From Forest Nursery Notes, Summer 2008

165. Tree-seedling compost as a component in *Sphagnum* peat-based growing media for conifer seedlings: physical and chemical properties. Veijalainen, A.-M., Heiskanen, J., Juntunen, M.-L., and Lilja, A. Acta Horticulturae 779:431-438. 2008.

Tree-Seedling Compost as a Component in *Sphagnum* Peat-Based Growing Media for Conifer Seedlings: Physical and Chemical Properties

A.-M. Veijalainen[1], J. Heiskanen and M.-L. Juntunen
Finnish Forest Research Institute
Suonenjoki Research Unit
FIN-77600 Suonenjoki
Finland

A. Lilja
Finnish Forest Research Institute
Vantaa Research Unit
P.O. Box 18, FIN-01301 Vantaa
Finland

[1] New address: University of Kuopio, Department of Environmental Science
PO Box 1627, FI-70211 Kuopio, Finland

Keywords: density, forest nursery, germination, nutrients, organic matter, particle-size distribution, water-retention capacity

Abstract

Approximately 150 million forest tree seedlings are delivered for planting annually in Finland. The seedlings affected by plant diseases or pests, or not meeting the quality requirements, as well as the used growing media, weeds, clipped grass and fallen leaves comprise the biodegradable waste formed in forest nurseries. Currently there is an increasing political and economical pressure on minimizing the generation and landfilling of waste materials. A practical solution for forest nurseries would be composting of biodegradable waste on-site, and then using the compost as a component of growing media for seedling production. Before this, the suitability of composted tree-seedling waste for growing media in tree-seedling production needs to be assured. In this study, growing-media mixtures were (by volume): 100% light sphagnum peat (100P), 100% tree-seedling compost (100C) and peat mixtures with 25 or 50% of compost (75P25C and 50P50C, respectively). Particle-size distribution, bulk density, water-retention capacity, particle density, loss on ignition, pH, electrical conductivity, total and plant available nitrogen (N), phosphorus (P) and potassium (K) concentrations, as well as the germination capacity of Norway spruce were studied. The tree-seedling compost was found to have a relatively fine texture and high density compared with peat. These physical properties may lower the air-filled porosity and oxygen-diffusion rate, and thus have a negative effect on the germination and growing in the mixtures with a high compost content. The results indicate that tree-seedling compost has a potential to be used as a minor component in growing media in tree nurseries, although the irrigation and fertilizer requirements need further studies.

INTRODUCTION

Approximately 150 million forest seedlings are delivered for planting annually in Finland. Scots pine (*Pinus sylvestris* L.), Norway spruce (*Picea abies* (L.) Karst.) and European silver birch (*Betula pendula* Roth) are the main tree species produced by forest nurseries. At present, about 95% of the production is container seedlings, the rest being bare-root seedlings (Finnish Forest Research Institute, 2004). If tree seedlings are affected by plant diseases or pests, or not meeting the size and shape requirements, they are discarded before selling. The biodegradable waste produced by nurseries therefore includes discarded tree seedlings and their growing media, as well as weeds, clipped grass and fallen leaves.

Currently there is increasing environmental, political and economical pressure on minimizing the generation and landfilling of wastes. In addition, transportation of biodegradable wastes from one site to another is not good policy, involving energy consumption during transport frequently over long distances in Finland. The Landfill Directive 1999/31/EC encourages composting of biodegradable wastes with the utilization of produced compost for agricultural benefit or ecological improvement. The practical solution for forest nurseries would be to compost biodegradable wastes on-site, and use the composted tree-seedling waste as a component of growing media in the seedling production.

