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The Effect of Plug Cell Volume on the Post-transplant Growth for *Impatiens walleriana* Pot Plant

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Summary

The following research was undertaken to determine the effect of propagation container volume on growth of *Impatiens walleriana*, an important bedding plant, at the commercial sale stage. *Impatiens walleriana* 'Accent White' seeds were germinated and grown on four different plastic plug trays (50, 128, 288 and 512 cells per tray). When plants reached the transplant stage, twenty plants for each plug tray were transplanted into 800 cm^3 pot^{-1}. Our results showed that the restrictions imposed on the root system, when plants are grown in smaller plug cell trays, decreased the dry weight accumulation at transplant and sale stages. The changes in the shoot/root ratio at transplant stage may explain the lesser plant growth in the 512 cells plug tray. There were changes in root system characteristics (both main root length and root thickness) and in total porosity at transplant stage. The highest dry weight accumulation in plants from the 50 plugs tray and the relationship with post-sale behaviour was discussed.

Zusammenfassung

Einfluss der Einzeltopfgröße auf das Wachstum von *Impatiens walleriana*. Ziel der Untersuchungen war für *Impatiens walleriana*, einer wichtigen Beetpflanze, im Verkaufstadium die Auswirkung der zur Jungpflanzenkultur verwendeten Topfgröße auf das Pflanzenwachstum zu ermitteln. Saatgut der *Impatiens walleriana*-Sorte 'Accent White' wurde in vier unterschiedlichen Multitopfplatten aus Styropor (50, 128, 288 oder 512 Einheiten pro Platte) ausgesät und kultiviert. Sobald die Pflanzen das Topfstadium erreicht hatten, wurden sie in 800 cm^3-Töpfe getopft. Unsere Ergebnisse zeigten, dass die durch die Kultur in kleineren Topfeinheiten bedingten Beschränkungen des Wurzelsystems, die Trockengewicht-Zunahme der Pflanzen im Topf- und Verkaufsstadium reduzierten. Die Veränderungen des Spross/Wurzel-Verhältnisses im Topfstadium könnten das geringere Wachstum in den 512er-Topfplatten erklären. Im Topfstadium sind Veränderungen in den Wurzelsystem-Eigenschaften (sowohl bei der Wurzellänge als auch der –dicke) und im Gesamtporenvolumen zu beobachten. Die höchste Trockensubstanz-Zunahme in den in 50er-Topfplatten kultivierten Pflanzen und der sich daraus ergebende Einfluss auf das Verhalten der Pflanzen beim Kunden wird diskutiert.

Key words. bedding plant – *Impatiens walleriana* – root restriction – transplant container

Introduction

The plug system for seedling propagation has been adopted in recent years by bedding plant growers to minimize labour costs, increase crop uniformity, and reduce cropping duration. Many growers are specialized in plantlet production in plugs and the time required for seedlings to reach a transplantable size determines greenhouse utilization efficiency and greatly affects production costs. Growing media and container design are two factors that influence plant growth (KEEVER et al. 1985; BILDERBACK and FONTENO 1987). Considerable research has been conducted regarding the development of media with optimal physical properties. It has been suggested that air space values for a given medium cannot be reported accurately without regard for container size (KARLOVICH and FONTENO 1986). RUTER and VAN DER WERKEN (1991) have indicated an interaction between container design and media that influenced water-holding capacity and air space. BILDERBACK and FONTENO (1987) found similar results and noted that growers should consider the container-medium combination as a unit and not as two independent factors. Consequently, reporting physical parameters of container media without recording container design might result in erroneous conclusions.

Plug production is characterized by special plug trays. Vegetable plug growers mainly use larger trays. The smaller the cell size, the more is the plug influenced by fluctuations in moisture, nutrients, oxygen, pH and soluble salts in the soil.

The decision about plug sizes is mainly based on the type of the crop grown, the production time or the schedule. Larger plugs allow to produce a finished plant in a shorter period of time than smaller plugs.

Bedding plant producers progressively adopted containers of reduced plug size, leading to a limited soil

volume available for the root system (STYER and KORANSKI 1997). This choice permits an increasing plant density, but have the disadvantage of root restriction, which may cause considerable changes in plant growth and physiology. Although information on the effect of physical root restriction on plant growth is available for several vegetable species (CARMI and HEUER 1981; KEEVER et al. 1985; KRIZEK et al. 1985; RUFF et al. 1987; CARMI 1995; LIU and LATIMER 1995), respective information is rarely available for ornamental bedding plants (MUGNAI et al. 2000).

