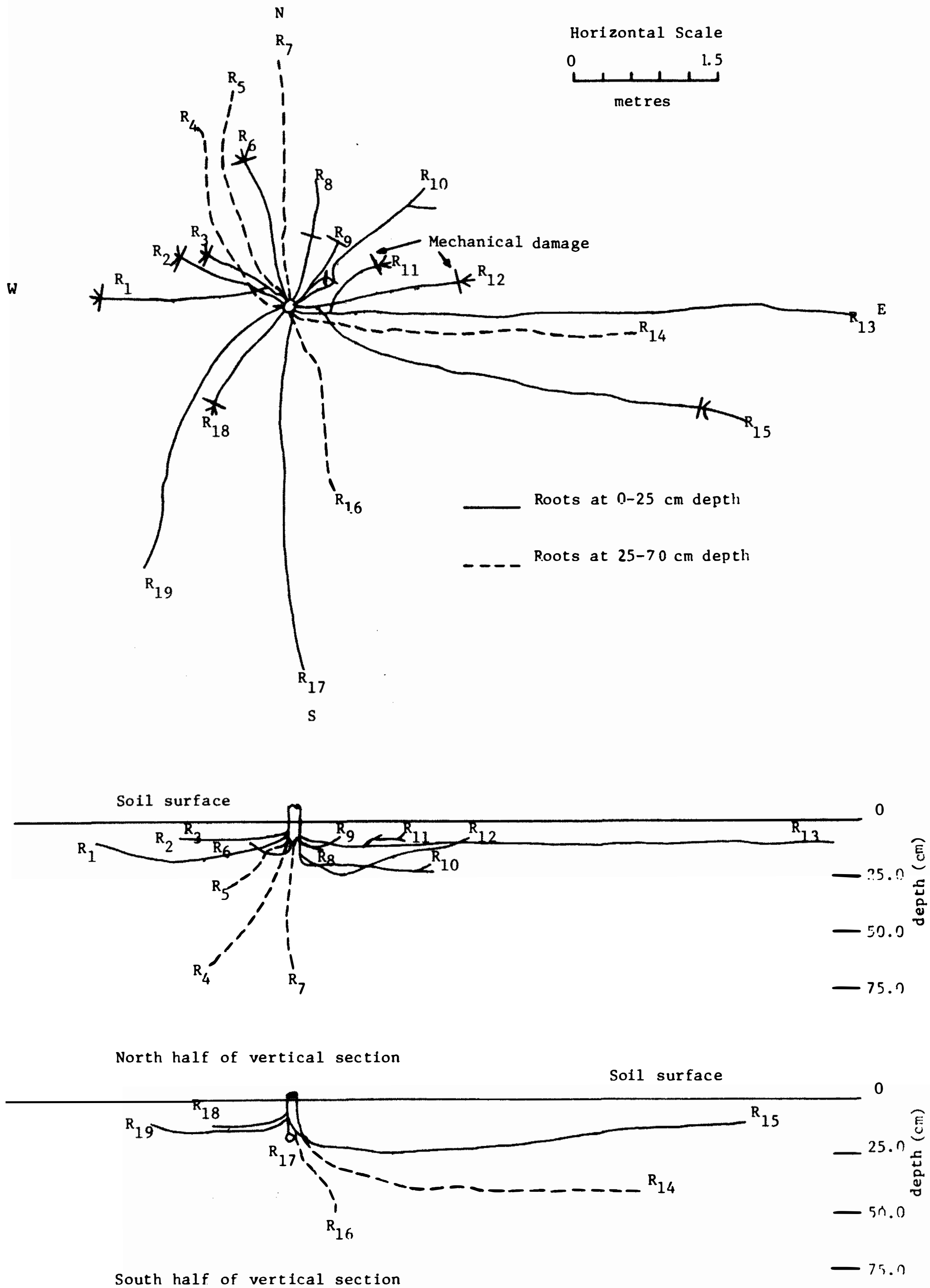

Figure 7. Root distribution of a hybrid poplar with a dead top at Saskatchewan Landing

The asymmetrical root distribution seemed to be caused by the proximity of the nearest tree in each direction. The closest tree to the west was less than 3 m away, while the next tree to the east was over 6 m distant.

About 75% of the roots were closer than 25 cm to the soil surface, and close to 80% of these shallow roots showed evidence of some mechanical damage due to soil cultivation. Most of the damaged roots developed branches at the wounds, but did not grow much farther out from the trunk. About 25% of the roots penetrated deeper than 25 cm to a maximum depth of 70 cm.

SOIL MOISTURE

Utilization of Soil Moisture Between Tree Rows

There was an uneven availability of soil moisture in relation to depth and distance from tree rows (Fig. 8). Almost 85% of the soil moisture capacity was available in the tree row at the 2.5 to 7.5-cm depth, while only 11% of the soil moisture capacity was available between the rows.

Moisture content was reduced to the vicinity of permanent wilting percentage in the tree rows at the 10 to 15-cm depth. The maximum available moisture between the rows was reduced to 37% of the soil moisture capacity. Available moisture was 74% in the 2.5 to 7.5-cm depth and only 37% in the 10 to 15-cm layer.

Effects of Cultivation and Mowing

The cultivation treatment conserved 24.8% more total soil moisture than the control and 20% more than mowing treatments over all sites. The difference in soil moisture under mowing and control was not significant. Figure 9 shows the average soil moisture content during the growing season (May 25 to October 3) according to geographical locations, soil textures, and treatments. At Danielson Park cultivation conserved 53% more moisture than mowing on either heavy or light soil; no difference was detected between mowing and control. Average soil moisture was equally low under all treatments at Saskatchewan Landing. At Rowan's Ravine, the cultivation