Composting and the use of compost product in horticulture and agriculture have been researched widely (e.g., Gouin, 1977; Haug, 1993; Marfá et al., 2002): such studies have involved the treatment of easily degradable material with a high nitrogen (N) content. Tree-seedling waste, in contrast, has a low N content, and it contains cellulose associated with hemicellulose and lignin as lignocellulose, which is relative resistant to biodegradation and requires relatively long composting time, because lignin serves as a physical and chemical barrier to enzymatic degradation of wood polysaccharides (Eriksson et al., 1990; Kaakinen et al., 2004). Many studies have shown the beneficial effect of compost utilization on greenhouse and nursery-crop production systems (e.g., Fitzpatrick et al., 1998; Bugbee, 2002). However, the composition of the biodegradable waste and composting method will influence the quality of the compost product. In addition, the properties of the growing medium have a special role in container-plant production, where the roots of the plant are restricted to a small volume (Bunt, 1988). The optimal amount of the compost used in container media depends upon the specific plant species to be grown (Wilson et al., 2002). Therefore, the evaluation of the basic chemical and physical properties of the compost is necessary in order to determine the suitability of composted tree-seedling waste as a constituent of growing media in tree-seedling production. The objective of this study was to evaluate these properties of growing-media mixtures of peat and composted tree-seedling waste and the effect of mixtures on the germination of Norway spruce (*Picea abies* (L.) Karst.).

MATERIALS AND METHODS

Growing-media mixtures were prepared volumetrically by hand using a 10 L bucket. The mixtures were peat (P) to compost (C) ratios (%, by volume): 100/0 (100P), 75/25 (75P25C), 50/50 (50P50C) and 0/100 (100C). The peat was unfertilized but limed (2 kg m^{-3}) light sphagnum peat (Finnpeat M02, Kekkilä, Finland). The compost for inclusion in media was taken from a four-year-old (1998–2002) stacked compost made of rejected bare root- and container-tree seedlings (with peat in containers) and weeds at Suonenjoki forest nursery in the Central Finland. The compost medium was sieved through a mesh size of 4 mm before mixing to remove coarse, undegraded woody twigs.

The gravimetric particle-size distribution of mixtures was determined with mechanical dry sieving (Retsch Corp., Germany). The air dried sample of 0.3 dm^3 was sieved through standard sieves of 10, 5, 1 and 0.1 mm diameter for two minutes (Puustjärvi, 1977; Heiskanen, 1993). Bulk density (Db, g cm^{-3}) was determined as the ratio of dry mass (dried at 105°C for 24 hours) to saturated volume (Heiskanen, 1993). Particle density (Ds, g cm^{-3}) was measured using a liquid pycnometer method (Heiskanen, 1992). Total porosity (Tp, by volume) was estimated as (Ds - Db) / Ds. Volumetric water-retention capacity (WRC) of the mixtures was determined at desorption (from -0.1 to -100 kPa) by using a pressure plate apparatus (Soilmoisture Equipment Corp., USA). The test cylinders were filled with a mixture to the same bulk density as the mixture used to fill containers in practice (Heiskanen, 1993).

The amount of organic matter (OM,% DM) of the mixtures was determined as loss of mass on ignition at 550 °C for 3 hours. The pH was measured with a pH meter (model 3020, Jenway, England) at a ratio of 5:1 distilled water to air dried and ground material (by volume). The Electrical conductivity (EC, mS cm^{-1}) was measured using a conductivity meter (Radiometer Copenhagen CDM-80) at the same ratio as the pH.

The total N concentrations of the mixtures were determined with a CHN analyzer (CHN-600, Leco Co, St Joseph, USA), and the total phosphorus (P) and potassium (K) concentrations were determined following dry digestion (550°C, extraction of the ash with 2 M HCl) (Halonen et al., 1983), by inductively coupled plasma atomic emission spectrophotometry (ICP/AES, ARL 3800). Total soluble N was analyzed from the extract of 1 M KCl by flow injection analysis (Quikchem 8000 FIA-analyzer, A83200, Lachat). Plant-available exchangeable K and soluble P were analyzed from the extract of acidic (pH 4.65) 1 M ammonium acetate by inductively coupled plasma atomic emission spectrophotometry (ICP/AES, ARL 3800). The number of germinating Norway spruce seeds was counted 7, 14 and 21 days after sowing (Leinonen, 1998).

