HortTechnology October-December 1998 8(4)

The Effect Of Container Size

D. Scott NeSmith[1] and John R. Duval[2]

ADDITIONAL INDEX WORDS. seedlings, pots, pot size, cell size, root restriction, transplant flats, greenhouse production, seedling trays

SUMMARY. Transplants for both vegetable and floral crops are produced in a number of various sized containers or cells. Varying container size alters the rooting volume of the plants, which can greatly affect plant growth. Container size is important to transplant producers as they seek to optimize production space. Transplant consumers are interested in container size as it relates to optimum post-transplant performance. The following is a comprehensive review of literature on container size, root restriction, and plant growth, along with suggestions for future research and concern.

Several factors influence transplant production and performance. This workshop reviews much of the research in this area to date. While factors are discussed individually, it is imperative to remember that few of these factors will act independently to influence transplant quality and performance. In fact, the transplant production process involves optimizing the many factors that govern both seedling production and post-plant performance. McKee (1981a, 1981b) provides a comprehensive review of components affecting transplant production and establishment, including effects of various container sizes or soil volumes. This review will focus on research from the past two decades concerning the effect of container size on transplant production and field performance. Discussions of other transplant topics will be minimized, as they will be discussed by others in accompanying review articles.

The issue of container size is extremely important to both transplant producers and transplant consumers. A trend among many commercial transplant producers is toward more cells per tray (smaller containers), which increases the number of plants produced, while reducing the need to develop more transplant production space (Vavrina, 1995). This trend also reduces propagation costs per plant, since production costs are directly related to container size and type (Dufault and Waters, 1985; Marsh and Paul, 1988). While the use of smaller containers may improve the efficiency of transplant production, it is unclear how plants grown in smaller root volumes will perform under postplant field conditions. A major effect of decreased container size is that it increases root restricting conditions experienced by transplants.

Plants undergo many physiological and morphological changes in response to reduced rooting volume, which can affect transplant quality and performance. Root and shoot growth, biomass accumulation and partitioning, photosynthesis, leaf chlorophyll content, plant water relations, nutrient uptake, respiration, flowering, and yield all are affected by root restriction and container size. Plant responses to reduced soil volume have been reported for a wide range of crops with some conflicting data among them. There are differences in responses reported between species and even between cultivars within a species.

In general, as container size increases plant leaf area, shoot biomass and root biomass increase (Cantliffe, 1993). Growth rates of shoots and roots are interdependent (Tonutti, 1990). Roots rely upon plant aerial portions for photosynthates and various hormones, while plant aerial portions rely on the roots for water, nutrients, support, and hormones. The delicate balance between roots and shoots can be upset when the root system is restricted in a small rooting volume. The resulting imbalance can have short term, as well as long term, effects on plant growth.

Optimal transplant root growth depends on favorable soil or media conditions including water, fertility, and the physical rooting environment (Leskovar et al., 1990). Transplants with relatively large root systems generally suffer less post-plant shock and thus come into production earlier than plants with small root systems (Weston and Zandstra, 1986). Container grown plants in general have a different root morphology than field seeded crops. For example, restricting tomato *(Lycopersicon esculentum L*) roots results in a loss of Primary roots and an increase in the number of lateral roots (Peterson et al., 1991a). Transplanted watermelons (Citrulluslanatus(Thumb.) Matsum & Nakai) had decreased taproot dominance and in some instances no taproot at all (Elmstrom, 1973). These alterations in root morphology may be more pronounced with smaller container sizes

[1] Associate professor, Department of Horticulture, Georgia Experiment Station, Griffin, GA 30223
[2] Graduate research assistant, Department of Horticulture, Georgia Experiment Station, Griffin, GA 30223

and could predispose plants to drought stress since a significant reservoir of soil water resources goes unexplored. When root restricted seedlings are planted in the field they are often unable to compensate for evapotranspiration even if they are well watered after transplanting (Aloni et al., 1991). Root restriction can mimic the effect of soil moisture stress even when there is sufficient soil moisture for normal plant growth (Krizek et al., 1985).

When roots are confined in a container that restricts their growth, the roots compete for essential resources. Increased root mass and decreased rooting space leads to competition for available oxygen (Peterson et al., 1991b). Container geometry and media selection also have a pronounced effect on soil moisture content and aeration. In general, as container height and width are decreased the amount of media pore space decreases, reducing both media water holding capacity and aeration (Bilderback and Fonteno, 1987). Increasing the root mass in the container further reduces the amount of pore space.

