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EFFECT OF TRANSPLANT GROWTH STAGE ON TOMATO PRODUCTIVITY

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Abstract. Transplant quality of tomato depend on such factors as microclimate parameter, substrate, plant nutrition and other. The growth stage is very important indices of their quality. The objective of research was to determine the effect of the growth stage of tomato transplants on their quality and yield. Research was carried out in a greenhouse of the Institute of Horticulture, Lithuanian Research Centre for Agriculture and Forestry in the period of 2008–2010. The investigated transplant growth stage of tomato cv. Cunero F_1 5–6 leaves, 7–8 leaves and 9–10 leaves. Tomato transplants with 9–10 leaves were elongated and their leaves area were the highest. Plants with 7–8 leaves according to stem and leaves ratio were qualitative, accumulated in leaves the highest content of photosynthetic pigments and had the highest SLA. Tomato transplanted with older transplant started to flower the fastest compared to 5–6 leaves transplant. Higher total yield was produced by 7–8 leaves transplants. The least early yield was produced by 5–6 leaves transplant. The growth stage of tomato transplants had no effect on the average tomato fruit weight.

Key words: tomato, yield, dry matter, photosynthetic pigments, fruit weight

INTRODUCTION

Vegetable productivity is influenced by properly grown transplants. Transplants quality is highly dependent from various factors such as light, temperature, CO_2, air humidity, water supply, fertilization, substrate, cultivation methods, vegetable species or varieties [Atherton and Rudich 1986, Weston 1988, Ciardi et al. 1998, Vavrina 1998, Damato and Trotta 2000, Głowacka 2002, Paul and Metzger 2005, Brazaitytė et al. 2009, 2010, Juknys et al. 2011]. The one of their quality indices also is the age and growth stage of transplants. The duration of transplants growth affect the vegetable development, vegetative mass, biochemical composition, output of standard transplants,

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growth after transplantation, resistance to unfavorable conditions, labor expenses of transplant cultivation [Vavrina 1998, Schrader 2000, Handley and Hutton 2003, Henare and Ravanloo 2008]. Research data indicated that the optimal transplant age and growth stage differs for each vegetable. It may be counted either in weeks, decades, or in appropriate number of leaves. Vavrina and Orzolek [1993] noted that a good tomato yield can be obtained from 2–13 week transplants. Salik et al. [2000] indicated that 5 week tomato transplants better grew after transplantation and their yield was higher than that of 4 or 6 week transplants. With an increase in the age of bell pepper transplants from 30 to 77 days, an early vegetable yield also increases [McCraw and Greig 1986, Weston 1988]. According to Harmon and coauthors [1991] the optimal transplant age of eggplant was between 35 and 49 days.

Growers prefer planting young strong-growing transplants. Transplants of an older age produce an earlier yield, while young transplants when being planted undergo less stress [Vavrina 1998]. Vegetables transplanted at their older age develop faster generatively than vegetatively [Schrader 2000, Orzolek 2004]. Planting of young tomato transplants (3–4 weeks) require a longer growing period for obtaining an optimal yield. When planting older transplants (7–9 weeks) their yield is early, but the vegetables are more affected by garden pest. The optimal transplants age depends on substratum, environmental conditions and vegetable cultivation technology in a certain location as well as on the grower‘s preference [Palamakumbura 1987, Leskovar and Cantliffe 1990]. Vavrina [1991] stated that the industrial standard for a tomato transplant in Florida is 6 weeks.

Cultivation of vegetables (cucumbers, tomatoes) in peat bags in polymer film covered greenhouses is one of the most widely used methods in Lithuania. When cultivating tomatoes in peat bags they may be transplanted both of younger and older age. Optimally developed transplants determined not only the earlier, but the higher yield. The optimal choice of transplant age or growth stage plays a significant economical role because such transplants begins yielding faster and the prices of early tomatoes are higher. In addition, greenhouse heating expenses will be optimized. Different climatic conditions results a different number of days till transplanting of proper development seedlings. Therefore the objective of our research is to determine the effect of the growth stage of transplants cultivated in peat bags on their quality and vegetable yield.