The differences in particle-size distribution were tested with multivariate analysis of variance (SPSS 12.0.1 for Windows). Because the sum of the particle fractions within samples is 100%, the five particle-fraction classes were transformed to four new ones prior to analysis to obtain a distribution that is closer to multinormal. Transformations to four new variables were done according to equation: $\ln(y+1)-\ln(x+1)$, where x is 0.1–1 mm fraction and y represents separately other four fractions (Aitchinson, 1986). Multivariate analysis of variance was used to test the differences in WRC between mixtures, using matric potential as repeated factor. The differences in chemical and other physical properties and germination capacity (21 days) between growing-media mixtures were tested by one-way analysis of variance. For each variable, the homogeneity of variances among treatments was tested with Levene's test. Total N and plant-available K concentrations were transformed to reciprocal values and germination data were arcsin transformed before the statistical analysis to equalize variances. Means were compared for significant differences at $p<0.05$ by Tukey's test. The change in Ds, loss on ignition, pH (tested as $[H^+]$) and EC within each growing-media mixture during the growing season was tested by a paired-samples t-test.

RESULTS

The difference in particle-size distribution was significant between growing-media mixtures ($p<0.001$). The particle size in pure compost (100C) was relatively fine as it was dominated by particles <1 mm (>80%). In pure peat (100P), the respective proportion was notably lower (<50%) (Fig. 1). Db increased significantly along with the proportion of compost in the growing medium (Fig. 1). Tp decreased significantly with the increasing proportion of compost in the growing medium (Fig. 2). WRC at desorption differed significantly between mixtures (Fig. 2). Water retention at near saturation (-0.3 kPa) was significantly less in 100C than in media containing peat, which suggests that finer pores predominate within the pore space in this compost (Fig. 2).

During the first growing season in seedling containers (PL-81F, Lännen Plant Systems, Finland), OM as determined by the loss on ignition decreased significantly in all growing-media mixtures except 100P (Fig. 3). The difference between growing-media mixtures remained significant during the growing season. Correspondingly, Ds increased significantly in all other mixtures except in 100P (Fig. 3). In 100C, however, this trend was reversed ($p<0.05$). Overall the pH increased significantly in all mixtures (Fig. 3). EC was initially high in 100C compared to other mixtures ($p<0.05$) (Fig. 3). During seedling growth, the EC slightly increased in 100P and 75P25C, while it decreased significantly in other media ($p<0.001$).

Total N concentration was significantly lower in 100C than in other growing-media mixtures (Table 1). However, the total plant-available N concentration did not significantly differ between 100C, 50P50C and 75P25C. Total P, total K and the plant-available K concentration increased along with the proportion of the compost in the growing medium. Despite that, the plant-available P concentration was the lowest in 100C ($p<0.05$) (Table 1). The germination capacity (21 days) of seeds in 100P, 75P25C and 50P50C was 92, 91 and 90%, respectively. In 100C the germination capacity was significantly lower (76%) than that of the other growing-media mixtures (Fig. 4).

DISCUSSION

The tree-seedling compost was found to have a relatively fine texture and high density compared with peat. In addition, water-retention characteristics suggest that total porosity and the proportion of coarse pores are low. Therefore growing-media mixtures with high compost content have a lower air-filled porosity and thus lower oxygen diffusion rate, which may have a negative effect on root and shoot growth (Bunt, 1988). Correspondingly, the proportion of small pores is high, and thereby the amount of the available water may be low, because the movement of the water from the inner small pores to the outer regions of the particles is slow in growing media with high compost content (Bunt, 1988).

During seedling growth, the peat-containing media tended to become compacted as the Ds increased, most probably due to degradation of the material into smaller particles (Ingram et al., 1991; Heiskanen, 1995). In 100C, however, the trend was reverse, because the daily movement of seedling containers and overhead irrigation caused loss and leaching of minerals, which obviously decreased Ds and slightly increased the loss on ignition (Ingram et al., 1991).

