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Effect of container size on the growth and development of tomato seedlings

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A B S T R A C T

Seedlings growth and development of tomato (*Lycopersicon esculentum* L.) as influenced by various container size was evaluated at Botswana University of Agriculture and Natural Resources (formerly Botswana College of Agriculture) from March-April 2015. Propagation containers with different cell sizes (volumes of 18.5 cm^3, 65 cm^3 and 170 cm^3 being treatments) were used. The experiment was laid as a completely randomized design (CRD) with four repetitions. Tomato seedlings were grown in a net shade house of 80%. The following growth and development parameters were recorded; plant height, leaf number and area, and shoot fresh and dry weights. Data was subjected to analysis of variance (ANOVA). Plant height showed a non-significant ($p>0.05$) difference in response to treatments in the first three weeks followed by a highly significant ($p<0.01$) response in the fourth week. The latter response was revealed for leaf number and area, and shoot fresh and dry weights except for a significant ($p<0.05$) response in week two for leaf number. Generally bigger (170 cm^3) cells significantly enhanced the performance of the seedlings as compared to smaller (18.5 cm^3) cells. As a result the bigger cells are recommended as the most desirable containers for quality seedlings.

Introduction

Tomato (*Lycopersicon esculentum* L.) is one of the most cultivated vegetable food crop in most regions of the world, ranking second in importance to potatoes (*Solanum tuberosum* L.) (Anastacia *et al.*, 2011; FAO, 2015). It is a member of the Solanaceae family, which includes chilli peppers, bell peppers, eggplant, Irish potato and tobacco (Heuvelink, 2005). Tomato seedlings are usually grown in controlled environments structures such as greenhouses and growth chambers using containers of different cell sizes. The containers are required to hold the growing medium (Ray and Sinclair, 1998) and container sizes are key components for the growth and survival of seedlings. Container size has a huge effect on plant growth and it may affect root and shoot growth, biomass accumulation and partitioning, photosynthesis, leaf-chlorophyll content, plant water relations, nutrient uptake, respiration and flowering (Al-Menaie *et al.*, 2012). Physiological

experiments are sometimes conducted in controlled environments where plants are grown in containers with limited soil volume. A well-recognized problem with growing plants under these conditions is the possibility that the plants may become root bound. Numerous studies have shown a general reduction in growth associated with small container sizes (Kratky *et al.,* 1982; Peterson *et al.,* 1984; Robbins and Pharr, 1988; Cantliffe, 1993; Townend and Dickinson, 1995; Whitfield *et al.,* 1996; NeSmith and Duval, 1998; Schrader, 2000; Al-Menaie *et al.,* 2012). These reductions in growth have been shown to occur in both solid media as well as in hydroponic nutrient solution. On a positive note, according to Schrader (2000), smaller containers or cells reduce production costs.

The effect of container size and root restriction on leaf growth has been documented for several crops; soybean (Krizek *et al.,* 1985), tomato (Weston and Zandstra, 1986), bell pepper (Weston, 1988), marigold (Latimer, 1991), euonymus (Dubik *et al.,* 1992), squash (NeSmith, 1993), cabbage (Csizinszky and Schuster, 1993), watermelon (Liu and Latimer, 1995) and salvia (Van Iersel, 1997). In all cases, as rooting volume decreased, leaf area also decreased. Shoot growth is greatly impacted by varying container size and root restriction. Reduction in shoot growth and biomass as a result of small containers has been reported for tomato (Peterson *et al.,* 1991), marigold (Latimer, 1991), watermelon (Hall, 1989; Liu and Latimer, 1995) and muskmelon (Maynard *et al.,* 1996). 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 the field.

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. The issue of container size is extremely important for transplant producers as they seek to optimize production space with smaller sized containers whereas consumers are interested in larger sized containers as it relates to optimum post-transplant performance. A trend among many commercial transplant producers is towards more cells per tray (smaller containers) which increases number of plants produced and reduce production costs (Schrader, 2000) while reducing the need to develop more transplant production space (NeSmith and Duval, 1998). Moreover, the plant's adaptation to transplanting and its ability to reestablish normal growths quickly in the field are important considerations when determining the most desirable cell size.