MATERIAL AND METHODS

Research was carried out in the Institute of Horticulture, Lithuanian Research Centre for Agriculture and Forestry in a greenhouse covered with double polymeric film Multispan 9.60 SR ("Richel", France) in the period of 2008–2010. Tomato cv. Cunero F_1 were cultivated in polymer pots filled with peat substratum in a heated nursery on the racks under illumination of high pressure sodium lamps (Philips SON-T Agro). During transplants cultivation the day/night temperature was 20–23/15–18°C and the relative air humidity was 50–60%. Tomatoes were sown weekly three times in February. They were simultaneously transplanted into the greenhouse on the second half of March. There they were cultivated in 20 l peat bags, 2 transplants in a bag. Their density was

2.5 plants per m^{-2}. In a greenhouse tomatoes were fertilized with "Nutrifol" (green, brown), magnesium sulfate, saltpeter, in respect of a growth stage. Water was acidified with nitric acid. Salt concentration in a feeding solution was EC 2.8–3.0, acidity – pH 5.5–5.8. The end of tomato vegetation was the second half of October. During plants cultivation the day/night temperature was 19–26/15–19°C and the relative air humidity was 60–80%. The investigated transplant growth stage: 1 – transplanted with 5–6 leaves (duration of transplants growth 35–42 days, depending on the year), 2 – transplanted with 7–8 leaves (duration of transplants growth 40–49 days), 3 – transplanted with 9–10 leaves (duration of transplants growth 48–56 days). The plot area – 6.4 m^2. Four replications were done in randomized block design.

Biometrical observations and content of photosynthetic pigments in leaves was established at the end of transplant growth. There were calculated specific leaf area (SLA, leaf area divided by the dry weight of leaves) and shoot:root ratio (SRR – is the ratio of shoot dry mass to root dry mass).

During vegetation the vegetable height and the leaves area were measured (three times a week during vegetation after transplanting), dry matter content was determined in leaves and fruits (three times during vegetation: I measurement – at the start of yielding, II measurement – at full yielding, III measurement – at the second half of yielding).

The leaf area of transplant and plants was measured by "WinDias" leaf area meter (Delta-T Devices Ltd., UK). To determine dry weight of transplant, tomato leaves and fruits were dried in a drying oven at 105°C for 24 h. Photosynthetic pigments content per one gram of fresh foliage weight was measured in 100% acetone extract according to D. Wettstein method [Gavrilenko and Zigalova 2003] using "Genesys 6" spectrophotometer (ThermoSpectronic, USA). Measurements were performed in four replicates (n = 4). The fully formed leaves were analyzed. The tomato yield was recorded. Tomatoes fruits were harvested three times a week, next were separated into marketable and non-marketable. Data were analyzed by ANOVA statistical package. The Fisher's LSD and Duncan's range tests were used to determine significant treatment effects. Statistical significance was evaluated at $p \leq 0.05$.

RESULTS

Tomato transplants with 5–6 leaves were the lowest, their leaves area was small and their dry weight of leaves and stems were the least (tab. 1). The tallest tomato transplants had 9–10 leaves and they were twice taller than 5–6 leaves plants, and 1.4 times taller than those with 7–8 leaves. Their leaves area was 2.4 times higher than that of 5–6 leaves transplants, and 1.2 times higher than that of 7–8 leaves vegetables. The dry leaves weight was 2.5 and 1.3 times larger than that of 5–6 and 7–8 leaves transplants, respectively. The transplants with 9–10 leaves had the root dry weight 2.6 times greater than that of 5–6 leaves plants, and 1.3 times greater than that of 7–8 leaves plants. The highest SLA was found in transplants with 7–8 leaves. The higher SRR ratio was found in older transplants.

Table 1. Some morphological characteristics and physiological indices of tomato transplants at their different growth stage (means for 2008–2010)

Growth stage of transplant	Plant height cm	Stem diameter cm	Hypocotyl length cm	Leaf area cm^2	Dry weight, mg			Specific leaf area $cm^2 mg^{-1}$	Shoot: root ratio	Leaf: stem mass ratio
					leaf	stem	roots			
5–6 leaves	26.1 a*	0.64 a	2.65 a	205.90 a	990 a	460 a	290 a	0.208 a	5.00 a	2.1 b
7–8 leaves	38.1 a	0.60 a	2.35 a	413.69 a	1915 ab	1115 ab	555 a	0.216 a	5.46 a	1.70 a
9–10 leaves	52.8 b	0.63 a	1.75 a	490.55 a	2480 b	1795 b	745 a	0.198 a	5.74 a	1.40 a

*Values indicated by the same letters within the columns are not statistically different at $P \leq 0.05$

Older transplant started to flower faster than younger transplant. The vegetables transplanted with 5–6 leaves flowered 8–12 days later than those transplanted with 9–10 leaves (tab. 2). Tomatoes transplanted with 7–8 leaves flowered 3–4 days later than the 9–10 leaves transplants.