EC was initially high in 100C owing to concentration of the electrolytes during composting (Riviere and Milhau, 1983). During seedling growth, EC clearly decreased in 100C and 50P50C, probably due to leaching after irrigation and nutrient uptake by plants. The possible lack of colloids in the compost with low OM content may have promoted the leaching (Minnich and Hunt, 1979). The rise in pH was probably caused by the presence of bicarbonates in the irrigation water and dissolution of lime in peat-containing media (Bunt, 1988).

The nutrient concentrations were low in all studied growing-media mixtures compared to base-fertilized and limed sphagnum peat (Finnpeat M6, Kekkilä, Finland) commonly used for tree-seedling production in Finland (Juntunen and Rikala, 2001). Therefore, there is a need to optimize the specific level of each nutrient in the studied mixtures prior to or during seedling growth to achieve a balance of essential plant nutrients (Ingestad, 1979). Plant growth is better with balanced nutrient levels even at low fertility (Bunt, 1988). The lower germination capacity of Norway spruce seeds in pure compost cannot entirely be explained by the higher electrical conductivity of the compost, although high salinity has been reported to be detrimental to seed germination and subsequent growth and development (Bunt, 1988). Other factors, such as undetermined toxins, pre-emergence damping-off or higher density together with lower amount of the available water in pure compost may have affected germination and primary root development (Bunt, 1988; Heiskanen and Rikala, 1998).

CONCLUSIONS

The tree-seedling compost used in this study showed potential for use as a minor component of growing media in tree nurseries, although properties of the growing-media mixtures e.g., irrigation and fertilizer requirements need further research. It is evident that the physical and chemical properties of growing media, such as aeration and availability of water and nutrients have a major effect on the growth of seedlings. Physical properties can be improved, e.g., by mixing tree-seedling compost with peat, vermiculite or other material, which provide space for air and water in growing media. Chemical properties can be adapted to optimal conditions by mixing specific level of nutrients to growing media mixture prior to or during seedling growth. On the other hand, there are also alternative uses for the compost, for example landscaping, lawns or as soil conditioners.

ACKNOWLEDGEMENTS

We thank the staff of the Suonenjoki Research Unit and Nursery for their help, the Central Laboratory of the Finnish Forest Research Institute for the chemical analyses and Dr. H. Heinonen-Tanski for her comments on the manuscript. This work was supported by the Foundation for Research of Natural Resources in Finland and Metsämiesten Säätiö.

Literature Cited

Aitchinson, J. 1986. The Statistical Analysis of Compositional Data. Chapman and Hall, London.

Bugbee, G.J. 2002. Growth of ornamental plants in container media amended with biosolids compost. Compost Science & Utilization 10(2):92–98.

Bunt, A.C. 1988. Media and mixes for container-grown plants. Unwin Hyman Ltd, London.

Eriksson, K.-
degradatior
Finnish Forest
Agriculture
Fitzpatrick, G.
ornamental
33(6):941–
Gouin, F.R. 19
sewage slu
Halonen, O.,
Metsäntutk
Haug, R.T. 19
Boca Ratoi
Heiskanen, J.
soil with lic
Heiskanen, J. 1
in tree nurs
Heiskanen, J.
year culturi
Heiskanen, J.
rooting of
16:27–42.
Ingestad, T. 1
seedlings. F
Ingram, D.L.,
ornamental
and Agri. S
Juntunen, M.-
from the sta
Kaakinen, S., J
tissue chen
second grov
Leinonen, K.
dormancy, v
Hakapaino
Marfá, O., Le
between gr
peat-substit
321.
Minnich, J. and
PA, USA.
Puustjärvi, V. 1
Liikekirjapa
Rivière, L.-M.
substrates fo
Wilson, S.B., S
for containe

Eriksson, K.-E.L., Blanchette, R.A. and Ander, P. 1990. Microbial and enzymatic degradation of wood and wood components. Springer-Verlag, Berlin.

Finnish Forest Research Institute. 2004. Finnish Statistical Yearbook of Forestry. STV Agriculture, forestry and fishery 2004:45. Finnish Forest Res. Inst., Vammala.