The following research was undertaken to determine the effect of the plug volume on growth of *Impatiens walleriana*, an important bedding plant, at the commercial sale stage.

Materials and Methods

Impatiens walleriana 'Accent White' (Goldsmith Ind., USA.) seeds were germinated and grown in plastic plug trays (Blackmore Inc. USA.) listed in Table 1, using a Fafard Germinating Mix® media (Canadian *Sphagnum* peat moss-perlite-vermiculite 70:20:10 v/v).

When plants reached the transplant stage with 4 true expanded leaf pairs, twenty plants for each tray were transplanted into 800 cm^3 pot^{-1} with a Canadian peat-base media.

Plants were harvested at sale stage (twenty replicates); they were dried at 80 °C for 48 hours and weighed. At that, main root thickness and main root length were recorded. For main root thickness measuring a Digimess (0–2,5 mm) micrometer was used.

Samples of the medium were collected at the beginning and the end of the Experiment 2 and porosity were determined according to the methodology and equations suggested by FONTENO (1996). The standard pot used had holes in the bottom that were tape-closed and covered on the inside by nylon screens. The volume of medium was recorded and water was added slowly until the medium was saturated to the surface, and the volume of added water was registered. The tape from the bottom of the container was removed and the drained water was collected for 60 minutes. The wet sample was weighed, then dried and reweighed.

The values from the above procedures were used to calculate total porosity and air-filled porosity using the following equations:

$$\text{Total porosity (\% v/v)} = \frac{\left(\text{wet weight} - \text{dry weight}\right) + \text{drained volume}}{\text{media volume}} \times 100$$

$$\text{Air-filled porosity (\% v/v)} = \frac{\text{drained volume}}{\text{media volume}} \times 100$$

The experiments were repeated twice. Data were subjected to analysis of variance and means were statistically checked by Tukey tests (P=0.05).

Table 1. Cell volume for the plug trays.

Cells per tray	Cell volume (cm^3 $cell^{-1}$)
50	55.70
128	17.37
288	6.18
512	2.50

Results

When *Impatiens walleriana* seeds were germinated and grown in trays of increasing cell number, a significant decrease in dry weight of roots and shoots was only found at the transplant stage for plantlets in trays with 512 cells. A higher shoot/root ratio for a higher number of cells per trays was found, too (Fig. 1).

Plants grown in 800 cm^3 pots showed at the sale stage statistical significant differences, which corresponded to the size of the plug cell used for plantlet production.

The highest total dry weight was found for plants from trays with 50 cells and the lowest total dry weight for plants from trays with 512 cells. These results are mainly related to significant differences in shoot dry

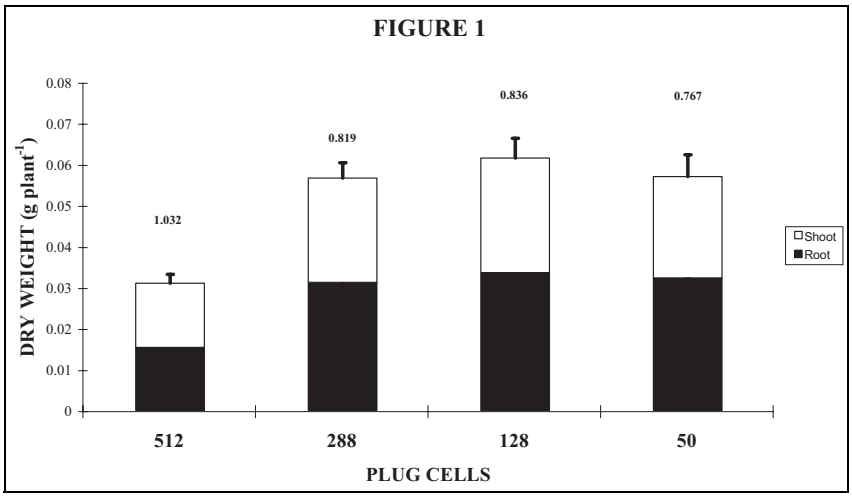


Fig. 1. Total dry weight of *Impatiens walleriana* seedlings propagated in four different plug cell volumes until the transplant stage. Bars are means of twenty replicates and standard errors are indicated. The data on the top of each bar showed the shoot/root ratio.