Table 2. The number of days since transplanting till tomato flowering

Year	5–6 leaves	7–8 leaves	9–10 leaves
2008	20	14	10
2009	25	16	13
2010	18	13	10
Mean	21	14.3	11

Table 3. The effect of tomato transplant growth stage on plant height, number of leaves and leaves areas (means for 2008–2010)

Growth stage of transplant	I measure			II measure			III measure		
	plant height cm	number of leaves	leaf area cm^2	plant height cm	number of leaves	leaf area cm^2	plant height cm	number of leaves	leaf area cm^2
5–6 leaves	39.55a*	10.35 a	1917.55 a	66.35 a	11.67 a	3914.40 a	87.4 a	16.07 a	5796.03 a
7–8 leaves	55.98 b	11.50 b	3083.66 a	81.9 b	13.67 b	4939.89 a	108.9 b	17.57 ab	6372.41 a
9–10 leaves	62.73 b	11.87 b	3149.49 a	86.32 b	14.17 b	4925.14 a	112.00 b	18.37 b	7383.83 a

*Values indicated by the same letters within the columns are not statistically different at $P \leq 0.05$

Tomato transplants of different growth stage were growing and developing unequally. During vegetation in the first measure the transplants with 9–10 leaves were taller than 5–6 and 7–8 leaves transplants (tab. 3). During the third measurement the height of both 7–8 leaves and 9–10 leaves transplants was almost equal. They were 24.6 and 28.1%, respectively, taller than 5–6 leaves transplants.

In all three measurements small leaf area was determined in tomatoes which transplants had 5–6 leaves (tab. 3). During the second measurement (after 20 days of transplanting) the leaves area of 7–8 and 9–10 leaves transplants was similar. After 30 days of transplantation the highest leaves area was at 9–10 leaves transplants. It was 27.4 and 15.9 % higher than that of 5–6 and 7–8 leaves transplants, respectively.

Tomatoes transplanted with 7–8 leaves accumulated in their leaves the highest content of photosynthetic pigments (tab. 4). The content of carotenoids in their leaves was 19.2% higher than in 5–6 and 9–10 leaves transplants. The chlorophyll (a+b) content was higher by 17.5 and 20.3%, respectively. The photosynthetic pigments content in 5–6 and 9–10 leaves transplants was similar.

Table 4. The effect of transplant growth stage on photosynthetic pigment content and the chlorophyll *a* to *b* ratio in leaves of tomato (means for 2008–2010)

Growth stage of transplant	Photosynthetic pigment content and ratio, $mg \cdot g^{-1}$ f. m.				
	chlorophyll a	chlorophyll b	chlorophyll a+b	chlorophyll a and b ratio	carotenoids
5–6 leaves	0.9 a*	0.33 a	1.23 a	2.72 a	0.26 a
7–8 leaves	1.08 b	0.39 b	1.48 b	2.80 a	0.31 a
9–10 leaves	0.92 a	0.34 a	1.26 a	2.74 a	0.26 a

*Values indicated by the same letters within the columns are not statistically different at $P \leq 0.05$

Table 5. The effect of transplant growth stage on content of dry matter in leaves and fruits of tomato (means for 2008–2010)

Growth stage of transplant	Dry matter content, %					
	I analysis		II analysis		III analysis	
	leaves	fruits	leaves	fruits	leaves	fruits
5–6 leaves	10.42 a*	4.87 a	10.59 a	4.85 a	11.03 a	5.33 a
7–8 leaves	10.89 a	4.59 a	10.49 a	5.01 a	11.44 a	5.67 a
9–10 leaves	10.23 a	5.11 a	10.28 a	5.00 a	11.00 a	5.41 a

*Values indicated by the same letters within the columns are not statistically different at $P \leq 0.05$

