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Regenerating Upland Black Spruce Cutovers on the Lake Nipigon Forest using Techniculture Mini-Plugs

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Regenerating Upland Black Spruce Cutovers on the Lake Nipigon Forest using Techniculture Mini-Plugs

R.C. Booth[1] and R.L. Fleming[2]

INTRODUCTION

Plantation establishment using conventional bareroot or container stock is among the most commonly used and expensive regeneration options for reestablishing black spruce (*Picea mariana* [Mill.] B.S.P.). One lower-cost alternative which has shown considerable promise on certain sites in north central Ontario is the outplanting of Techniculture® mini-plug stock[3]. In 1988, Domtar Inc., in conjunction with the Ontario Ministry of Natural Resources (OMNR) Northwestern Ontario Forest Technology Development Unit, began studying the use of mini-plugs to regenerate upland shallow-soiled sites on the Lake Nipigon Forest. Initially, mini-plugs were investigated as a regeneration option for the second coupe strips of alternate black spruce strip clearcuts. Good results have since extended their use to a variety of clearcuts within the coarse textured, shallow-soiled complex which

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[3]All references to mini-plugs in this note refer to stock produced in Techniculture, Inc. (Salinas, CA) plug cavities.

characterizes much of this region (Sims and Towill 1988). By 1994 Domtar had planted about 325 000 mini-plugs on these site types on the Lake Nipigon Forest.

Techniculture® mini-plugs consist of a 4.5 cm long, 1.3 cm diameter peat/polymer mix in which seedlings are grown for 10–12 weeks in the greenhouse to a target height of 4 cm (Fig. 1). The plugs were originally designed for agricultural production by Castle and Cook Inc., and are now produced by Techniculture, Inc., Salinas, CA. They were adapted by the OMNR Thunder Bay Forest Nursery to produce black spruce greenhouse stock for mechanized transplanting to nursery beds (Klapprat 1988). In the greenhouse, mini-plug stock are grown in 32 x 32 cm styrofoam blocks with 400 cavities per block. Stock production costs generally range from one third to one half of that for conventional container stock. A variety of dibbles and planting spears have been used for planting mini-plugs in the field.

Results of Domtar's initial outplanting trials were promising; mini-plug survival and height growth for most plantings were similar to that of conventional container stock (paperpot and later vent block container stock) over a 4 year period (Booth 1992). This study, a co-operative undertaking between Domtar and the Canadian Forest Service, is designed: (1) to investigate the subsequent growth and development of seedlings in the initial mini-plug trials; (2) to determine, through a replicated series of outplantings, the potential of mini-plugs for reforesting a wider range of site types with different competition levels in this region; and (3) to characterize environmental conditions, ecophysiological responses and growth patterns associated with these outplantings on three common site types.

METHODS

Outplanting Trials

Remeasurement of Older Plots

Between 1988 and 1991 Domtar set out 40 paired sample plots on shallow-soiled, coarse-textured sites with light competition to compare mini-plug establishment with that of Japanese FH-408 paperpot or Beaver Plastics (Edmonton, AB) 165 vent block container stock. Each plot consisted of two adjacent blocks, one planted with 9 mini-plugs, the other with 9 conventional container stock. Seedling survival and growth in these plots were reassessed in 1992, 1993, 1994 and 1995.

Site Suitability Investigations

Detailed seedling outplanting experiments were established in June 1992 and June 1993 on eight soil type-competition level combinations common to the Lake Nipigon Forest (Table 1). In each year, five plots, each consisting of 25 mini-plugs and 25 vent block 165 container stock, were set out on each of the eight soil type-competition level combinations. All seedlings were planted on the side of scalps created with a Bracke scarifier. Each plot was characterized according to Northwestern Ontario Forest Ecosystem Classification (NWO FEC) Soil and Vegetation Type, B horizon soil texture, soil depth, Soil Moisture Regime, humus form (Sims et al. 1989) and competition index (Towill and

Archibald 1991). Seedling survival and growth were assessed in each plot at the end of the first and second growing seasons.

Ecophysiology

Ecophysiological studies were conducted during the 1993 and 1994 growing seasons on three of the most commonly-occurring soil type-competition level combinations (Table 1). Growing season precipitation, solar irradiance, screen-height air temperature and humidity, wind speed and wind direction were monitored each year with a climate station. Replicated measurements of microclimatic conditions (seedling height air temperature, and root zone soil temperature and moisture) were made throughout each growing season in Bracke-created scalps and for undisturbed (raw humus) surfaces at each site. Five blocks, each consisting of 50 paired seedlings of each stock type, were planted in Bracke scalps at each site in both June 1993 and June 1994. In June 1994, equal numbers of seedlings were also planted on undisturbed surfaces using a similar experimental design.

Seedling stomatal conductance, transpiration, mid-morning twig xylem pressure potential, shoot osmotic potential and turgor loss point were measured at selected intervals during the growing season. Seedling survival, growth, and needle macronutrient concentration and content were measured at the end of each growing season. Frost heaving was assessed in June of the year following planting. In addition, needle nutrient concentrations and contents were determined after three growing seasons for both stock types for the range of site suitability plots.