Figure 8. Soil moisture content between two tree rows at Danielson Park

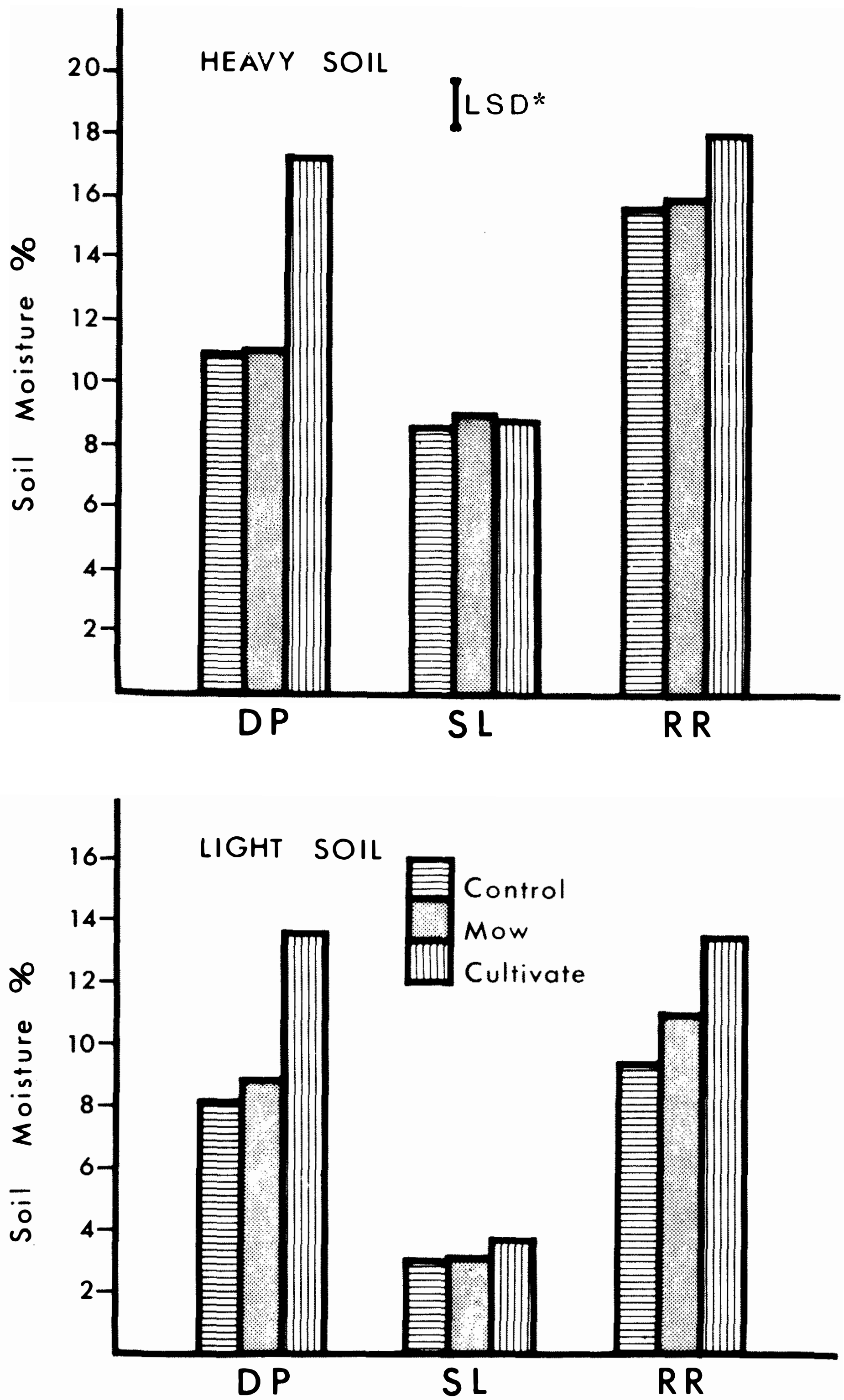

Figure 9. Average soil moisture % during the growing season at Danielson Park (DP), Saskatchewan Landing (SL), and Rowan's Ravine (RR) under different treatments in heavy and light soils

* Least significant differences - 95% level.

treatment retained 14.5% more moisture than mowing and 25% more than the control on light soil. The difference between mowing and control was not significant.

Figures 10-15 show the march of soil moisture content during the growing season by four different soil layers in heavy and light soils according to geographical locations. In the Rowan's Ravine heavy-soil area (Fig. 10), all treatments retained some available soil moisture during the entire growing season. Under cultivation, soil moisture potential was never below -3 atm in any of the measured soil horizons. In the mowing treatment and in the control, soil moisture was lost rapidly beginning in mid-June, exhausting all available moisture in the top 25 cm of the soil by mid-August. However, available moisture was present in the 25 to 64-cm soil layers during the entire growing season. Water losses from the surface layers under the cultivation treatment were greater in the light soil area (Fig. 11) than in the heavy soil area from July to August, but soil moisture potentials below -3 atm were not measured in any soil layer. Available moisture was almost completely exhausted in the control treatment by mid-September, but it was adequate in the mowing and cultivated treatments during the entire growing season.

In the Danielson Park heavy-soil area (Fig. 12), all available soil moisture was exhausted from the top 38 cm of the soil by early July in the control and mowing treatments, and from all soil horizons from early August to October in the control treatment. The cultivated soils retained available moisture at all times during the growing season, and soil moisture potential below -3 atm was recorded only in the top 13 cm during August. Soil moisture content was rapidly reduced in the second half of June to unavailable levels under the control and mowing treatments in the Danielson Park light soil area (Fig. 13), and stayed below -15 atm until the end of the growing season. The cultivation treatment retained soil moisture at above -3 atm potential in the deeper soil layers during the entire growing season. Evaporation losses were rapid from the top 25 cm of the soil in the second half of June; available moisture reserves were exhausted in the top 13 cm of the soil in August and September.