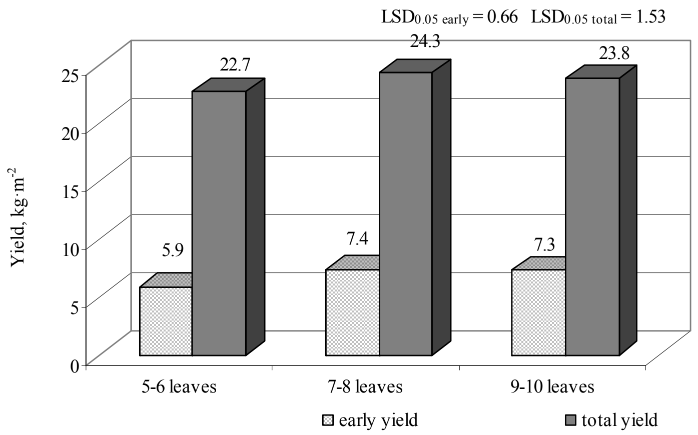

Fig. 1. The effect of tomato transplant growth stage on early and total fruit yield (means for 2008–2010)

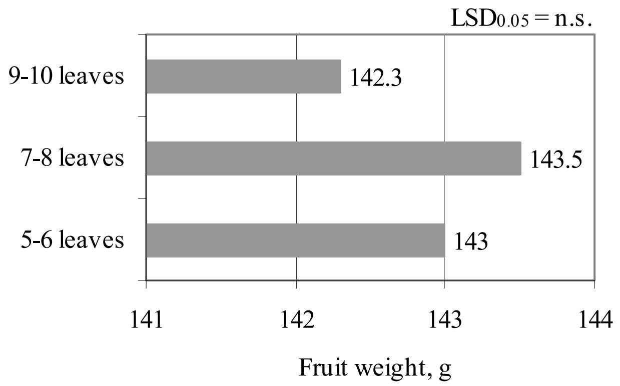

Fig. 2. The effect of tomato transplant growth stage on average fruit weight (means for 2008–2010)

The growth stage of transplants had no significant effect on accumulation of dry matter in leaves and fruits during vegetation. There the dry matter content was slightly fluctuating depending on the transplants growth stage, however, according to the average data (average of three measurements) the 7–8 leaves transplants accumulated most of dry matter in their leaves (tab. 5). At the start of yielding in the fruits of 9–10 leaves transplants the content of dry matter was the highest. During the full yielding in the fruits of all tomatoes the content of dry matter was similar and it fluctuated from 4.8 to 5.0%. At the second half of yielding the fruits of tomato 7–8 leaves transplants accumulated most of dry matter. According to the average data (average of three measurements) the accumulation of dry matter in 9–10 leaves transplants was slightly higher.

Tomato harvest was affected by their transplant growth stage (fig. 1). Higher early yield (i.e. the first yielding month) was obtained from 7–8 leaves tomato transplants. In the first yielding month it amounted to 7.4 kg m^{-2} and it was by 26.4% higher (significant difference) than the yield of 5–6 leaves tomato transplants and by 2.1% higher (nonsignificant difference) than in 9–10 leaves transplants. The total yield of tomato was higher when their transplants had more leaves i.e. 7–8, or 9–10. Higher total yield was produced by 7–8 leaves transplants. It was 7.1% (significant difference) higher than that from 5–6 leaves transplants and 2.3% higher (nonessential difference) than that from 9–10 leaves transplants.

According to data the tomato transplant growth stage had no effect on the average fruit weight (fig. 2). The size of fruits of different growth stage tomato transplants is almost equal.

DISCUSSION

Many factors determine transplant quality, including leaf area, root to shoot ratio, root volume, fertilization, height, transplant age and shipping [Cantliffe 1993]. According to our research data transplants with 9–10 leaves was elongated and their leaf area and fresh weight were the largest. The growth stage of transplants had an effect on vegetable growth intensity. According to our data tomatoes transplanted of older age were taller and had more leaves than vegetables transplanted at their younger age. According to the Palamakumbura‘s [1987] data the vegetables transplanted at 30 days age were taller than those transplanted at 15 days age. Older transplants begin to flower faster. It is confirmed by other researchers [Palamakumbura 1987, Salik et al. 2000] and our research data.