Shoot growth is greatly impacted by varying container size and root restriction. Shoot height and biomass reduction in small containers have been reported for tomato (Peterson et al., 1991a), marigold *(Tagetes erecra L.)* (Latimer, 1991), muskmelon (Cucu*mis melo* var. reticulatus) (Maynard et al., 1996), and watermelon (Hall, 1989; Liu and Latimer, 1995). Hall (1989) also noted that the rate of vine growth was greater in plants grown in larger cells than in smaller ones once transplanted to he field. Liu and Latimer (1995) found that shoot growth reductions in watermelons could occur as soon as 4 to 5 d after seedling emergence depending on container size. Increases of top biomass for burford holly (Ilex cornuta Lindl. & Paxton), euonymus (Euonymus *japonica* Thunb.), and azalea *(Rbododendron x* sp.) were linearly correlated with increasing pot size as noted by Keever et al. (1985). Euonymus (Eu*onymus kiautschovica* Loes.) grown in large containers had a higher mean relative growth rate than those grown in smaller containers (Dubik et al., 1992). Branching or lateral shoot growth of plants has been shown to decrease due to root restriction in bell pepper *(Capsicum annuum* L.) (NeSmith et al., 1992), salvia *(Salvia splendens*F. Sellow ex Roem & Schult.) (van Iersel, 1997), and soybean (Gly*cine max* L.) (Krizek et al., 1985). Larger container sizes resulted in an increase in the amount of dry matter present in stems of tomato (Kemble et al., 1994) and soybean (Krizek et al., 1985) when compared to smaller containers. Marigold transplants from small cells did not grow as well as those transplants from larger cells when transplanted to an unrestricted soil volume (Latimer, 1991).

The effect of container size and root restriction on leaf growth has been documented for bell pepper (Weston, 1988; NeSmith et al., 1992), marigold (Latimer, 1991), euonymus (Dubik et al., 1992), soybean (Krizek et al., 1985), cabbage *(Brassica oleracea* L. Capitata Group) (Csizinszky and Schuster, 1993), tomato (Weston and Zandstra, 1986), watermelon (Liu and Latimer, 1995), salvia (van Iersel, 1997), and squash *(Cucurbitapepo* L.) (NeSmith 1993a, 1993b). In all cases, as rooting volume decreased, less leaf area was produced. The reduction in leaf area was due to both smaller and fewer leaves per plant.

Reduced plant biomass under root restricting conditions could possibly be due to a lower photosynthetic rate; although, few container size or root restriction experiments have measured photosynthetic rate. Although, few container size or root restriction experiments have measured photosynthetic rate. Whole-plantphotosynthetic rate decreased with increased root restriction in bell pepper, as did leaf photosynthetic rate, although to a lesser degree (NeSmith et al., 1992). The decline in leaf photosynthetic rate in bell pepper in response to decreased rooting volume was coupled with reduced leaf chlorophyll content (NeSmith et al., 1992). In contrast, no reduction in soybean photosynthetic rate was observed in response to root restriction (Krizek et al., 1985). Summer squash (NeSmith, 1993a and 1993b) and salvia (van Iersel, 1997) net assimilation rate were reduced by prolonged root restriction.

Biomass distribution has been shown to differ with container size for some species, while it remains rather constant as container size changes for other species. In root restricted euonymus, 46% of assimilates were partitioned into the main stem compared to 21 % for the control group, with no difference in partitioning to the root system of the plants (Dubik et al., 1990). Krizek et al. (1987) found that root restricted tomato preferentially partitioned assimilates to the roots and decreased partitioning to the leaves. Both root and shoot biomass of salvia increased linearly with container volume (van Iersel, 1997). Total plant biomass decreased in bell pepper and squash with increased root restriction, but there was no disproportional biomass allocation to leaves, stems, or roots (NeSmith et al., 1992; NeSmith, 1993a). Root and shoot biomass were both reduced for watermelon transplants as cell size decreased, although root-to-shoot ratio remained constant (Liu and Latimer, 1995).

Plant development can be influenced by container size and increased or prolonged root restriction. The flowering period was reduced due to increased root restriction in tomatoes (Peterson et al., 1991a). As rooting volume increased, the time from sowing to anthesis was shortened for tomato (Kemble et al., 1994, Ruff et al., 1987) and salvia (van Iersel, 1997). Also, a delay in fruit maturation was shown for root restricted tomatoes (Ruff et al., 1987). In contrast, root restriction resulting from small containers did not have an influence on duration of flowering or time to anthesis in summer squash (NeSmith, 1993a). In bell pepper increased root restriction decreased the time necessary to begin and halt flowering (NeSmith et al., 1992). Root restriction has been viewed as a possible means to accelerate flowering and harvest of cotton (*Gossypium hirsutum*L.*)* (Ruff et al., 1987).