SEEDLING GROWTH AND SURVIVAL IN THE OLDER OUTPLANTINGS

In the older outplantings, paperpot stock exceeded mini-plug stock in total height, ground level basal area and stem volume over the first five growing seasons (Fig. 2a-c). By the sixth growing season, however, differences between the two stock types in each of these measures ceased to be significant ($p \geq 0.05$). These results reflected differences in both absolute and relative growth rates between stock types over the establishment period. Annual and cumulative height growth rates were similar ($p \geq 0.05$) for both stock types for all six growing seasons, but relative height growth rates of the mini-plugs consistently exceeded ($p < 0.05$) those of the conventional stock. Annual ground level basal area and stem volume growth of the conventional stock exceeded ($p < 0.05$) that of the mini-plugs over the first five growing seasons, but were no longer significantly different ($p \geq 0.05$) by the sixth growing season. In contrast, relative ground level basal area and stem volume growth of the miniplugs exceeded ($p < 0.05$) that of the paperpots over the first four growing seasons.

Mean seedling survival was not significantly different ($p \geq 0.05$) for the two stock types for all growing seasons except growing season three, during which paperpot survival exceeded mini-plug survival (Fig. 2d).

SEEDLING GROWTH AND SURVIVAL IN THE SITE SUITABILITY PLOTS

On all site types examined, vent block stock consistently demonstrated greater survival, height growth, total basal area, and total volume than mini-plug stock over the first two growing seasons (Table 2). The mini-plugs, however, had greater relative height growth rates over this period than the vent block stock. These results are similar to those for the older outplantings at this stage in plantation development. A comparison of results from site suitability plots with similar site conditions to the older plots (i.e., shallow soils with low competition levels) reveals comparable results for the mini-plugs and better results for the vent block stock in the site suitability plots than in the older plots at this stage of development. However, while the mini-plug averages were similar, the 1992 mini-plugs were considerably lower than, and the 1993 mini-plugs considerably higher than the older plot averages. In contrast, both the 1992 and 1993 vent block plantings exceeded mean values for growth and survival in the older plantings at this stage. Follow-up assessments of the site suitability plots will be required in future years to provide a more meaningful comparison of performance with the older outplantings.

In addition to differences in performance between the two stock types, there were also differences in performance between site types. These differences were more pronounced for the mini-plug stock than the vent block stock, and for the 1992 plots than the 1993 plots.

For the 1992 planting, mini-plug total height, basal area and stem volume after two growing seasons were greater ($p<0.05$) on sites with moderate to heavy competition and coarse loamy soils than on sites with light competition and coarse loamy soils or on sites with very heavy competition and clayey soils (Fig. 3a-c). The vent block stock planted in 1992 showed similar, but less pronounced trends in growth among site types over this period. In contrast, there were no significant differences ($p \geq 0.05$) in seedling survival after two growing seasons among site types for either stock type.

For the 1993 planting, the only significant difference ($p<0.05$) in the performance of either stock type among the different site types was in seedling survival. Greater mini-plug survival occurred on deep, coarse loamy soils than on clayey or very shallow, coarse loamy soils. Vent block survival was poorest on very shallow, coarse loamy soils. Neither stock type demonstrated significant differences in seedling height, basal area or stem volume growth among site types over the first two growing seasons.

A leading contributor to mini-plug mortality for the 1992 plantings was frost heaving. The incidence of severe frost heaving (entire plug heaved) averaged 12 percent for this stock type and ranged from 1–30 percent among soil type-competition level combinations (Fig. 4a). Severe frost heaving of the vent-block stock was less of a problem, averaging 5 percent, but ranging from 1–21 percent among soil type-competition level combinations (Fig. 4b). Heaving was most severe on the very shallow sites and the clayey soils. Severity was related to B horizon soil texture; finer B horizon soil textures were associated with greater amounts of frost heaving. The 1993 plantings suffered little frost heaving: in total only three percent of the mini-plugs and <1 percent of the vent block stock planted in 1993 were severely frost heaved.

Overall, for the two stock types and planting years combined, better seedling height growth over the first two growing seasons was found on sites with moderate to heavy competition and coarse loamy soils than on sites with light competition and coarse loamy soils or on sites with very heavy competition and clayey soils. Second year survival was poorest on sites with light competition and very shallow coarse loamy soils.

CLIMATIC CONDITIONS AND MICROCLIMATE

Total June–August precipitation during the 1992, 1993 and 1994 growing seasons was 90, 125 and 116 percent of 30 year climate normals for this region. Despite the dry to fresh Soil Moisture Regimes associated with these sites (Sims et al. 1989), root zone soil water was usually plentiful throughout both the 1993 and 1994 growing seasons (Fig. 5). Indeed, on the more shallow-soiled sites excess soil water at times may have had a negative impact on tree growth by reducing soil aeration in both years. It is also noteworthy that rainfall in September 1992 was twice that of 30 year normals for this month. This would render soils more susceptible to frost heaving.

In 1993, mean daily soil and air temperatures for a given depth (height) in Bracke scalps usually varied by <1 °C among the three sites. Because of their smaller size and thus shallower planting depth, mini-plugs experienced mean daily soil temperatures about 0.5°C warmer and mean daily maximum soil temperatures about 1.5°C warmer than container stock during the summer. This resulted in a difference of about 60 growing degree days.

SEEDLING PHYSIOLOGICAL RESPONSES

During the first growing season, stomatal conductance and soil-plant liquid flow resistance were consistently higher for the mini-plugs than for the container stock at all three sites (Fig. 6). In contrast, there were few differences in midday twig xylem pressure potential, osmotic potential or turgor loss points for the two stock types. Mean midday twig xylem pressure potentials of the two stock types measured during the summer of 1993 usually varied between -0.8 and -1.2 megapascals (MPa). This was well in excess of the turgor loss points which generally ranged from -1.9 to -2.1 MPa.

