

# Effect of cultivar, root container size and temperature on days to flower and number of leaves before flowering in tomato

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## Abstract

Seedlings of three tomato cultivars, 'Reika', 'Marryroad' and 'First Power' were grown in either pots or plug trays in order to clarify the interaction effect of cultivar and root container size on the number of days to flowering and the number of leaves preceding the first inflorescence under different temperature regimens. The number of days to flowering was greater in seedlings raised in plug trays than those in pots, regardless of temperature regimen. Flowering was delayed at 23/18°C compared with 30/25°C for seedlings raised in either pots or plug trays. The number of leaves preceding the first inflorescence was greater in seedlings raised in plug trays than those in pots, except for 'Marryroad' at 23/18°C. Regardless of root container size, the number of leaves preceding the first inflorescence was greater in 'First Power' than in 'Reika' and 'Marryroad' at 30/25°C. These results suggest the importance of cultivar choice for the production of tomato seedlings with a small number of leaves preceding the first inflorescence using plug trays in cool conditions.

**Key words:** *Lycopersicon esculentum* Mill., plug tray, root restriction, temperature

## Introduction

Currently, some farmers harvest tomato fruits only from the first truss, or from the first to the third trusses, in order to transplant tomato seedlings at a high density in glasshouses several times a year. This cultivation method is effective for increasing yearly yield, although it requires a large number of transplants. The raising of seedlings using plastic plug trays reduces the cost of transplants because it requires a small amount of artificial growth media, and many operations such as seeding, water supply and transplantation can be mechanized. Therefore, seedlings raised in plug trays are commonly used in such a high-density cultivation method. However, transplants raised in summer exhibit spindly growth, especially transplants raised in plug trays, because of high temperatures and low light intensity caused by mutual shading.

A smaller number of leaves preceded the first inflorescence under low temperatures at the early stage of development, lead to an increase in early yield (Wittwer and Teubner, 1956; Calvert, 1957). The number of leaves preceding the first inflorescence in tomato seedlings usually increases in summer due to high temperatures (Oda *et al.*, 2005). Therefore, seedlings raised in summer come into flower later than those in other seasons, leading to reductions in early yields. To overcome this problem, Oda *et al.* (2005) proposed that tomato seedlings raised in plug trays in highlands should be transported to lowlands in the summer.

There are many studies about the effect of root container size on the growth and yield of tomatoes. Small container size was found to restrict growth and delay flowering in tomatoes (Knavel, 1965; Weston and Zandstra, 1986). However, little is known about the interaction effects of cultivar, temperature, and root container size on the number of leaves preceding the first inflorescence and the days to flowering. Here, we studied the number of leaves

preceding the first inflorescence and the days to flowering when three different cultivars of tomato seedlings were raised in either pots or plug trays under different temperature conditions.

## Materials and methods

Seeds of tomato plants (*Lycopersicon esculentum* Mill. cvs. 'Reika', 'Marryroad' and 'First Power') were sown in either plastic pots (15 cm in diameter) or plug trays with 128 cell packs in glasshouses on 27 October 2005. Temperatures in the glasshouses were maintained at 23/18°C or 30/25°C (day/night temperatures) and shifted between 5 a.m. and 6 a.m. and between 6 p.m. and 7 p.m. Photoperiods were not controlled. Plastic pots and cell packs were filled with 1,000 mL and 22 mL of a growth medium (Soil Mix, Sakata, Yokohama, Japan), respectively. Plug trays with 8 × 16 cell packs were 52.5 × 26.5 × 4.5 cm in size.

Seedlings that had been raised in plug trays were periodically removed from cells at transplanting stage, ten seedlings of each cultivar were transplanted into 15 cm pots. 'Reika', 'Marryroad' and 'First Power' seedlings raised in plug trays attained the transplanting stage 29, 25, and 26 days after sowing (DAS) at 23/18°C, respectively. At 30/25°C, the corresponding values were 20, 20, and 22 DAS, respectively. At transplanting, an additional five seedlings of each cultivar were randomly sampled from the plug trays. Seeds of the three cultivars were also sown directly into 15 pots each, and seedlings from five pots were sampled when those raised in the plug trays were transplanted into pots. Ten seedlings raised in either pots or plug trays were harvested at anthesis of the first flower in the first inflorescence. Fresh mass and seedling height were measured at transplanting. At flowering, the number of leaves preceding the first inflorescence, fresh mass and seedling height were measured. Shoot apices were observed under a stereoscopic microscope to check flower

initiation in seedlings raised in pots and plug trays when the latter seedlings were transplanted into pots. Because of limited glasshouse facilities, temperature treatments were not replicated. Therefore, data were subjected to analyses of variance in each temperature regimen, and mean separation was performed by the least significant difference (LSD) ( $P < 0.05$ ).