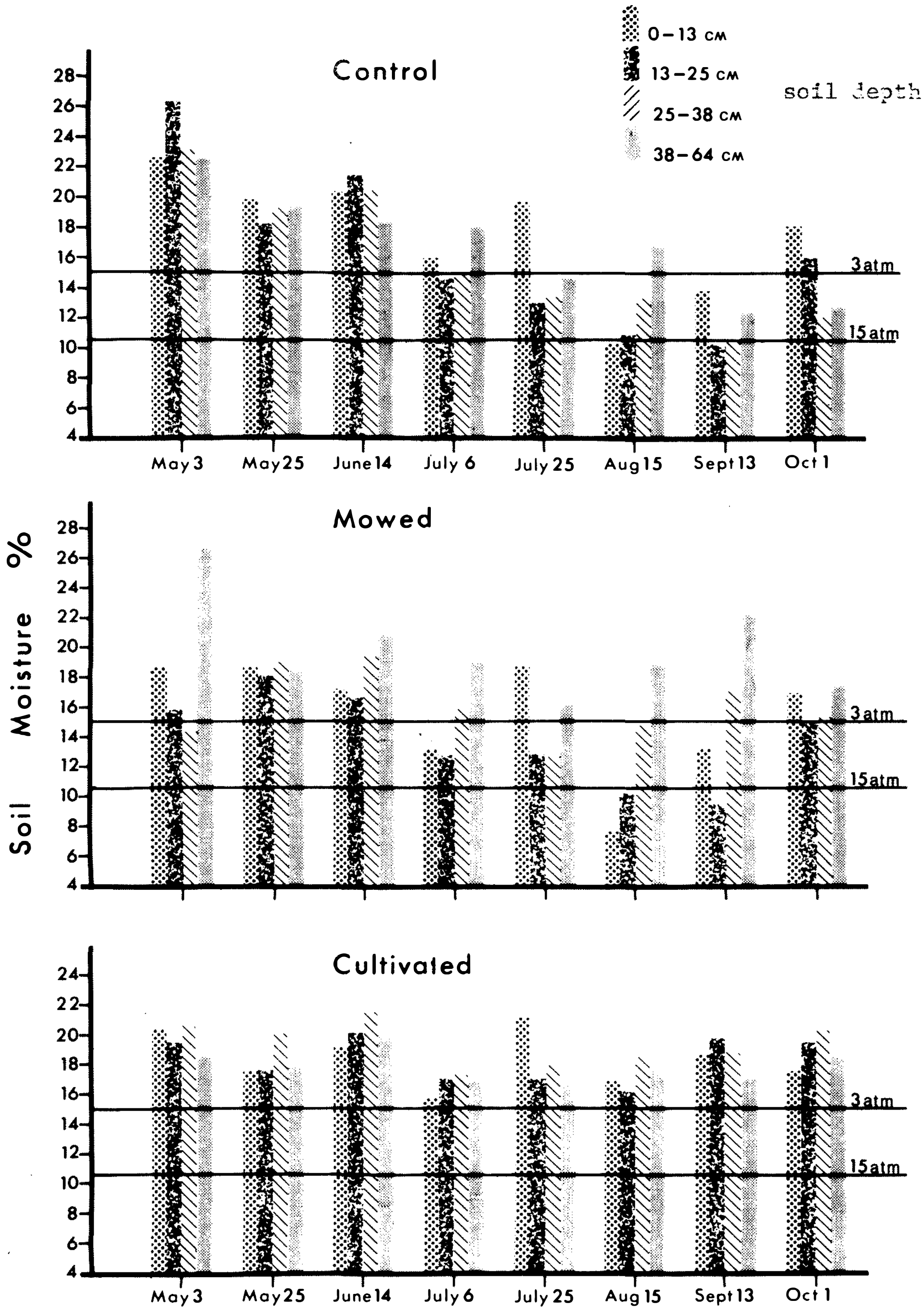

Figure 10. The march of soil water content through the growing season in the Rowan's Ravine heavy-soil area under control, mowing and cultivation treatments

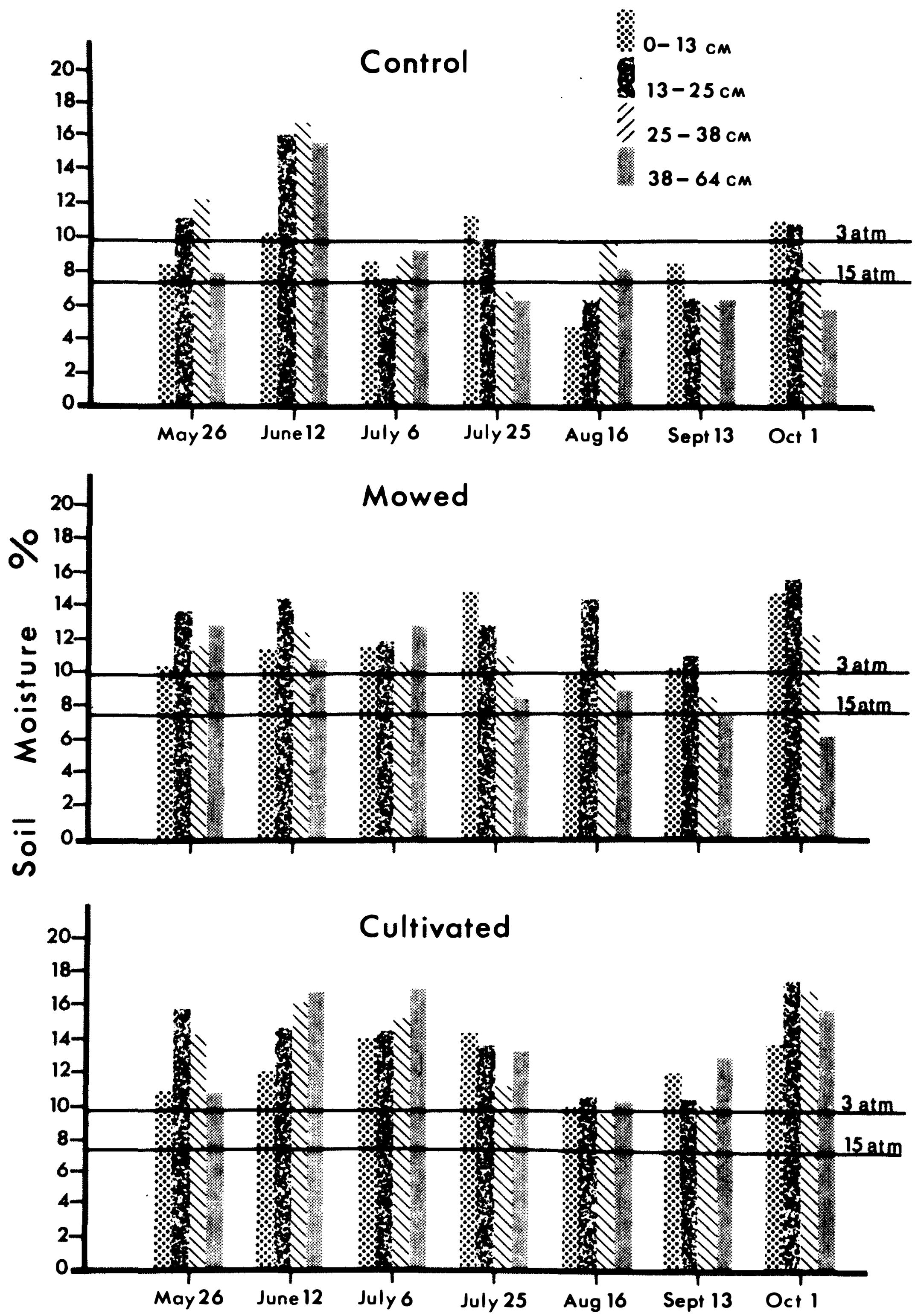

Figure 11. The march of soil water content through the growing season in the Rowan's Ravine light-soil area under control, mowing and cultivation treatments