Fitzpatrick, G.E., Duke, E.R. and Klock-Moore, K.A. 1998. Use of compost products for ornamental crop production: Research and grower experiences. HortScience 33(6):941–944.

Gouin, F.R. 1977. Conifer tree seedling response to nursery soil amended with composted sewage sludge. HortScience 12(4):341–342.

Halonen, O., Tulkki, H. and Derome, J. 1983. Nutrient analysis methods. Metsäntutkimuslaitoksen tiedonantoja 121.

Haug, R.T. 1993. The Practical Handbook of Compost Engineering. Lewis Publishers, Boca Raton.

Heiskanen, J. 1992. Comparison of three methods for determining the particle density of soil with liquid pycnometers. Commun. in Soil Sci. and Plant Analysis 23:841–846.

Heiskanen, J. 1993. Variation in water retention characteristics of peat growth media used in tree nurseries. Silva Fennica 27:77–97.

Heiskanen, J. 1995. Compaction of growth media based on *Sphagnum* peat during one-year culturing of container seedlings. Suo 46:63–68.

Heiskanen, J. and Rikala, R. 1998. Influence of different nursery container media on rooting of Scots pine and silver birch seedlings after transplanting. New Forests 16:27–42.

Ingestad, T. 1979. Mineral nutrient requirements of *Pinus silvestris* and *Picea abies* seedlings. Physiol. Plant. 45:373–380.

Ingram, D.L., Henley, R.W. and Yeager, T.H. 1991. Growth media for container grown ornamental plants. Bulletin 241. Florida Cooperative Extension Service. Inst. of Food and Agri. Sciences, Univ. of Florida. http://edis.ifas.ufl.edu/CN004.

Juntunen, M.-L. and Rikala. R. 2001. Fertilization practice in Finnish forest nurseries from the standpoint of environmental impact. New Forests 21:141–158.

Kaakinen, S., Jolkkonen, A., Iivonen, S. and Vapaavuori, E. 2004. Growth, allocation and tissue chemistry of *Picea abies* seedlings affected by nutrient supply during the second growing season. Tree Physiol. 24:707–719.

Leinonen, K. 1998. *Picea abies* seed ecology: effects of environmental factors on dormancy, vigor and germination. Univ. of Helsinki Dept. of Forest Ecology Publ. 18. Hakapaino Oy, Helsinki.

Marfá, O., Lemaire, F., Cáceres, R., Giuffrida, F. and Guérin, V. 2002. Relationships between growing media fertility, percolate composition and fertigation strategy in peat-substitute substrates used for growing ornamental shrubs. Scientia Hort. 94:309–321.

Minnich, J. and Hunt, M. 1979. The rodale guide to composting. Rodale Press. Emmaus, PA, USA.

Puustjärvi, V. 1977. Peat and its use in horticulture. Turveteollisuusliitto ry. Publication 3, Liikekirjapaino, Helsinki.

Rivière, L.-M. and Milhau, C. 1983. The use of wood waste composts in the making of substrates for container crops. Acta Hort. 150:475–489.

Wilson, S.B., Stoffella, P.J. and Graetz, D.A. 2002. Development of compost-based media for containerized perennials. Scientia Hort. 93:311–320.

Tables

Table 1. Total and plant-available nitrogen (N), phosphorus (P) and potassium (K) concentrations (mg kg^{-1} dry matter) in the growing-media mixtures: 100% peat (100P), 75% peat/25% compost (75P25C), 50% peat/50% compost (50P50C) and 100% compost (100C) before growing season.

Growing medium	Nitrogen (N) (mg kg^{-1} DM)		Phosphorus (P) (mg kg^{-1} DM)		Potassium (K) (mg kg^{-1} DM)	
	Total	Soluble	Total	Soluble	Total	Soluble
100P	8800 ±820a[1]	170 ±10 a	220 ±20 a	55 ±8 a	240 ±10 a	150 ±10 a
75P25C	7220 ±1220 a	160 ±10 ab	470 ±30 b	91 ±4 b	940 ±80 b	450 ±20 b
50P50C	6070 ±1170 a	150 ±20 ab	530 ±30 c	62 ±5 a	1240 ±80 c	500 ±30 b
100C	3080 ±1460 b	150 ±10 b	540 ±30 c	37 ±5 c	1350 ±80 c	560 ±50 c

[1] Different letters indicate significant difference (p<0.05, Tukey's test).