FOLIAR NUTRIENT CONCENTRATIONS

After 2–3 growing seasons, the mini-plugs had higher needle concentrations ($p<0.05$) of most macronutrients (nitrogen [N], phosphorous [P], potassium [K], calcium [Ca], magnesium [Mg] and sulphur [S]) than the vent block stock (Fig. 7). However, mean needle weight of the vent block stock was usually greater than that of the mini-plugs. As a result, needle macronutrient contents were usually not significantly different between the two stock types. Large, consistent differences among site types in needle macronutrient concentrations or contents were not evident for most elements.

SILVICULTURAL IMPLICATIONS

Based on the results of these trials, mini-plugs represent a promising regeneration option for reforesting a number of coarse loamy soil types in north-central Ontario. Their small size and rudimentary rooting system make them well-suited for planting on shallow sites; and their lower production costs and comparable performance relative to some conventional stock types 5–6 years after outplanting also make them an attractive option on certain deeper soil types. There is, however, greater risk of frost-heaving associated with mini-plugs. Serious mini-plug frost heaving occurred in 2 of the 6 years of outplanting investigated by the authors.

Somewhat surprisingly, the best results in terms of growth, survival and physiological response over the first two years in the site suitability plots were obtained on site types with moderate to heavy competition. Trends in seedling development on these sites over the next few years, especially their response to competition and weed control, will determine the comparative value and suitability of outplanting mini-plugs on this range of conditions.

Greater mortality and poorer initial growth were associated with very shallow to deep coarse loamy sites with little competition. The most difficult sites for initial establishment of mini-plugs within this landscape complex appear to be the very shallow sites. Finer soil textures and above-average soil water levels during the period of this study likely contributed to the relatively poor performance of mini-plugs on these sites. Results from the older outplantings do, however, clearly indicate that once established, mini-plug seedlings perform reasonably well under these site conditions.

Finally, the results reported here should be viewed within the context of the general climatic conditions prevailing in the area. The location of the Lake Nipigon Forest immediately to the east of Lake Nipigon and to the north of Lake Superior results in moderated drying conditions during the growing season (e.g., relatively low mean daytime temperatures and saturation deficits). Climatic conditions may be more favorable for mini-plug establishment on shallow-soiled upland sites in this region than is generally found in areas west of Lake Superior. In dry years or on dry coarse sandy to fresh fine sandy soil types (NWO FEC S1 and S2) where near-surface soil moisture is limited, mini-plug establishment may be much poorer.

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Table 1. Number of sample plots established in 1992 and 1993, by competition level, stand type, and Northwestern Ontario Forest Ecosystem Classification (NWO FEC) vegetation and soil type. Shown are the number of plots established per soil type and competition level in the site suitability component, and the soil type-competition level combinations studied in the ecophysiology component (ecophys).

		NWO FEC Soil Type			
Competition level	Stand and NWO FEC Vegetation Types	Very Shallow (SS3)	Shallow (SS5-6)	Deep Sandy-Coarse Loamy (S2-S3)	Deep Clayey (S6)
Light	Sb or Sb(Pj) V30, V32, V33	10 Ecophys	10 Ecophys	10	x
Moderate	Sb (Bw/Bf) V19, V20	x	10 Ecophys	10	x
Heavy	Sb (Po/Bw/Bf) V19, V20	x	10	10	10

x Site type not investigated.

Table 2. Survival and growth of mini-plug and conventional stock, two growing seasons after outplanting. Vent block 165 containers are the conventional stock type in the site suitability plots and the 1991 older outplanting plots, whereas Japanese FH-408 paperpots are the conventional stock type in the 1988-1990 older outplanting plots.

Stock Type	Survival (percent)	Cumulative Height Growth (cm)	Basal Area (cm^2)	Stem Volume (cm^3)	Relative Height Growth (cm)
	Site Suitability Plots (all plots combined)				
mini-plug	79	11.8	0.06	0.32	1.5
Vent block	95	17.1	0.21	2.27	0.8
	Site Suitability Plots (shallow soil, low competition)				
mini-plug	72	11.1	0.06	0.37	1.4
Vent block	90	14.7	0.23	2.27	0.7
	Older Outplanting Plots (1988-1991)				
mini-plug	77	10.4	0.07	0.36	1.3
paperpot -vent block	84	9.3	0.18	1.74	0.5

Figure Captions

Figure 1. Comparison of black spruce mini-plug and vent block container stock at the time of outplanting.

Figure 2. Mean seedling height (a), ground level basal area (b), stem volume (c) and survival (d) of black spruce mini-plug and conventional (paperpot and vent block) stock over 6 growing seasons. Seedlings were spring-planted on shallow coarse loamy tills between 1988 and 1991.