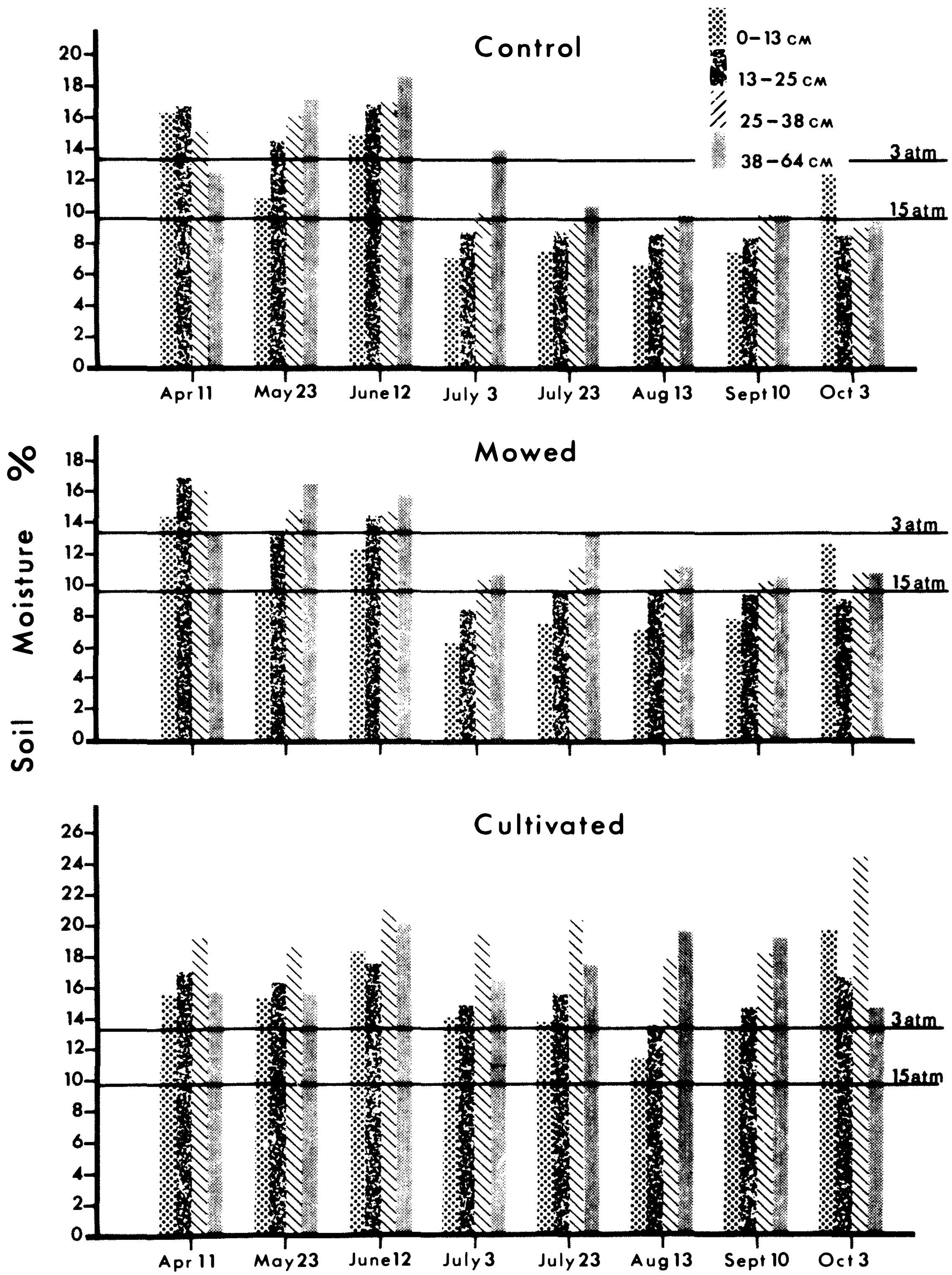

Figure 12. The march of soil water content through the growing season in the Danielson Park heavy-soil area under control, mowing and cultivation treatments