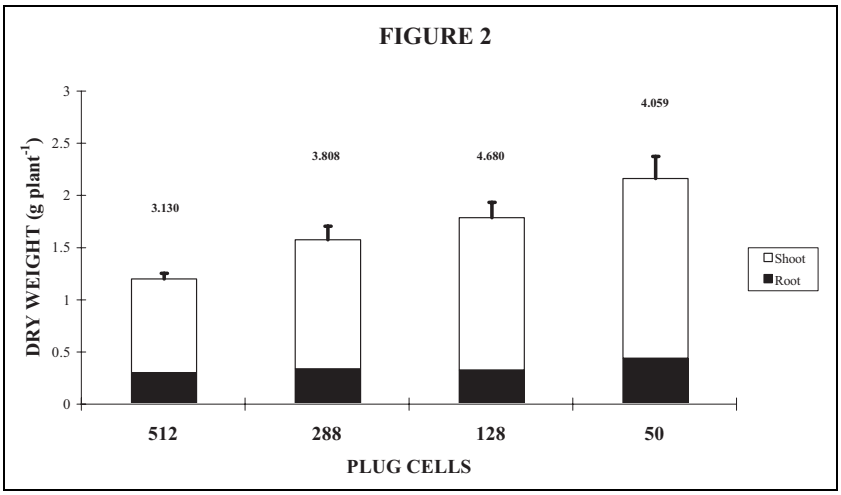


Fig. 2. Total dry weight of *Impatiens walleriana* plants at the sale stage (800 cm^3 pot^{-1}) for plants propagated in four different plug cell volumes. Bars are means of twenty replicates and standard errors are indicated. The data on the top of each bar showed the shoot/root ratio.

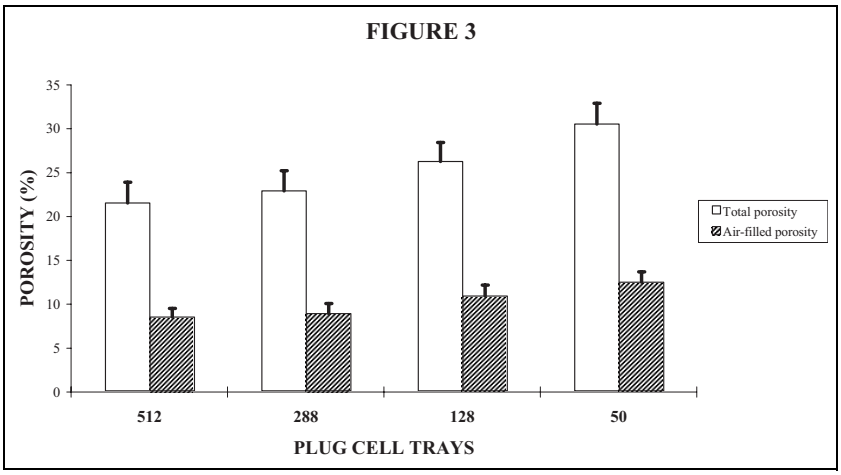


Fig. 3. Effect of four different plug cell trays during propagation on total porosity (%) and air-filled porosity (%) from *Impatiens walleriana* pot plants at the sale stages. Bars are means of twenty replicates and standard errors are indicated.

weight. In addition, higher shoot/root ratios were found for plants from 128 and 50 cells per tray (Fig. 2).

There was a decrease in total porosity of the substrate after eight weeks of growth in plants initially propagated in trays with 512 and 288 cells. Plants from 50 cell trays did not show significant changes in total porosity. A similar patter for the air-filled porosity data was found (Fig. 3).

At the sale stage, the main root length showed lowest means for plants propagated in 512-cell plug tray. On the other hand, plants transplanted from trays with 128 and 50 cells showed the highest main root thickness (Table 2).

Discussion

The primary function of a container is to provide a discrete space for the growth medium. This restricted space also affects the physical conditions of the medium (WHITE and MASTALERZ 1966; HEISKANEN 1993). Balancing the air and water content in media is one of the biggest problems facing plug growers. Plug cells have two basic problems: they may be too short and too small.

Root restriction is a physical stress imposed on a root system when plants are grown in small containers (DREW 1983; BUGBEE and FRINK 1986; VEEN 1988). This situation leads to a pronounced decrease in both root and shoot growth of the plants as we have shown from data plotted in Fig. 1. Although it has been well established that root stress induced by volume reduction, severely suppresses shoot growth (CARMI and HEUER 1981; RUFF et al. 1987), the physiological and biochemical processes involved are largely unknown.

Processes suggested to be involved in this growth reduction include inhibition of leaf elongation (PETERSON et al. 1991), changes in water content (TSCHAPLINSKI and BLAKE 1985; HAMEED et al. 1987), photosynthesis (ISMAIL and NOOR 1996), dry matter partitioning and nutrient uptake (BAR-TAL and PRESSMAN 1996), and hormone metabolism (CARMI and HEUER 1981; PETERSON et al. 1991, CARMI 1995; LIU and LATIMER 1995).