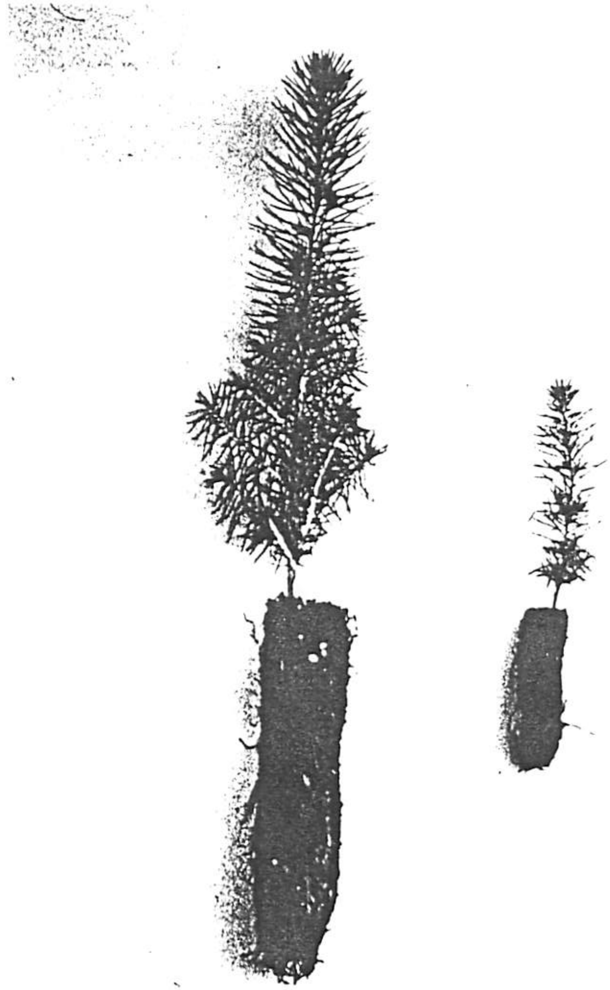
Figure 3. Mean mini-plug seedling height (a), ground level basal area (b) and stem volume (c) by site type after 2 growing seasons, for the 1992 planting. Soil types include very shallow (V. Shal), shallow, deep coarse loamy (Deep-cLo) and deep clayey (Deep-Cl) (Sims et al. 1990).

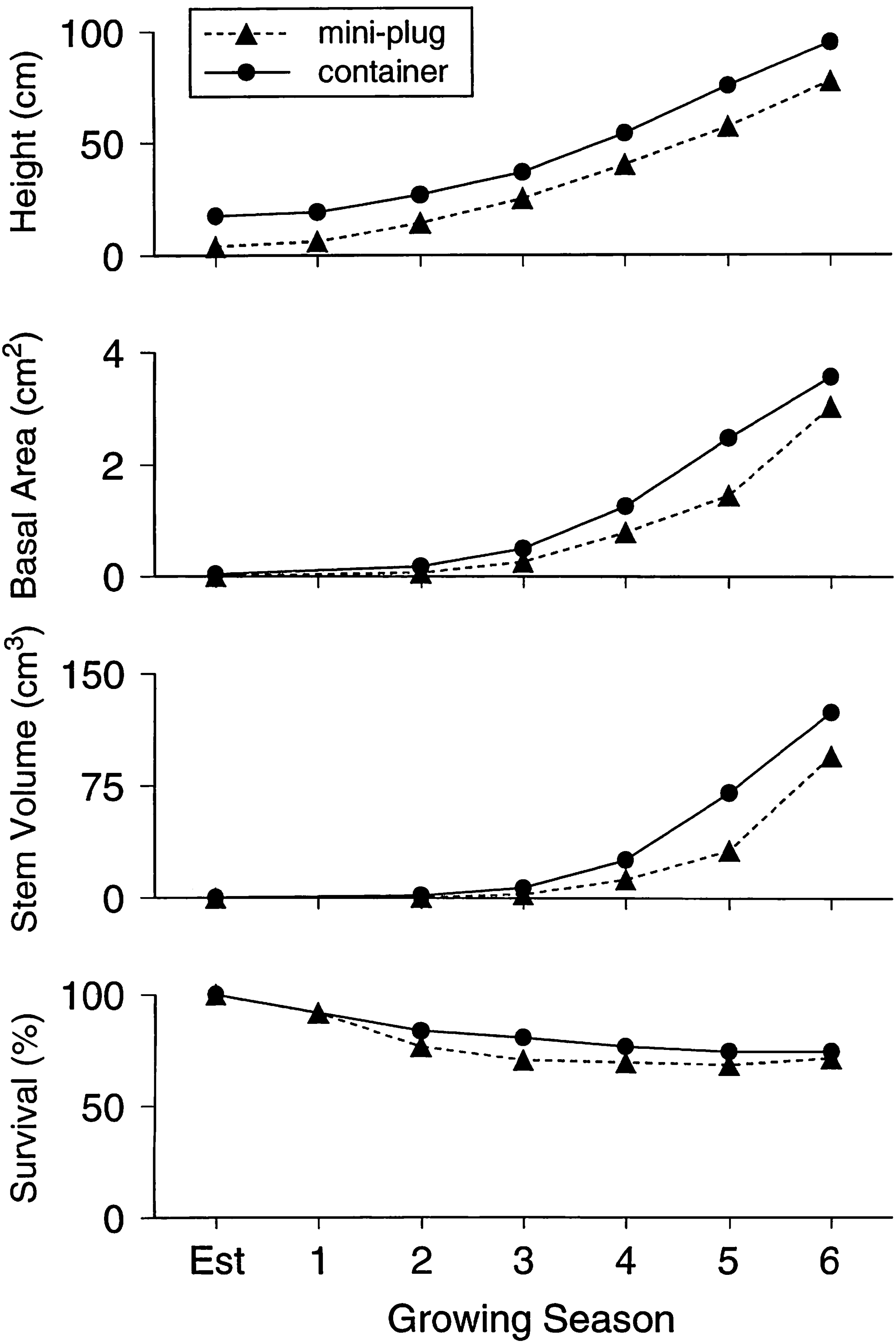
Figure 4. Incidence of severe frost heaving (entire plug heaved) of (a) mini-plugs and (b) vent block stock by site type, for the 1992 planting. Soil types include very shallow (V. Shal), shallow, deep coarse loamy (Deep-cLo) and deep clayey (Deep-Cl) (Sims et al. 1990).