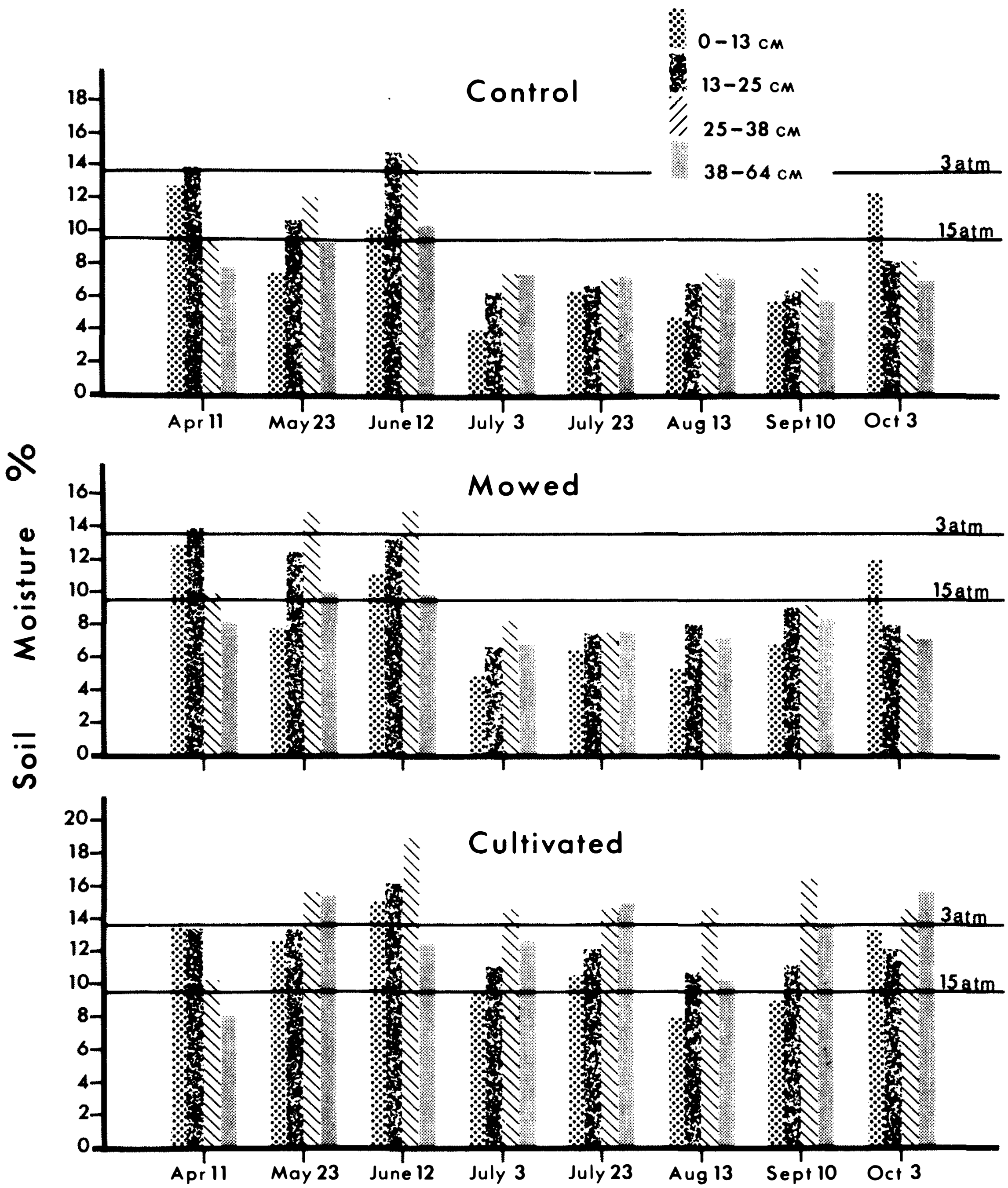

Figure 13. The march of soil water content through the growing season in the Danielson Park light-soil area under control, mowing and cultivation treatments

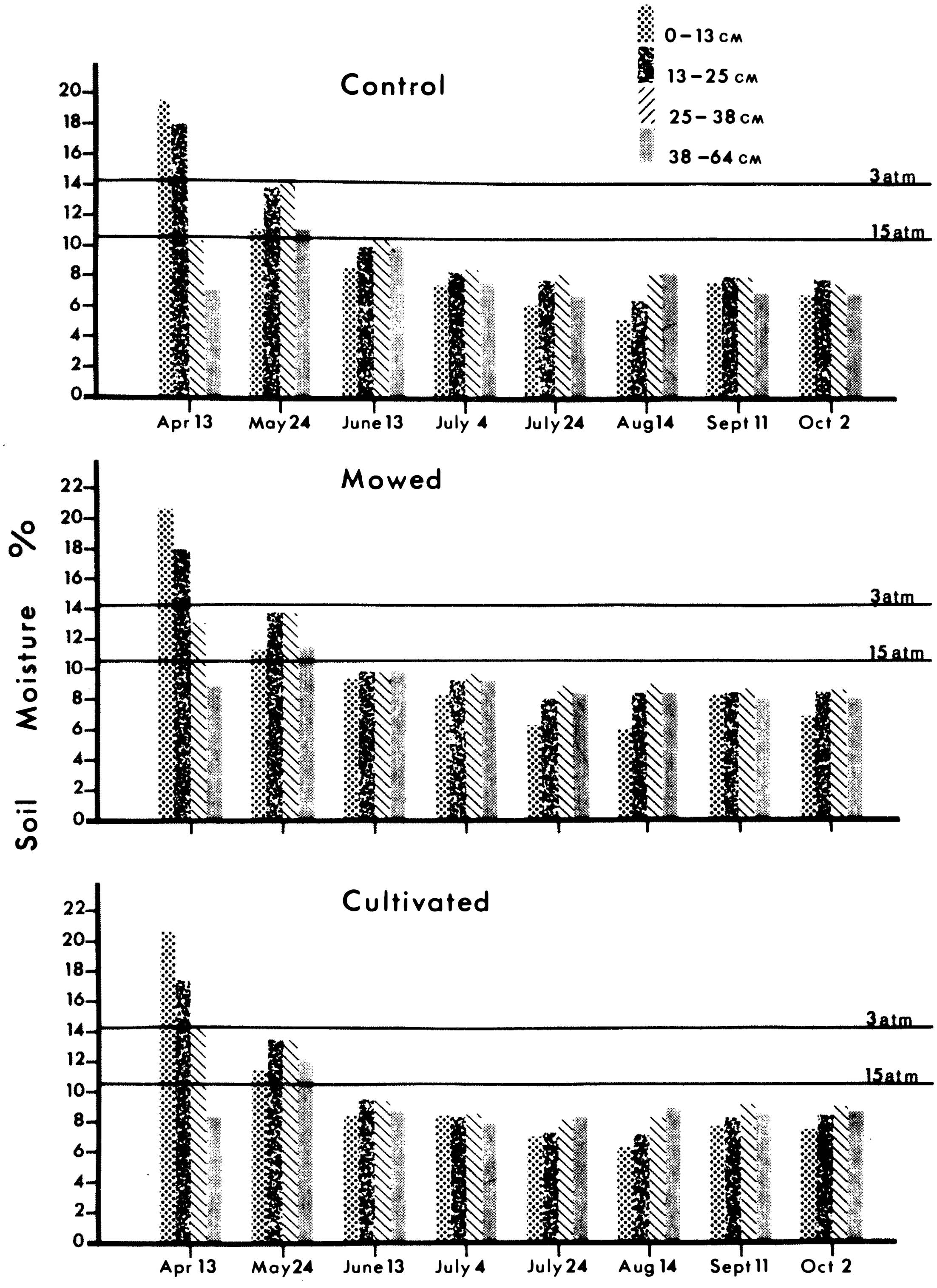

Figure 14. The march of soil water content through the growing season in the Saskatchewan Landing heavy-soil area under control, mowing and cultivation treatments