The mechanism of reduced plant growth in response to root restriction is still unclear. In these experiments, plants were monitored frequently to prevent drought stress, since the different plugs dried at different rates. There was no visual evidence of nutrient deficiency in any of the containers. KRIZEK et al. (1985) reported that inadvertent drought stress in small root volumes was not necessarily responsible for reduced shoot growth and that nutrient distribution was not affected by root restriction. Therefore, water and nutrient stress were not considered to be determinants of plant size in our research.

Information on the effect of physical root restriction on ultimate plant performance is not available for

Table 2. Changes in both main root thickness and main root length of *Impatiens walleriana* pot plant at the sale stage (800 cm^3 pot^{-1}) for plants propagated in four different plug cell volume.

cells per tray	Main rootthickness (μm)		Main root length (cm)	
	mean	standard error	mean	standard error
512	570.35 a	48.13	29.41 b	1.01
288	540.63 a	45.94	32.96 a	2.17
128	671.88 ab	61.22	34.09 a	1.78
50	648.75 b	43.23	36.78 a	3.78

*A different letter following the mean indicates a significant difference (P=0.05).

ornamental bedding plants. Of particular interest is the performance of plants that are stunted by a limited root volume, which was the case for those grown on 512 cell plug trays (Fig. 1).

When the shoot/root ratio at transplant stage was less than 1.0 (Fig. 1), the reserves available were invested to expand new leaves, which through an increasing export of photoassimilates let to higher rates of growth. This would be an alternative explanation for the higher dry weight accumulation observed in plants from plugs trays of 288, 128 and 50 cells plotted in Fig. 2.

The container size determines the volume of medium available for root growth. Root volume in the plug tray affects shoot growth, but not necessarily subsequent plant performance. Although transplant size was reduced by smaller root volumes, marketable yields of broccoli or cauliflower were not reduced (DUFAULT and WATERS 1985). Tomato (GORSKI and WERTZ 1985; WESTON and ZANDSTRA 1986) and pepper (WESTON 1988) transplants grown in small-volume containers were smaller at the time of field planting and had reduced early yields, but total yields were unaffected. Our results for *Impatiens walleriana* are not in agreement with these results. Fig. 2 showed that the stress imposed to root growth during the propagation stages determines a reduced increase in total dry weight after transplanting. GORSKI and WERTZ (1985) have reported that eggplant yields increased with increasing container size in agreement with our data.

Vegetable transplants were grown in relatively large cells. The smaller the cells, the greater the chance of the plants of being overwatered or underwatered. LATIMER (1991) has reported that the performance of marigold appears to be more sensitive to root restriction or transplant size than the most vegetable species. The same hypothesis would be fit for *Impatiens walleriana* in this research.

The physical properties of substrates initially considered appropriate for plant growth may deteriorate upon aging due to several processes. These processes generally result in decreased pore sizes. As pore size decreases, total porosity and air-filled porosity decreases too. This was true for plants grown from 512, 288 and 128 cells per tray, but not for plants from 50 cell trays (Fig. 3). On the other hand, the effect of root growth after transplanting could reduce the decrease in total porosity and air-filled porosity imposed by media compaction.

The higher main root length and main root thickness at the sale stage (Table 2) found for plants previously grown in 50 cell plug trays could be the result of the higher total porosity. These results are in agreement with LAMAIRE (1989), who has found that the structure of root systems is a result of the environment surrounding it and gives information on the effects related to changes in water and air availability for root growth.

Although the physiological and biochemical processes involved are largely unknown, it is clear that the change in root system morphology which probably include higher suberisation rate of roots under volume root restrictions when small cell plug trays were used for propagating ornamental bedding plants, could let explain this results.

Pot plant quality and maximum longevity is determined during production. Crop quality must be at the highest level when the plant leaves the production facilities. Quality often declines and longevity is decreased during transport, storage, and retail handling as plants are exposed to adverse transport conditions, such as exclusion of light in closed containers. Although the production factors affecting post production quality of flowering potted plants have been studied (NELL et al. 1997; DRUGE 2000) there is few research that includes the influence of cell plug tray on the post-transplant dry weight accumulation until the sale stage.

In summary, the only way to be economically competitive in the future is to decrease our costs and to increase our efficiency but it does not mean necessarily to use more cells per tray and smaller cells for *Impatiens walleriana* pot plant propagation in plugs. Optimisation for cell tray volume depends on the type of crop grown for ornamental bedding plants and is the subject for future research.

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