Figure 5. 1993 summertime trends in soil water potential at 15 cm for the very shallow-light competition (SS3), shallow-light competition (SS6C) and moderately-deep-medium competition (SS6M) sites. Also shown is daily precipitation for this same period.

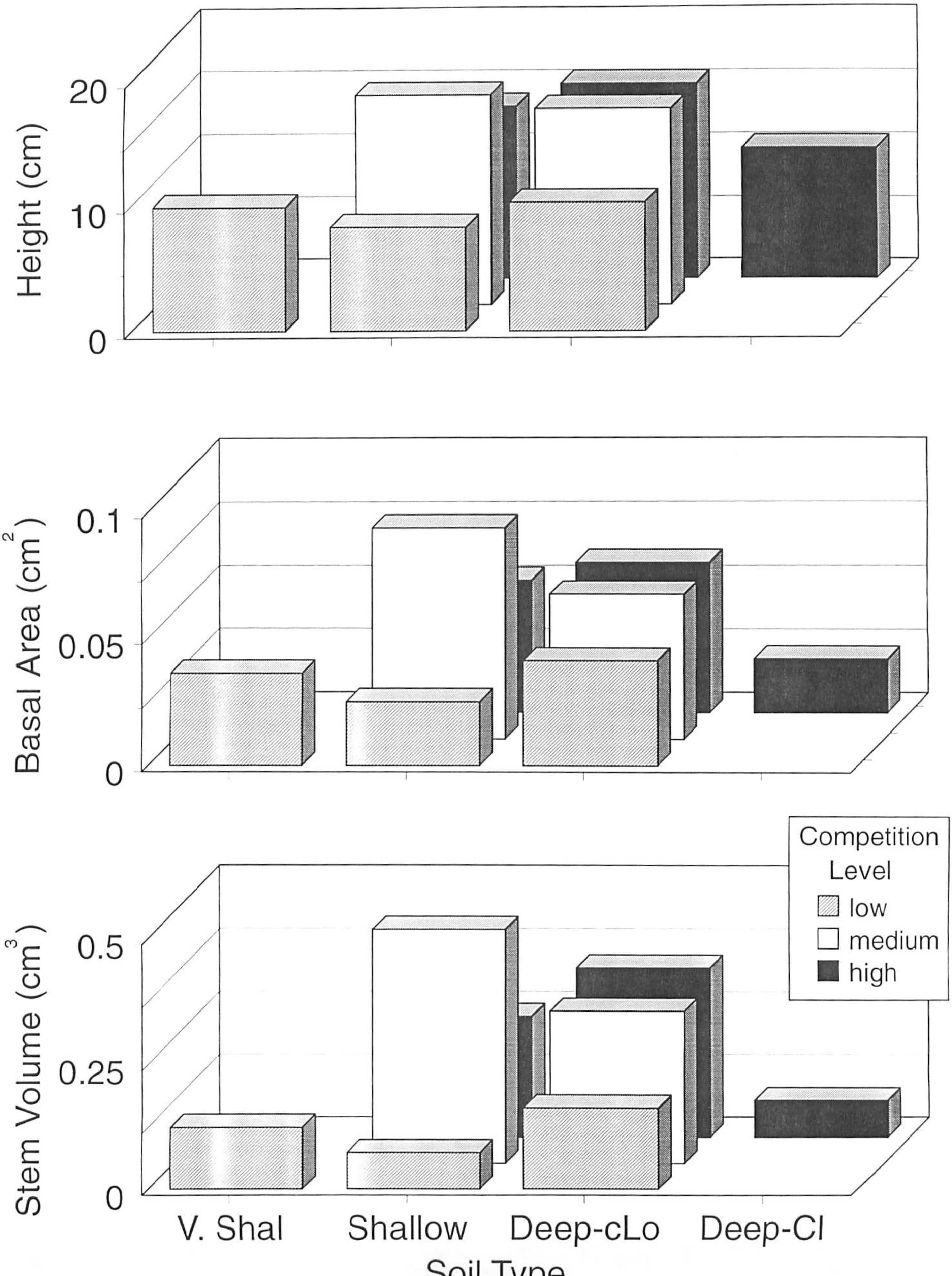
Figure 6. 1993 growing season trends in stomatal conductance of mini-plug and vent block container stock at the shallow-light competition site. Seedlings were planted 5 June 1993.

Figure 7. Mean foliar nitrogen (N), phosphorous (P) and potassium (K) concentrations of mini-plug and vent block container stock after two growing seasons at the three ecophysiology sites. Vertical bars represent standard errors of the mean.