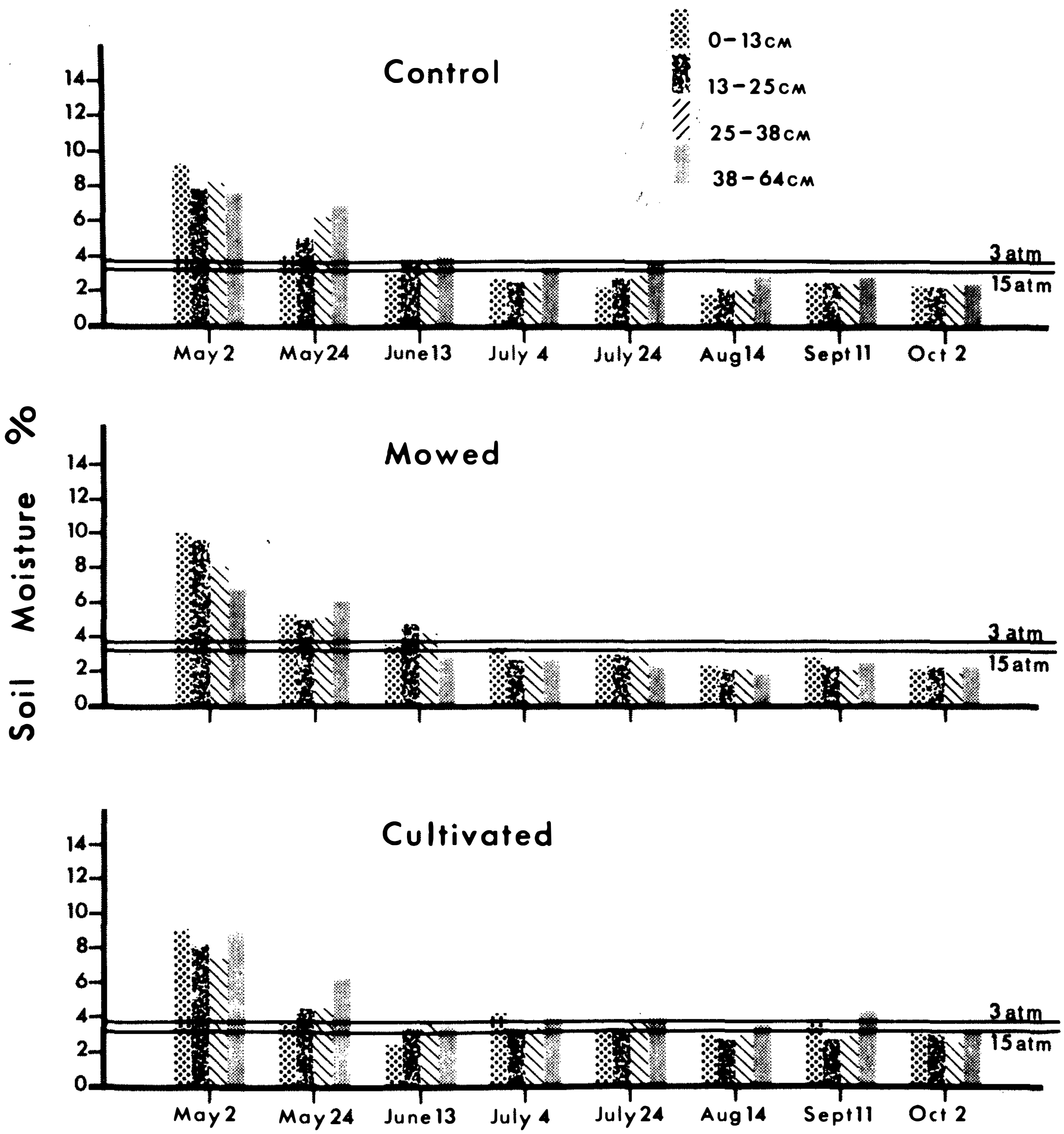

Figure 15. The march of soil water treatments through the growing season in the Saskatchewan Landing light-soil area under control, mowing and cultivation treatments

In the Saskatchewan Landing heavy-soil area (Fig. 14) soil moisture decreased rapidly from April 13 to unavailable levels by June 13 in all treatments and stayed more or less at the same low level through the entire observation period. Soil moisture losses were similar from the light-soil area, but there, some available moisture existed under cultivation until September. However, the total amount of that available moisture was very small (Fig. 15).

SPACING REQUIREMENTS

Results are expressed as spacing requirement by tree height (Figs. 16 and 17). Since Manitoba maple and green ash had very similar transpiration rates a single line was plotted for both species. Spacing calculations were made for Danielson Park and Rowan's Ravine only. Results from Saskatchewan Landing showed that there is insufficient available moisture supply at any spacing in a drought year.

DISCUSSION

CONDITION SURVEY

Moisture supply is a critical factor in the health and survival of hybrid poplars. The lower slopes and depressions collect snow drift and conserve moisture better than the exposed crests between the coulees and maintain a healthier stand of hybrid poplars.

Root excavation at Danielson Park showed that the depth of rooting of one tree with a dead top was restricted to about 50 cm. The very sharply turning roots could result from an impeding soil layer at 50-cm depth. The most likely reason for the lack of penetration below this level is the combination of compactness, high carbonate content, and salinity.

The alternative for the roots to utilize a larger soil volume is to spread horizontally. The excavation showed that roots of the examined hybrid poplar covered an approximately 8 x 9 m area. Since the original spacing of the plantation was closer than 3 x 3 m, the roots of several other trees penetrated into and competed for moisture in the rooting area of any individual tree, and this reduced the effective rooting area of