Figures

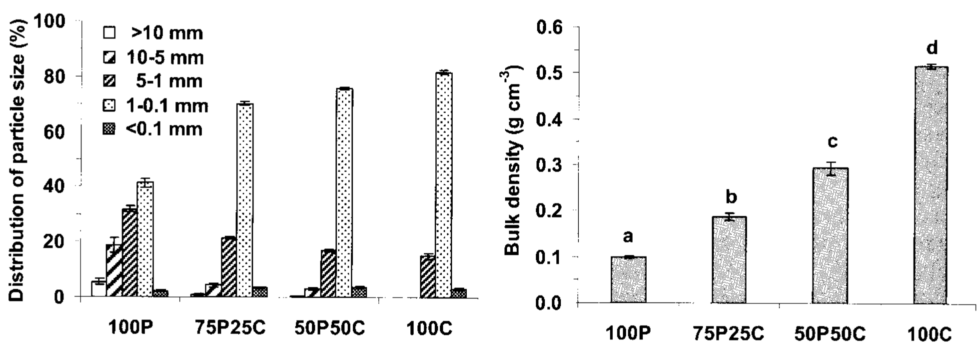

Fig. 1. Mean particle-size distribution (±sd) (n=3) and bulk density (±sd) (n=6) for the growing-media mixtures: 100% peat (100P), 75% peat/25% compost (75P25C), 50% peat/50% compost (50P50C) and 100% compost (100C) before growing season. Different letters indicate significant differences in bulk density (p<0.05 Tukey's test).

Fig. 2. Water-reten
saturation v
season. Tot
in the upper

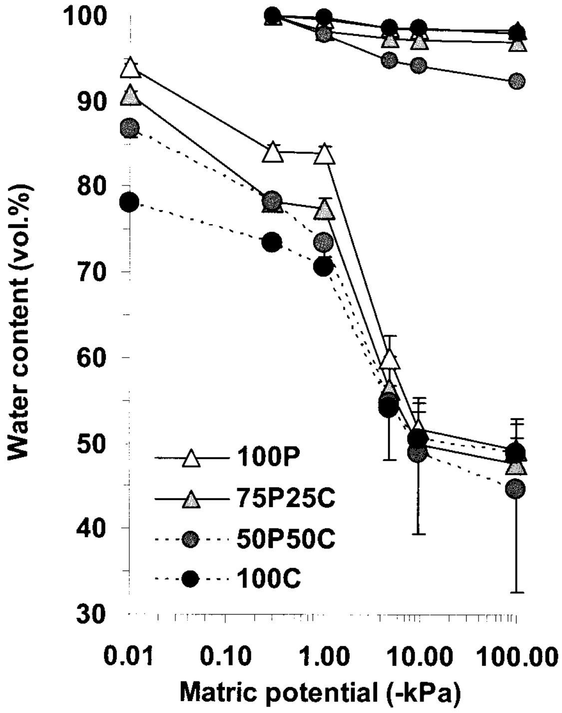

Fig. 2. Water-retention characteristics at desorption (mean+sd) (n=6) in relation to near-saturation volume (at -0.3 kPa) of the growing-media mixtures before growing season. Total porosity plotted at -0.01 kPa. Mean decrease in volume (shrinkage) in the upper (100% at -0.3 kPa).