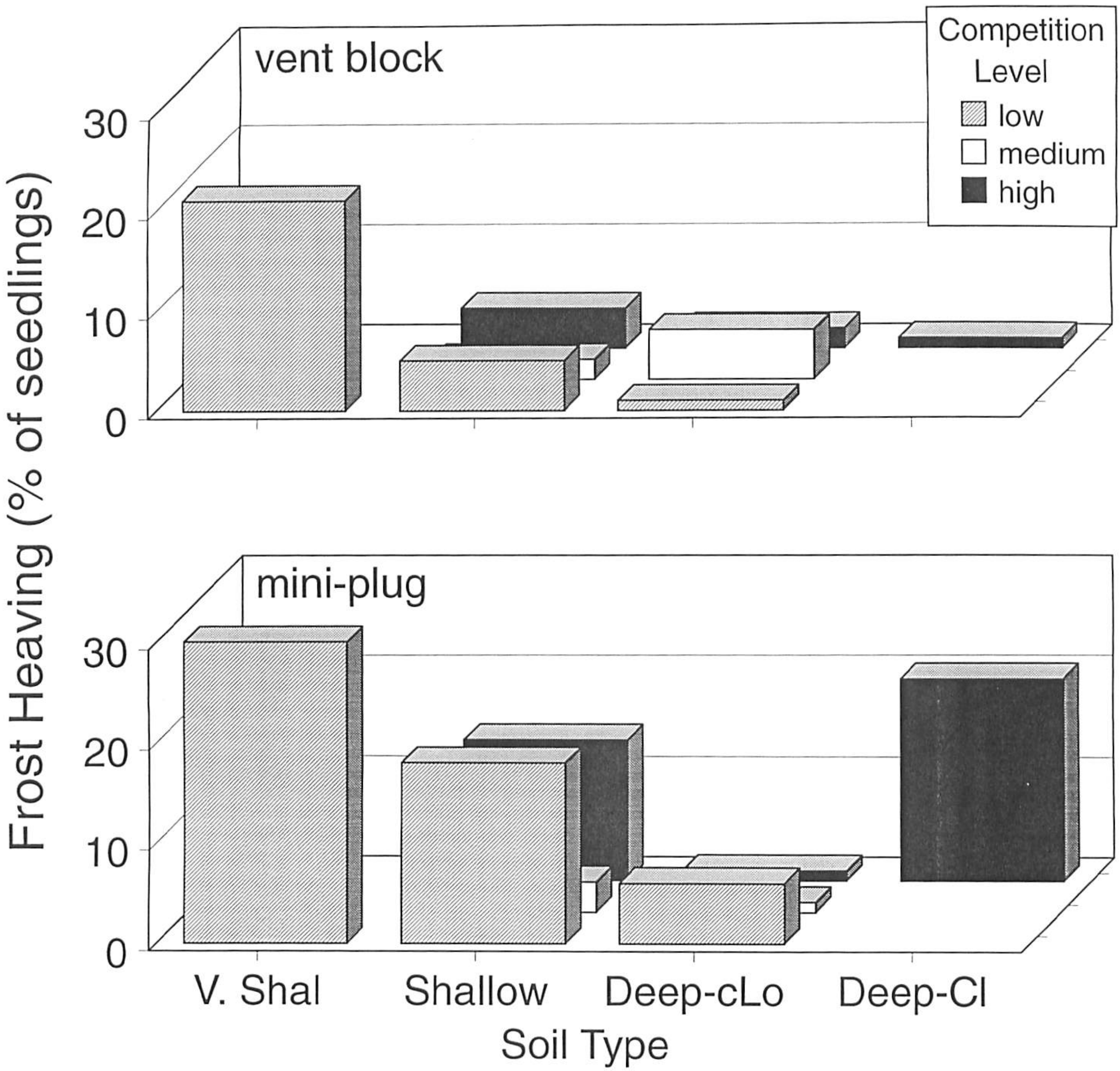




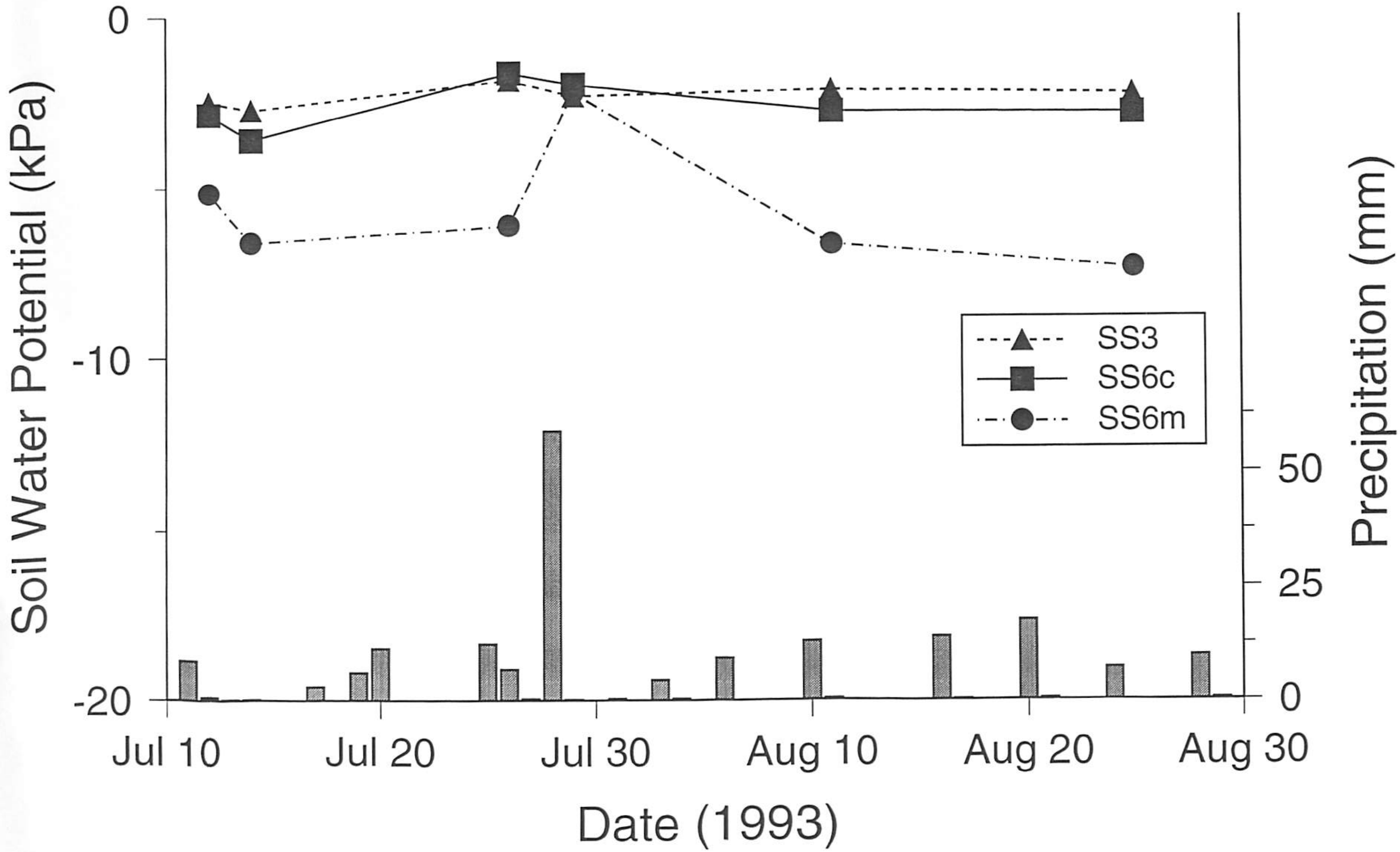
mini-plug
container
Height (cm)
100
50
0
Basal Area (cm2)
4
2
0
Stem Volume (cm3)
150
75
0
Survival (%)
100
50
0
Est
1
2
3
4
5
6
Growing Season