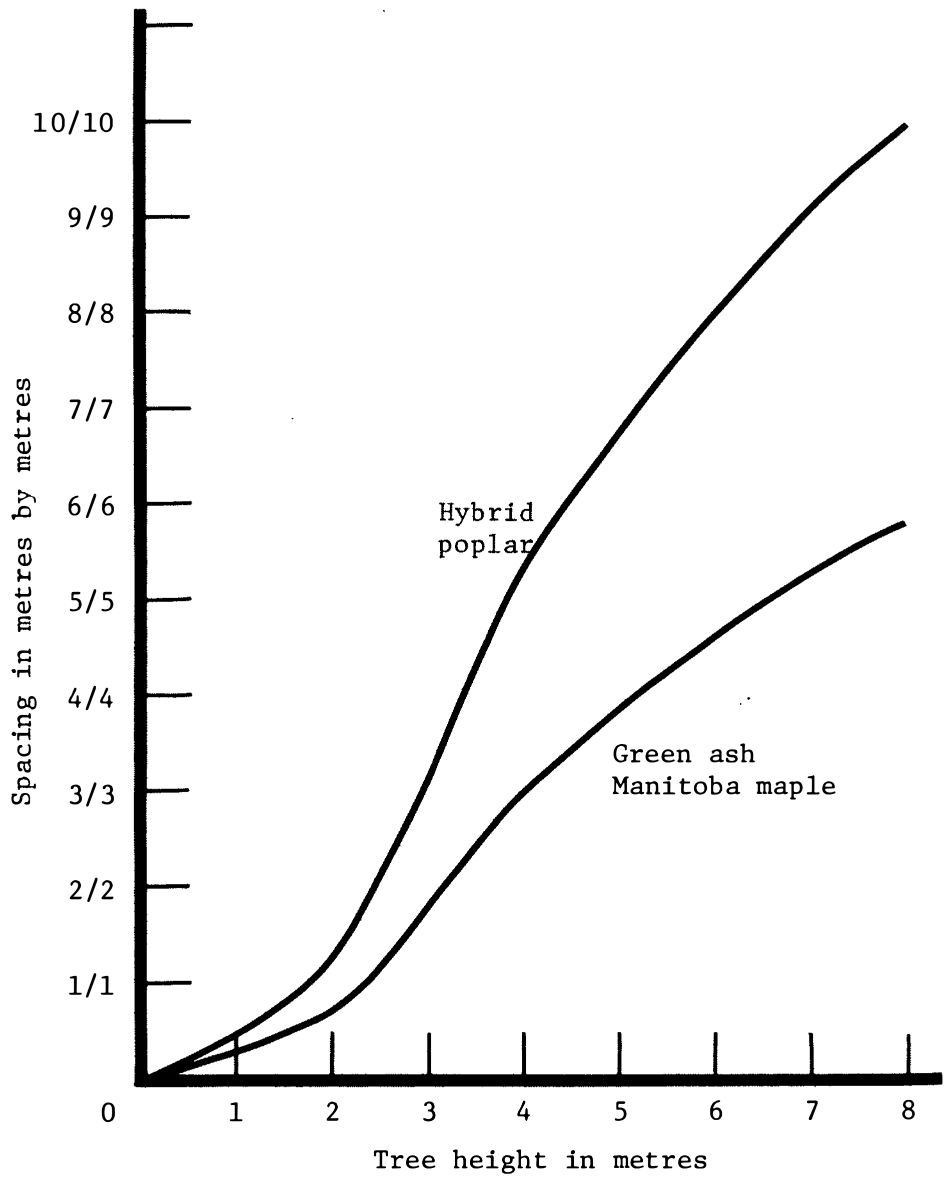

Figure 16. Spacing requirement for hybrid poplar, green ash and Manitoba maple in relation to tree heights on heavy soils

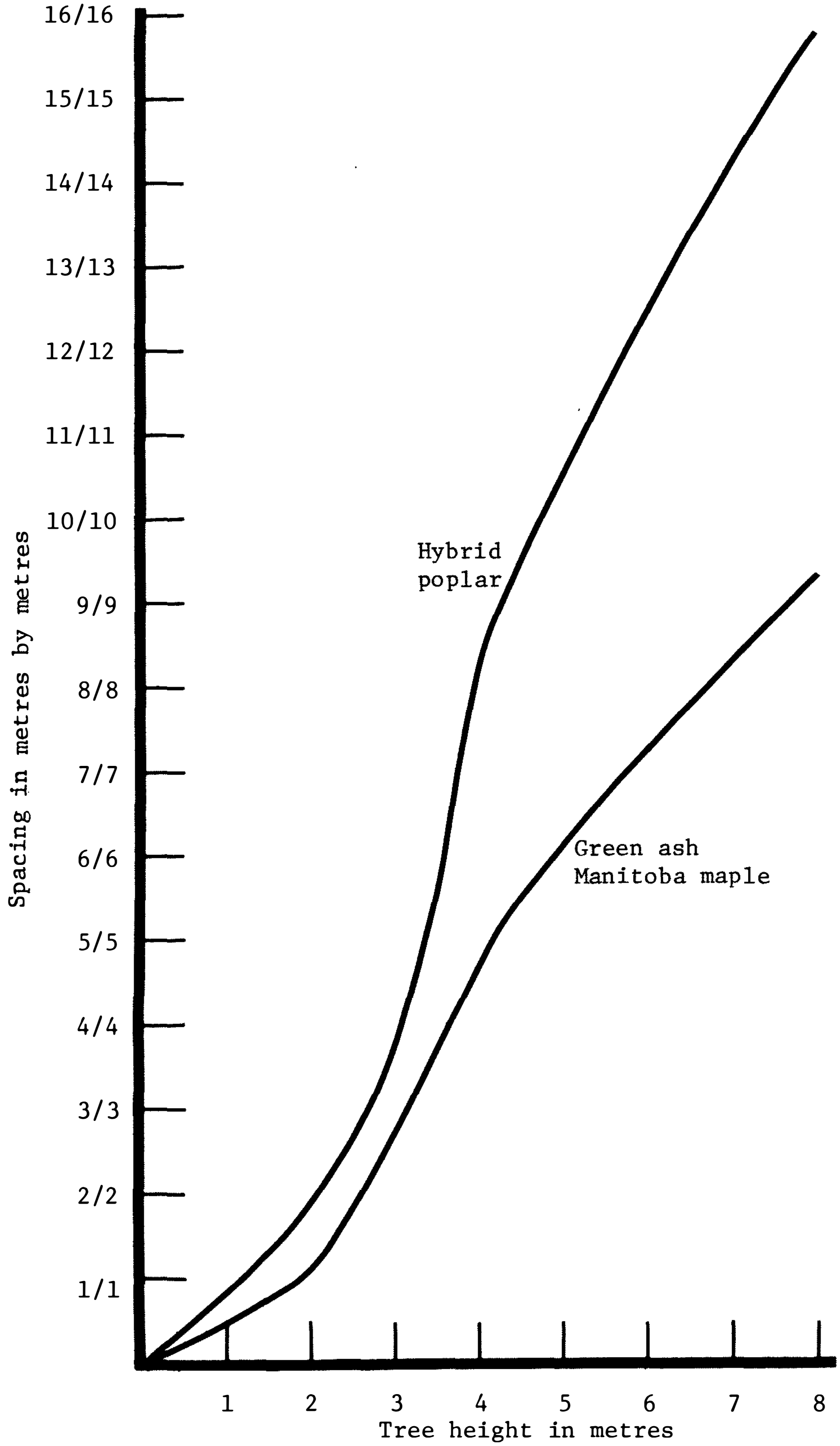

Figure 17. Spacing requirement for hybrid poplar, green ash and Manitoba maple on light soils

any tree to the spacing of the plantations. The rooting volume was further reduced by mechanical injury to 70% of the surface roots by cultivation. The wounded roots in general recover from the damage and continue to grow.