Other than varying sizes of containers or cells tomato productivity is also influenced by transplants management. Vavrina and Orzolek (1993) in a review of tomato transplant age noted that transplants quality is affected by numerous factors such as water supply, fertilization and substrate used. Therefore if no limitations are imposed on seedling management container size remain an important factor for consideration. Seedling trays are available locally with varying cell size and/or volume; therefore it is up to the grower to choose the best container to produce strong and vigorous transplants. If it calls for few cells per container (large containers) then more than one container could be used to produce more seedlings and vice versa. Despite the wide uses of containerized tomato seedlings and the need for more cells per container, information on how container size affect transplant growth and development of tomato seedlings is still considerably limited hence the need for the study reported in this paper.

Materials and methods

Experimental site

The study was conducted in a 80% net shade house at the Botswana University of Agriculture and Natural Resources (BUAN) formerly Botswana College of Agriculture, Sebele campus. Sebele is located between latitude 24°33'S and longitude 25°54'E at an elevation of 994 m above sea level.

Experimental design and planting

A completely randomized design (CRD) with three treatments repeated four times was used. The three treatments were plastic seedling containers [WEBCO (Pty) Ltd., Gauteng, South Africa; www.webcotools.co.za] of varying cell sizes or volumes of 18.5, 65 and 170 cm^3. Tomato seeds (rodade variety) were sown in seedlings containers filled with hygromix [Hygrotech (Pty) Ltd., Pretoria North, South Africa; www.hygrotech.co.za].

Cultural practices

Seedlings were watered in the morning and afternoon throughout the duration of the study. Water soluble multifeed P ® 5:2:4 (43) (Plaaskem (Pty) Ltd., Witfield, South Africa) fertilizer was applied once weekly after development of true leaves to boost the seedlings. Seedlings were also scouted daily for incidences of pests and diseases.

Measured parameters

Measurements of leaf number and plant height were collected weekly after development of true leaves on eight pre-determined and tagged seedlings in the middle of the seedling tray from each repetition until termination of experiment. Plant height was measured using a 30 cm ruler from the base to the terminal leaf. At termination of experiment, 10 plants were randomly sampled and their leaf area was measured using leaf area meter- A3 light-box (Delta-T Devices Ltd, Cambridge, England). All tagged seedlings were harvested and placed into weighing brown paper bag for determination of fresh and dry weights using an electronic balance- PGW 4502e (Adam®, Smith-Hamiltom, Inc., Miami Florida, US; www.adamequipment.com). The samples were oven dried to constant weight at 80°C using a hot air oven- Scientific Series 2000[Laval Lab, Inc., Laval (Quebec), Canada; http://lavallab.com].

Data analysis

Data was subjected to analysis of variance (ANOVA) using Analytical Software (2003). Where a significant F-test was used and means comparison tests carried out using Least Significant Difference (LSD) at $p \leq 0.05$.

Results and Discussion

Plant height

A non-significant ($p>0.05$) treatment effect was revealed in weeks 1 to 3 whereas a highly significant ($p<0.01$) treatment effect was revealed in week 4. Bigger cells (170 cm^3) followed by 65 cm^3 significantly increased the plant height as compared to the smaller cells (18.5 cm^3) (Table 1).The significant difference in plant height across the treatments is attributed to the varying container or cell sizes. This in line with the previous findings (Kratky *et al.*, 1982; Peterson *et al.*, 1984; Robbins and Pharr, 1988; Cantliffe, 1993; Townend and Dickinson, 1995; Whitfield *et al.*, 1996; NeSmith and Duval, 1998; Schrader, 2000; Al-Menaie *et al.*, 2012) who concluded that a reduction in container cell size increased the potential of root restriction and reduction

in plant growth is associated with small container size. According to Robbins and Pharr (1988) container size has been shown to affect a number of physiological processes including nutrient efficiency and photosynthesis rates although the relationship between photosynthesis rate and container size has not been consistent. Reduction in container cell size limits resources such as nutrients, available growth medium and space for roots to spread and as such root restriction will result in reduced plant growth.