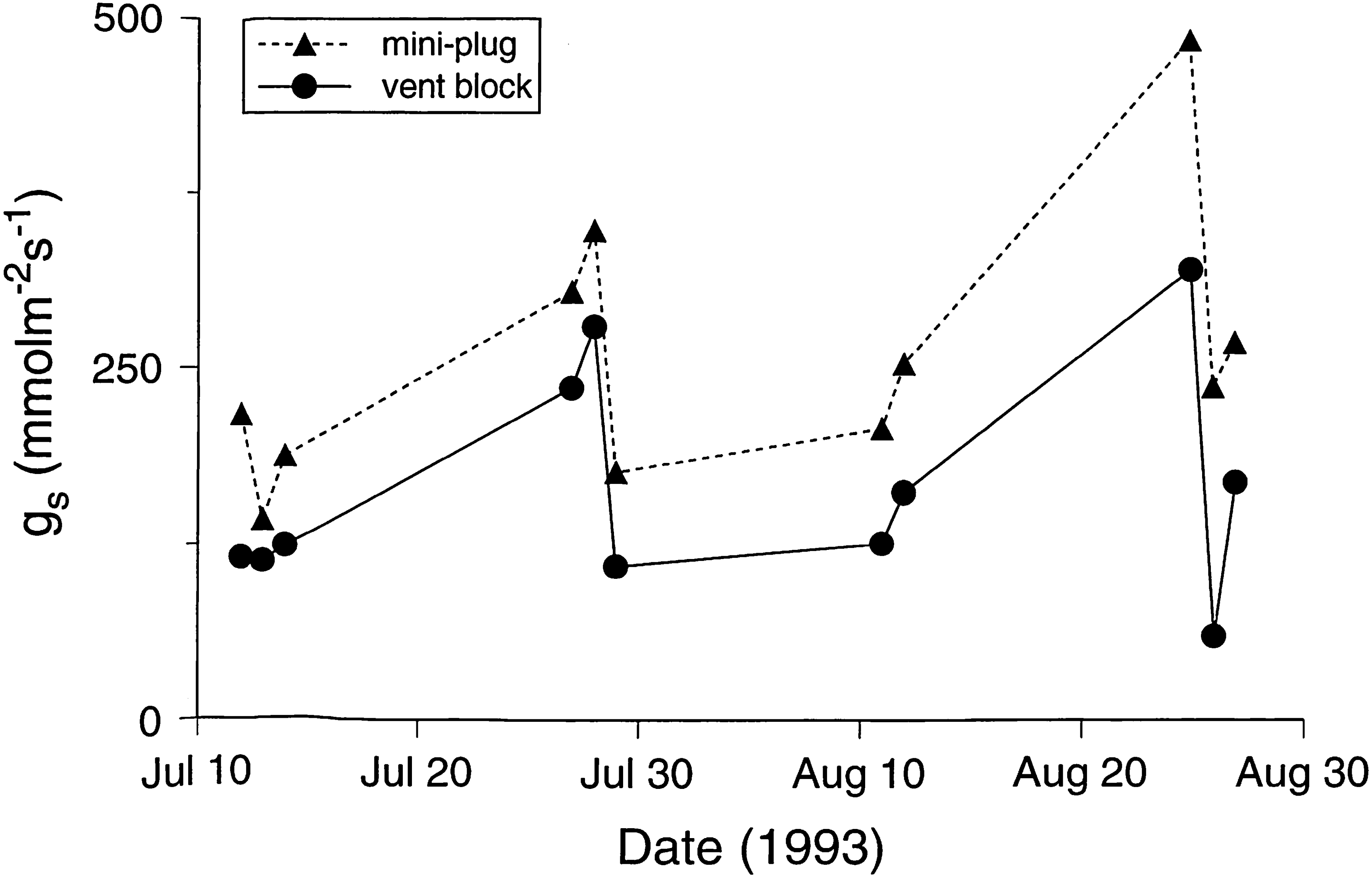
Height (cm)
20
10
0
Basal Area (cm²)
0.1
0.05
0
Stem Volume (cm³)
0.5
0.25
0
Competition Level
low
medium
high
V. Shal
Shallow
Deep-cLo
Deep-Cl
Soil Type