The health and quantity of surface roots are especially important, because the trees seem to rely on summer showers, which do not penetrate deeper than the top 13 cm, for moisture supply. The removal of weeds under the trees is necessary, because the approximately 30-35 cm annual precipitation is not sufficient for both trees and weeds.

Hybrid poplars at Saskatchewan Landing are the least affected by drought in light-textured, friable soils. Drought has a greater effect on trees in heavier-textured soils with a compacted horizon. Very few roots are able to penetrate this compact layer, which limits available rooting volume of the trees. The heavier-textured soil also has a higher percentage of stored moisture which is not available to trees. The higher mortality rate at Saskatchewan Landing as opposed to that in Danielson Park is probably due to more severe climatic conditions, because soil properties at Saskatchewan Landing seem equal to or better than those in Danielson Park.

Uneven moisture availability in the surface soil may be due partly to the presence of weeds in the tree rows or possibly to the elimination of many of the surface tree roots by cultivation. There are more tree roots in the 10 to 15-cm depth, which is out of reach of the cultivator. The higher moisture content of the 25 to 30-cm layer is probably due to its adverse physical properties, which hinder root penetration.

SOIL MOISTURE

The semiarid climate of southern Saskatchewan has a drought once in every 6-8 years. But even in a normal year, as 1973 was at Rowan's Ravine, the available soil moisture was insufficient for the maintenance of healthy trees without some moisture-conserving technique. Growth of Wheeler poplars without weed control at Danielson Park was severely retarded in years with above-average growing season precipitation in 1970 and 1971 (Lesko and Soos 1976). The application of some moisture-conserving technique is necessary every year in southern Saskatchewan tree plantations without irrigation or an easily accessible source of groundwater.

In this study the effects of partial removal of vegetation by mowing and total removal by cultivation were compared. Cultivation was the more effective method of conserving moisture. This result is supported by the better growth of Wheeler poplars at Danielson Park under cultivation than under mowing (Lesko and Soos 1976).

Cultivation not only controlled competing vegetation more effectively but also reduced evaporation. Laboratory experiments by Willis and Bond (1971) showed a reduction of 50% in evaporation rate by 7.5-cm deep tillage. Furthermore, tillage did not cause any temporary increase in evaporation over the control.

The moisture-conserving effectiveness of cultivation may be increased by the timing of the tillage. Lemon (1956) distinguished three stages of evaporation from soils: 1) rapid, steady loss, when capillary water movement to the surface equals evaporation demand, 2) rapidly declining loss rates, when capillary water supply to the surface declines continuously, and 3) low steady loss, when water moves to the surface only in vapor state. Obviously, cultivation is the most effective in moisture conservation if it disrupts capillarity at the beginning of the rapid steady loss evaporation stage. Willis and Bond (1971) found that evaporation was reduced by over 50% when tillage was applied on the first day after wetting. The reduction was 30% when tillage was applied 4 days after wetting and only 17% and 2.5% when tilled 7 and 18 days after wetting. The evaporation-reducing effect of tillage lasted for at least 70 days but to continuously lowering degrees.

From the above it is clear that the first spring cultivation should be carried out as early as possible to save winter moisture, and summer cultivations should follow major rain storms as soon as possible.

SPACING REQUIREMENTS

The excavated tree in Danielson Park had a height of about 6 m and a root distribution of about 8 x 9 m. This area compares well with the 8 x 8-m spacing estimate in Fig. 16. While firm conclusions cannot be drawn from the excavation of a single tree, the closeness of the spacing estimate with the actual root distribution tends to indicate that the spacing estimates determined may have some practical application. Further study will be required to verify this, but preliminary spacing recommendations can be given on the basis of available data.

RECOMMENDATIONS

SPECIES SELECTION

Manchurian elm, green ash, American elm, and Manitoba maple should be the main tree species for plantations in southern Saskatchewan. Hybrid poplars can be expected to perform well only in irrigated areas and in soils with a good groundwater supply. Colorado spruce have excellent survival, but their slow growth rate and small size do not allow for a decision on suitability at this time.

PLANTING SITES

Flat or depressional areas with heavier soils are more suitable for tree plantations in southern Saskatchewan than knolls or light soils. At Saskatchewan Landing new plantations should be established only where irrigation is possible or the groundwater is within reach of the roots. Lighter soils are more suitable for irrigation than heavy soils. Compact and saline soil layers may limit rooting depth in some locations at both Danielson Park and Saskatchewan Landing, potentially contributing to survival difficulties for trees in these areas.

SPACING

On heavy soils, plantations should be established in 2.5 x 2.5-m spacing. For hybrid poplars spacing should be increased to 5 x 5 m when the trees are 3 m tall, to 5 x 10 m at 4 m height, and to 10 x 10 m at 5-m tree height. For other species spacing should be increased to 2.5 x 5 m at 4-m height, and to 5 x 5 m final spacing at 5-m height.

On lighter soils, hybrid poplars should be established at 4 x 4-m spacing and increased to 8 x 8 m at 3-m height, to 16 x 8 m at 4-m height, and to 16 x 16 m at 6-m height. Other species can be planted in 2 x 4-m spacing increased to 4 x 4 m at 3 m-height, to 4 x 8 m at 4-m height, and to 8 x 8-m final spacing at 5-m tree height.

At these spacings trees should have a good chance for survival even in drought years.

MAINTENANCE

In years of normal summer precipitation low mowing is sufficient for adequate moisture conservation at Rowan's Ravine and Danielson Park, but shallow cultivation is essential in drought years. At Saskatchewan Landing neither treatment is sufficient to secure an adequate moisture supply to prevent top dieback in hybrid poplars in drought years.

ACKNOWLEDGMENTS

The cooperation of the staff of the Saskatchewan Department of Natural Resources at Rowan's Ravine, Danielson Park, and Saskatchewan Landing Provincial Parks and the technical assistance of V.S. Kolabinski, E.B. Robson, and T. Mueller are gratefully acknowledged.