## Results

At transplanting, seedlings raised in plug trays were much smaller than those raised in pots, regardless of cultivar and temperature regimen (Tables 1 and 2). At 23/18°C, 'Reika' seedlings were heavier and taller than 'Marryroad' and 'First Power' seedlings when they were raised in pots, but there were no significant differences among cultivars when they were raised in plug trays. At 30/25°C, there were no significant differences in the fresh mass of seedlings among cultivars raised in pots or plug trays. On the other hand, 'First Power' seedlings raised in pots were taller than 'Reika' and 'Marryroad' seedlings at 30/25°C.

Table 1. Effect of root container size and temperature on the fresh mass (g) of seedlings raised in pot and plug trays at the transplanting stage<sup>z</sup>

Cultivar	23/18°C		30/25°C	
	Pot	Plug tray	Pot	Plug tray
'Reika'	10.0 c <sup>y</sup>	0.7 a	3.5	0.7
'Marryroad'	2.8 ab	0.6 a	2.9	0.7
'First Power'	3.5 b	0.6 a	3.6	0.8
Significance				
Cultivar	**		NS	
Rooting volume	**		**	
Interaction	**		NS	

<sup>z</sup> Transplanting stages in 'Reika', 'Marryroad', and 'First Power' at 23/18°C were 29, 25, and 26 DAS, respectively. At 30/25°C, the corresponding values were 20, 20, and 22 DAS.

<sup>y</sup> Separation of means within a temperature regimen of 23/18°C by the LSD procedure ( $P = 0.05$ ).

NS- not significant, \*\* - significant at  $P \leq 0.01$ .

At both temperature regimens, seedlings raised in pots initiated flower buds at the time when seedlings raised in plug trays were transplanted into pots (25-29 DAS at 23/18°C and 20-22 DAS at 30/25°C). When seedlings were raised in plug trays at 23/18°C, one, three and five out of five seedlings initiated flower buds in 'Reika', 'Marryroad' and 'First Power', respectively. When seedlings were raised in plug trays at 30/25°C, flower initiation was not observed in any seedling at transplanting.

The number of days to flowering was greater in seedlings raised in plug trays than in those from pots, and it decreased with an increase in temperature, regardless of cultivar (Table 3). The number of days to flowering was not significantly different among the cultivars at 23/18°C when seedlings were raised in pots, while the number of days to flowering was more in 'Reika' and less in 'Marryroad' when seedlings were raised in plug trays. At 30/25°C, the number of days to flowering was greater in 'First Power' than in the other two cultivars for seedlings raised in either pots or plug trays.

The number of leaves preceding the first inflorescence was not significantly different among seedlings raised in pots and plug trays in 'Marryroad' (Table 4). On the other hand, the number of leaves preceding the first inflorescence was significantly greater in seedlings raised in plug trays than in those from pots in 'Reika' and 'First Power'. At 30/25°C, the number of leaves preceding

Table 2. Effect of root container size and temperature on plant height (cm) at the transplanting stage for seedlings raised in plug trays<sup>z</sup>

Cultivar	23/18°C		30/25°C	
	Pot	Plug tray	Pot	Plug tray
'Reika'	87.4 c <sup>y</sup>	21.4 a	57.1 c	31.4 ab
'Marryroad'	32.0 ab	17.3 a	44.3 bc	28.8 a
'First Power'	48.6 b	22.4 a	77.5 d	34.8 ab
Significance				
Cultivar	**		**	
Rooting volume	**		**	
Interaction	**		**	

<sup>z</sup> Transplanting stages in 'Reika', 'Marryroad', and 'First Power' at 23/18°C were 29, 25, and 26 DAS, respectively. At 30/25°C, the corresponding values were 20, 20, and 22 DAS.

<sup>y</sup> Separation of means within a temperature regimen of 23/18°C by the LSD procedure ( $P = 0.05$ ).

\*\* - significant at  $P \leq 0.01$ .

Table 3. Effect of root container size and temperature on the number of days to flowering

Cultivar	23/18°C		30/25°C	
	Pot	Plug tray	Pot	Plug tray
'Reika'	45.7 a <sup>z</sup>	63.0 e	35.2	47.7
'Marryroad'	46.1 a	55.7 c	35.9	46.4
'First Power'	48.5 a	59.9 d	39.7	51.9
Significance				
Cultivar	**		**	
Rooting volume	**		**	
Interaction	**		NS	

<sup>z</sup> Separation of means within a temperature regimen of 23/18°C by the LSD procedure ( $P = 0.05$ ).

NS- not significant, \*\* - significant at  $P \leq 0.01$ .

Table 4. Effect of root container size and temperature on the number of leaves preceding the first inflorescence

Cultivar	23/18°C		30/25°C	
	Pot	Plug tray	Pot	Plug tray
'Reika'	7.1 a <sup>z</sup>	9.1 b	7.5	9.4
'Marryroad'	7.4 a	7.5 a	7.6	9.4
'First Power'	7.5 a	8.7 b	9.3	12.0
Significance				
Cultivar	**		**	
Rooting volume	**		**	
Interaction	**		NS	

<sup>z</sup> Separation of means within a temperature regimen of 23/18°C by the LSD procedure ( $P = 0.05$ ).