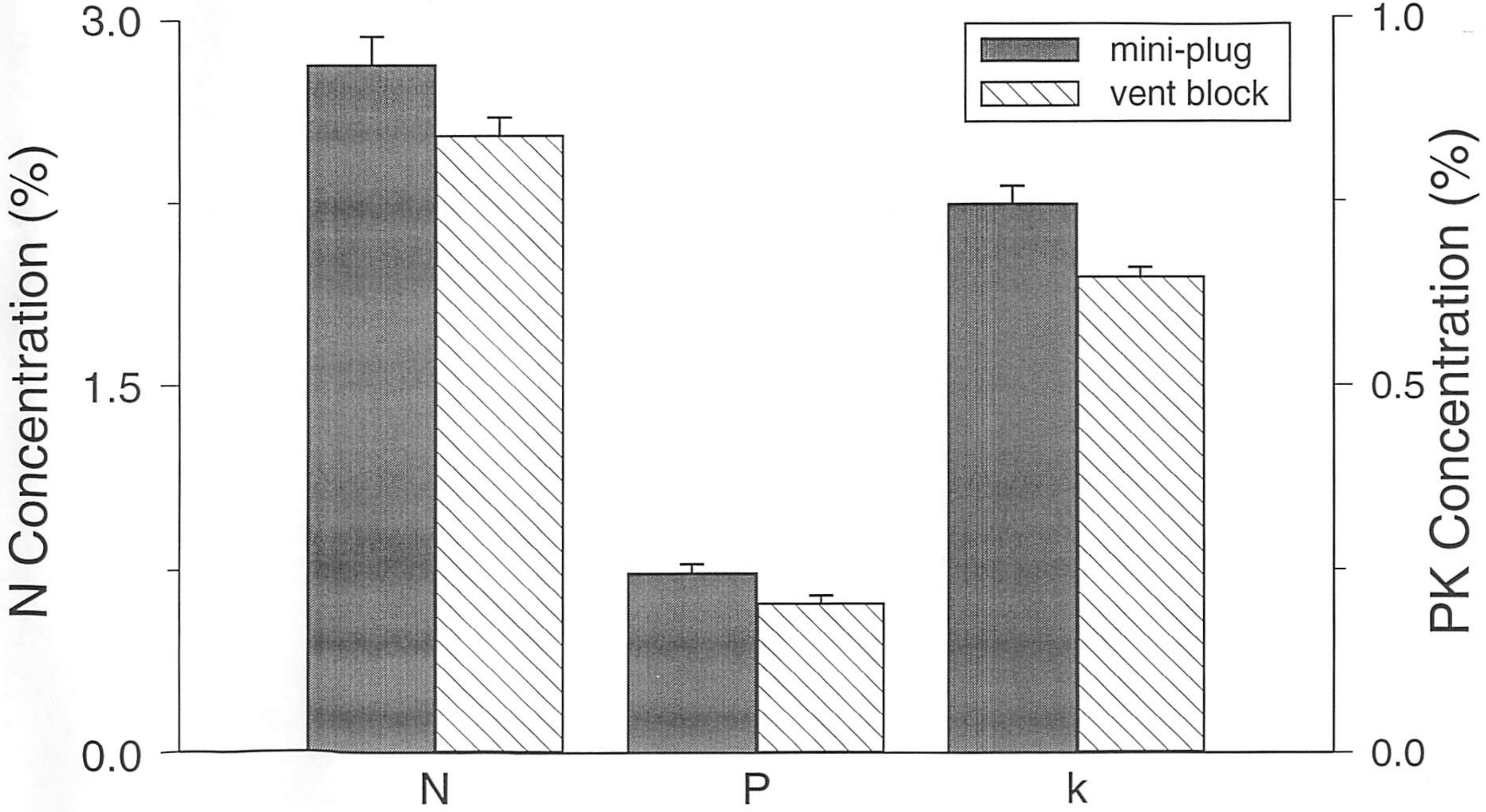
vent block
Competition Level
low
medium
high
30
20
10
0
mini-plug
30
20
10
0
Frost Heaving (% of seedlings)
V. Shal
Shallow
Deep-cLo
Deep-Cl
Soil Type



Soil Water Potential (kPa)
0
-10
-20
Precipitation (mm)
0
25
50
SS3
SS6c
SS6m
Jul 10
Jul 20
Jul 30
Aug 10
Aug 20
Aug 30
Date (1993)



500
250
0
mini-plug
vent block
g_s (mmolm^{-2}s^{-1})
Jul 10
Jul 20
Jul 30
Aug 10
Aug 20
Aug 30
Date (1993)


N Concentration (%)
3.0
1.5
0.0
PK Concentration (%)
1.0
0.5
0.0
mini-plug
vent block
N
P
k