Leaf number

There were significant ($p<0.05$) treatment differences revealed from weeks 2 to 4 in both leaf number and area. Containers with bigger (170 cm^3) cells significantly increased the leaf number and area as compared to the ones with smaller (18.5 cm^3) cells (Table 2). These significant differences are attributed to varying container cell sizes. Elsewhere, studies revealed positive and negative results for different crops with increase in rooting volume and vice versa respectively (Krizek *et al.*, 1985; Weston and Zandstra, 1986; Weston, 1988; Latimer, 1991; Dubik *et al.*, 1992; Csizinszky and Schuster, 1993; NeSmith, 1993; Liu and Latimer, 1995; Van Iersel, 1997). It is evident that reduction in container cell size led to reduced space for roots to spread which affect the uptake of available minerals from the growth medium and indirectly affecting other physiological processes such as photosynthesis and respiration (Robbins and Pharr, 1988). Leaves present the plant assimilation system necessary for photosynthesis upon which a plant can develop its vegetative mass.

Shoot (fresh and dry) weights

Shoot (fresh and dry) weights were significantly ($p<0.01$) affected by varying container sizes with the highest fresh and dry weights recorded for transplants grown in 170 cm^3 cells followed by 65 cm^3 and 18.5 cm^3 cells respectively (Table 3). These significant differences are attributed to varying container sizes and the consequences of the previous parameters (plant height, leaf number and area) which were significant throughout the study. Shoot growth is greatly impacted by varying container size and root restriction.

Table.1 Effect of container size on tomato plant height (cm)

Container size	Plant height (weeks after development of true leaves)			
	Week 1	Week 2	Week 3	Week 4
Cell size-18.5 cm^3	4.53	11.34	22.84	23.67^c
Cell size-65 cm^3	4.20	10.63	26.22	28.87^b
Cell size-170 cm^3	4.37	9.95	24.82	33.56^a
Significance	ns	ns	ns	**
LSD (0.05)	ns	ns	ns	4.46
CV (%)	7.11	6.03	11.26	7.78

** Highly significant at $p<0.01$, ^{ns} non-significant at $p>0.05$. Means separated by Least Significant Difference (LSD) Test at $p\leq0.05$, means within columns followed by the same letters are not significantly different.

Table.2 Effect of container size on tomato leaf number and leaf area (cm^2)

Container size	Weeks after development of true leaves				
	Leaf number				Leaf area
	Week 1	Week 2	Week 3	Week 4	Week 4
Cell size-18.5 cm^3	2	2.71^{b}	3.21^{b}	4.73^{b}	34.96^{c}
Cell size-65 cm^3	2	3.25^{ab}	4.96^{a}	5.21^{b}	75.48^{b}
Cell size-170 cm^3	2	3.58^{a}	5.21^{a}	6.88^{a}	196.26^{a}
Significance	-	*	**	**	**
LSD (0.05)	-	0.59	0.92	1.02	3.58
CV (%)	-	9.26	10.36	9.07	1.75

** Highly significant at $p<0.01$, * significant at $p<0.05$. Means separated by Least Significant Difference (LSD) Test at $p\leq0.05$, means within columns followed by the same letters are not significantly different.

Table.3 Effect of container size on tomato shoot (fresh and dry) weights

Container size	Shoot weight	
	Fresh weight (g)	Dry weight (g)
Cell size-18.5 cm^3	5.13^{c}	0.25^{c}
Cell size-65 cm^3	11.96^{b}	1.00^{b}
Cell size-170 cm^3	19.63^{a}	1.33^{a}
Significance	**	**
LSD (0.05)	0.71	0.17
CV (%)	2.19	9.68

** Highly significant at $p<0.01$. Means separated by Least Significant Difference (LSD) Test at $p\leq0.05$, means within columns followed by the same letters are not significantly different.

Shoot height and fresh weights reduction in small containers has been reported for tomato (Peterson *et al.*, 1991) and other crops elsewhere (Hall, 1989; Latimer, 1991; Liu and Latimer, 1995; Maynard *et al.*, 1996). Moreover, consistent reports elsewhere concluded that large differences existed in shoot dry weights for varying container sizes (Peterson *et al.*, 1984; Robbins and Pharr, 1988; Townend and Dickinson, 1995; Whitfield *et al.*, 1996). According to NeSmith *et al.*, (1992), reduced plant weights under root restricting conditions could possibly be due to a lower photosynthetic rate; although, few container size or root restriction studies have measured photosynthetic rate.

In conclusion, Bigger (170 cm^3) cells enhanced tomato seedlings growth and development with respect to plant height, leaf number and area, and shoot fresh and dry weights. This signifies that for quality seedlings, bigger containers are the most desirable.

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