Many morphological and physiological responses of plants to varying container sizes and root restricting conditions have been reported. However, of most concern to the end user of the transplant is the post-plant performance of the seedlings. Of particular concern is crop yield resulting from transplants grown in different container sizes. Varying transplant container size has shown mixed results on harvested yield. No reduction in yield was shown for watermelon (Hall, 1989; Vavrina et al., 1993), pepper (Bar-Tal et al., 1990), broccoli *(Brassica oleracea L.* Italica Group) (Dufault and Waters, 1985), and cauliflower *(B. oleracea L.* Botrytis Group) (Dufault and Waters, 1985) with regard to container size used for transplant production. However, yields were increased in tomato (Weston and

Zandstra, 1986), cauliflower (Csizinszky and Schuster, 1988), cabbage (Marsh and Paul, 1988), watermelon (Liu and Latimer, 1995), muskmelon (Maynard et al., 1996), and bell pepper (Weston, 1988) as transplant container size increased, Marigold flower cover was increased for plants transplanted from larger cell trays (Latimer, 1991). Nicola and Cantliffe (1996) indicated that yield and earliness of lettuce *(Lactuca sativa L.)* was more related to growing season and soil type than to transplant quality resulting from various container sizes. Differing observations between yields of species and cultivars in response to transplant container size have not been thoroughly explained.

Contradictory evidence and differing responses between species and cultivars in response to rooting volume suggest a need for further experimentation. It is difficult to optimize transplant production with regard for both the propagator and the end user without such information. Reducing transplant container size generally increases the probability of root restriction, but the length of time a plant remains in the container is also a major factor to be considered. Determining when root restriction occurs, along with the identification of the consequences of prolonged restriction, is important in developing improved transplant production systems. Transplant age, a topic to be discussed elsewhere, must be considered when selecting cell sizes for production units. One goal for the transplant industry could be to develop production systems that minimize the time in which plants are under root restricting conditions. Continued experimentation on the interaction of container size, transplant age, and other factors is needed. Experiments need to particularly measure crop performance following transplanting (i.e., vegetable yield, bedding plant flower coverage, ornamental plant longevity) as this will ultimately govern acceptance of transplants by consumers. Research integrating economics into transplant production and performance would be beneficial in developing optimum production systems for both the transplant producer and consumer.

Literature cited

Aloni, B., L Daie, and L. Karni. 1991. Water relations, photosynthesis, and assimilate partitioning in *leaves of* pepper *(Capsicum annuum)* transplants: Effect of water stress after transplanting. J. Hort. Sci. 66:75-80.

Bar-Tal, A., B. Bar-Yosef, and U. Kafkafi. 1990. Pepper transplant response to root volume and nutrition in the nursery. Agron. J.82:989-995.

Bilderback, T.E. and W.C. Fonteno. 1991. Effects of container geometry and media physical properties on air and water volumes in containers. J. Environ. Hort. 5:180-182.

Cantliffe, D.J. 1993. Pre- and postharvest practices for improved vegetable transplant quality. HortTechnology 3:415-417.

Csizinszky, A.A. and D.J. Schuster. 1988. Impact of insecticide schedule, N and K rates, and transplant container size on cauliflower yield. Applied Agr. Res. 3:12-16.

Csizinszky, A.A. and D.J. Schuster. 1993. Impact of insecticide schedule, N and K rates, and transplant container size on cabbage yield, HortScience 28:299-301.

Dubik, S.P., D.T. Krizek, and D.P. Stimart. 1990. Influence of root zone restriction on mineral element concentration, water potential, chlorophyll concentration, and partitioning of assimilate in spreading euonymus (E. kiautschovica Loes. 'Sieboldiana'). J. Plant Nutr. 13:677-699.

Dubik, S.P., D.T. Krizek, D.P. Stimart, and M.S. McIntosh. 1992. Growth analysis of spreading euonymus subjected to root restriction. J. Plant Nutt. 15:469-486.

Dufault, R.J. and L. Waters, Jr. 1985. Container size influences broccoli and cauliflower transplant growth but not yield. HortScience 20:682-684.