NS- not significant, \*\* - significant at  $P \leq 0.01$ .

the first inflorescence was significantly greater in 'First Power' than in the other two cultivars for seedlings raised in either pots or plug trays.

## Discussion

Root restriction stress due to limited rooting zone volume causes reductions in leaf area, dry mass of leaves, stems and roots, plant height and node numbers (Hameed *et al.*, 1987; Peterson *et al.*, 1991). Regarding reproductive development, Ruff *et al.* (1987) reported that plants grown in small containers flowered about three days later than those grown in large containers. On the other hand, Carmi (1986) found no delay in flowering in root-restricted cotton plants. The present study showed that the root restriction stress delayed anthesis regardless of temperature regimen, in accordance with the result of Ruff *et al.* (1987).

The number of leaves preceding the first inflorescence is determined by two processes, *i.e.*, leaf production rates during the vegetative stage and the time of flower initiation (Dieleman and

Heuvelink, 1992). In the present study, the effect of root container size on the number of leaves preceding the first inflorescence differed among cultivars at 23/18°C; root restriction stress increased the number of leaves preceding the first inflorescence in 'Reika' and 'First Power' but not in 'Marryroad' (Table 4). In relation to this different response to root restriction stress among cultivars, it is noteworthy that 'Reika' seedlings could be easily plucked out from cell packs three to four days later than 'Marryroad' and 'First Power' seedlings, and 'First Power' seedlings could be plucked out from plug trays one day later than 'Marryroad' seedlings. Judging from slower root development and an increased number of leaves preceding the first inflorescence, it is likely that 'Reika' is most sensitive to root restriction stress, while 'Marryroad' seedlings are affected to only a minor degree. It is not clear whether root restriction stress affects flower initiation through a suppressive influence on root development or if it affects flower initiation independently from root development. However, the results of the present study suggest that the number of leaves preceding the first inflorescence would increase in cultivars with slower root development if seedlings were raised in plug trays at 23/18°C. At 30/25°C, root development was faster than at 23/18°C. It is possible that fast root development causes root restriction stress to seedlings much earlier at 30/25°C than at 23/18°C, resulting in an increase in the number of leaves preceding the first inflorescence in all cultivars.

The retardation of flower initiation in 'Reika' when raised in plug trays at 23/18°C could account for the increased number of leaves preceding the first flower in this cultivar compared with 'Marryroad'. However, this explanation would not be applicable for 'First Power', because there was no difference in the number of leaves preceding the first inflorescence between 'First Power' and 'Reika', although flower initiation occurred earlier in 'First Power' than in 'Reika'.

Temperature does not affect the time to flower initiation at high light intensity, while high temperature delays flower initiation at low light intensity (Calvert, 1959). On the other hand, the rate of leaf production increases with an increase in temperature. As a result, the stimulating effect of high temperature on the number of leaves preceding the inflorescence was more evident as the light intensity decreased (Calvert, 1959; Hussey, 1963; Uzun, 2006). In the present study, the number of leaves preceding the first inflorescence increased with an increase in temperature in 'First Power', but not in 'Reika' and 'Marryroad', when they were raised in pots (Table 4). This suggests that the effect of temperature on the number of leaves preceding the first inflorescence differs among cultivars; 'First Power' is more sensitive to high temperature than 'Reika' and 'Marryroad'. The higher sensitivity of 'First Power' to high temperature is also inferred from an increase in plant height of pot-raised seedlings at 30/25°C (Table 2).

When plants are crowded, mutual shading may occur. In the present study, plant height at transplanting was greater in 'First Power' than in 'Reika' and 'Marryroad' when seedlings were raised in pots at 30/25°C, but there were no significant differences in plant height among cultivars when raised in plug trays. Therefore, an increase in the number of leaves preceding the first inflorescence in 'First Power' can be ascribed to the light intensity the seedlings received.

Oda *et al.* (2005) reported that high temperature delayed the number of days to flowering. In the present study, however, the number of days to flowering decreased with an increase in temperature (Table 3). Flower development after flower initiation is influenced by temperature; high temperatures hasten flower development (Calvert, 1957). In the present study, seedlings were grown under different temperature regimens until flowering, while seedlings were raised under different temperature regimens for only 20 days in the experiment of Oda *et al.* (2005). It is possible that the effect of temperature on the number of days to flowering is changed by the duration of temperature treatment.

In conclusion, seedling response to root restriction stress and high temperatures differed among cultivars, although it is unclear how root restriction stress delays flower initiation. Furthermore, the results of the present study suggest that cultivars that can develop roots rapidly in plug trays and at low-temperature conditions should be chosen if farmers want to reduce the number of leaves preceding the first inflorescence and the number of days to flowering by raising tomato seedlings in cool conditions.

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