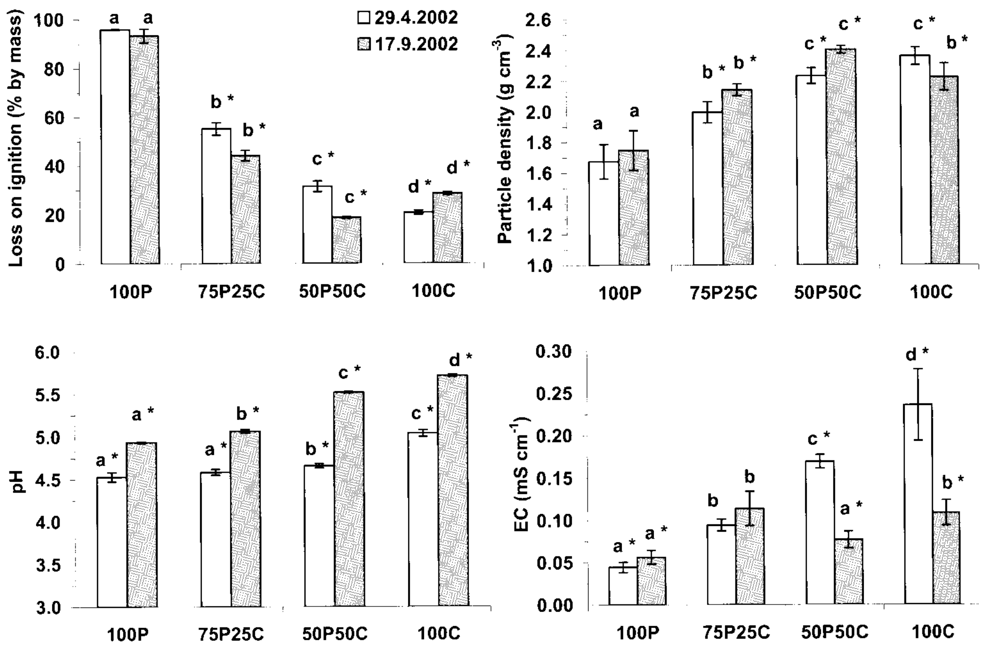

Fig. 3. Means for loss on ignition, particle density, pH and electrical conductivity (EC) (±sd) (n=6) of the growing-media mixtures. Different letters indicate significant differences between growing-media mixtures and asterisks significant differences within variables between seasons (29th April and 17th September) (p<0.05, Tukey's test).

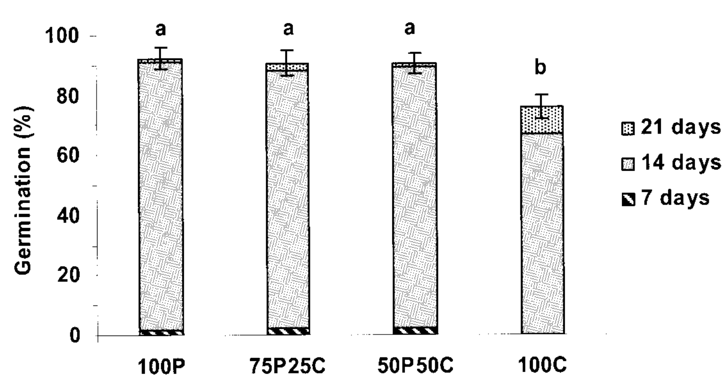

Fig. 4. Cumulative germination of Norway spruce (*Picea abies* (L.) Karst.) seeds (±sd) in the growing-media mixtures during 7, 14 and 21 days. Different letters indicate significant differences (p<0.05 Tukey's test).

Weekly Fr
Load Man

A.M.R. Abde
Department V
National Res
Cairo
Egypt

Y.N. Sassine
Department
Saint Josef U
Beirut
Lebanon

Keywords: s

Abstract
Fluct
common ph
fruits on th
regular wee
(*Capsicum*
controlled c
applied nam
develop to f
were allowe
Data
and small fr
was very st
manipulatio
Fruit yield i
of sweet pep
in MFL con
treatments
climate cond

INTRODU
A ma
1989). Whil
grow on a p
Bann Hofma
factor respo
fruit set als
(*Phaseolus*
tried to use
However, cl
Pruning stra
Uffelen, 198
Bruin, 1993
venient labo
Ther
competition
regularity of

Proc. IS on Grov
Ed.: J.-C. Miche
Acta Hort. 779,