Elmstrom, G.W. 1973. Watermelon root development affected by direct seeding and transplanting. HortScience 8:134-136.

Hall, M.R. 1989. Cell size of seedling containers influences early vine growth and yield of transplanted watermelon. HortScience 24:771-773.

Keever, G.J., G.S. Cobb, and R.B. Reed. 1985. Effect of container dimension and volume on growth of three woody ornamentals. HortScience 20:276-278.

Kemble, J.M., J.M. Davis, R.G. Gardner, and D.C. Sanders. 1994. Root cell volume affects growth of compact- growth -habit tomato transplants. HortScience 29:261-262.

Krizek, D.T., A. Carmi, R.M. Mirecki, F.W. Snyder, and J.A. Bruce. 1985. Comparative effects of soil moisture stress and restricted root zone volume on morphogenetic and physiological responses of soybean (Glycine max (L.) Merr.). J. Expt. Bot. 36:25-38.

Latimer, J.G. 1991. Container size and shape influence growth and landscape performance of marigold seedlings. Hortscicnce 26:124-126.

Leskovar, D.I., D.J. Cantliffe, and P.J. Stoffella. 1990. Root growth and rootshoot interaction in transplants and direct seeded pepper plants. J. Expt. Bot. 30:249354.

Liu, A. and J.G. Latimer. 1995. Root cell volume in the planter flat affects watermelon seedling development and fruit yield. HortScience 30:242-246.

Marsh, D.B. and K.B. Paul. 1988. Influence of container type and cell size on cabbage transplant development and field performance. HortScience 23:310-311.

Maynard, E.T., C.S. Vavrina, and W.D. Scott. 1996. Containerized muskmelon transplants: Cell volume effects on pretransplant development and subsequent yield. HortScience 31:58-61.

McKee, J.M.T. 1981a. Physiological aspects of transplanting vegetables and other crops. I. Factors which influence reestablishment. Hort. Abstr. 51:265-272.

McKee, J.M.T. 1981b. Physiological aspects of transplanting vegetables and other crops. II Methods used to improve transplant establishment. Hort. Abstr. 51:355368.

NeSmith, D.S., D.C. Bridges, and J.C. Barbour. 1992. Bell pepper responses to root restriction. J. Plant Nutr. 15:2763-2776.

NeSmith, D.S. 1993a. Influence of root restriction on two cultivars of summer squash (Cucurbita *pepo* L.). J. Plant Nutr. 16:421-431.

NeSmith, D.S. 1993b. Summer squash response to root restriction under different light regimes. J. Plant Nutr. 16:765-780.

Nicola, S. and D.J. Cantliffe. 1996. Increasing cell size and reducing medium compression enhance lettuce transplant quality and field production. HortScience 31:184-189.

Peterson, T.A., M.D. Reinsel, and D.T. Krizek. 1991a. Tomato *(Lycopersicon esculentum* Mill. cv 'Better Bush) plant response to root restriction. Alteration of plant morphology. J. Expt. Bot. 42:1233-1240.

Peterson, T.A., M.D. Reinscl, and D.T. Krizek. 1991b. Tomato *(Lycopersicon esculentum* Mill. cv 'Better Bush') plant response to root restriction. Root respiration and ethylene generation. J. Expt. Bot. 42:1241-1249.

Ruff, M.S., D.T. Krizek, R.M. Mirecki, and D.W. Inouye. 1987. Restricted root zone volume: Influence on growth and development of tomato. J. Amer. Soc. Hort. Sci. 112:763-769.

Tonutti, P. and C. Giulivo. 1990. Effect of available soil volume on growth of young kiwi plants. Acta Hort. 282:283-294.

van Iersel, M. 1997. Root restriction effects on growth and development of salvia *(Salvia splendens).* HortScience 32:11861190.

Vavrina, C.S. 1995. An introduction to the production of containerized vegetable transplants. Univ. of Florida, Gainesville, Coop. Ext. Serv., Bul. 302.

Vavrina, C.S., S. Olsen, and J.A. Cornell. 1993. Watermelon transplant age: Influence on fruit yield. HortScience 28:789790.

Weston, L.A. 1988. Effect of flat cell size, transplant age, and production site on growth and yield of pepper transplants, HortSciencc 23:709-711.

Weston, L.A. and B.H. Zandstra. 1986, Effect of root container size and location of production on growth and yield of tomato transplants. J. Amer. Soc. Hort. Sci. 111:498-501.