With younger tomato transplants having more chlorophyll in their leaves, the specific leaf area values and a relative growth rate may have a more efficient photosynthetic system than older transplants [Leskovar and Cantliffe 1990]. Coughenour et al. [1984] affirm, that the leaf is thicker than the specific leaf area is higher. According to our research data the highest SLA was in transplants with 7–8 leaves, while that of the older transplants was the lowest (tab. 1). The higher SRR of transplants with 7–8 leaves and 9–10 leaves shows that partitioning direction of dry matter was to their above-ground part. More pigments were accumulated in leaves at the start of yielding by vegetables transplanted with 7–8 leaves (tab. 4). Besides, during the vegetation period more dry matter was accumulated in the leaves of these vegetables (average of three measurements), and consequently their yield was higher.

The age of transplants is one of the factors affecting the vegetables yield [McCraw and Greig 1986, Weston 1988]. The vegetables cultivated from older transplants produce earlier yields [Liptay 1988]. Various researchers state that the age of vegetable transplants affects the early and total yield not of all vegetables. Vavrina et al. [1993] indicated that watermelon transplant age had no effect on the early and total yield of these vegetables. Nesmith [1993] investigated the effect of 2, 4, 6 and 8 week muskmelon transplants age on their productivity. Research data indicate that the transplant age affected neither their early nor their total yield. In the experimental work on agricultural elements by various researchers the effect of the transplant age on cucumber yield was also studied [Junior et al. 2004, Handley and Hutton 2003]. It is estimated that planting 29 and 34 day transplants their cucumber yield was less than that from the vegetables whose transplants were 19 or 24 day old [Junior et al. 2004]. According to Liptay [1988], notwithstanding the fewer yields of younger cucumbers, the total yield of different age vegetables is similar. Hasandokht and Nosrati [2010] present the data that the older the cucumber transplants, the larger their total yield. Some researchers state that the yield of tomato transplants ranging from 3 to 6 week old increased linearly with age [Weston and Zandstra 1989]. The others say that the transplant age has no impact on tomato yield [Leskovar et al. 1991]. In our tests the transplant growth stage affected the early and total yield of tomatoes cultivated in peat bags. The total tomato yield of former 7–8 leaves transplants was the highest. An early yield was higher of tomatoes transplanted with 7–8 and 9–10 leaves.

It is estimated that the transplant age affects the average fruit weight: the younger transplants the lighter the average fruit weight [Jankauskienė and Brazaitytė 2005]. Lopes and Goto [2003] present their data that the younger tomato transplants the greater the fruit weight. Our research data showed that tomato transplant growth stage had no effect on the average fruit weight. Literature data indicates the tomato transplants with leaf and stem mass ratio from 1.5 to 2.0 is a high quality [Tarakanov et al. 1982]. According to our research transplants with 7–8 leaves this index was 1.7 (tab. 1). Besides, these seedlings after transplantation produced higher early and the highest total yield than transplant with 5–6 leaves.

CONCLUSIONS

The tomato transplants growth stage has an impact on their quality, early yield and total yield. Tomato transplants with 7–8 leaves according to stem and leaves ratio are qualitative. According to data of photosynthesis pigments, specific leaf area tomato transplants with 7–8 leaves had a more efficient photosynthetic system what determined higher yield. The transplant growth stage has no effect on the average tomato fruit weight.

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WPŁYW POZIOMU ROZWOJU ROZSADY POMIDORA NA PÓŹNIEJSZY WZROST I FORMOWANIE PLONU

Streszczenie. Celem badań było określenie wpływu fazy wrostu rozsady pomidorów na jej jakość i plon. Badania prowadzono w latach 2008–2010, w szklarni Instytu Ogrodnictwa Litewskiego Centrum Badań Rolniczych i Leśnych. Badano rozsadę pomidora odmiany ‘Cunero F1’ w fazie 5–6, 7–8 i 9–10 liści. Rozsada pomidora sadzona w fazie 9–10 liści posiadała wysokie pędy i największą powierzchnię liści. Rozsada z 7–8 liśćmi na pędzie, oceniając stosunek masy pędu z liśćmi do masy korzeni oraz masy liści do masy pędu, miała lepszą jakość, zawierała w liściach najwięcej barwników fotosyntetycznych i posiadała największą specyficzną powierzchnię liści. Pomidory sadzone z 9–10 liśćmi zakwitały najszybciej. Większy plon ogółem formowały rośliny z rozsady z 7–8 liśćmi niż z 5–6 liśćmi. Najmniejszy plon wczesny wytworzyła rozsada sadzona w fazie 5–6 liści. Faza wrostu rozsady pomidora nie miała wpływu na średnią masę owocu.

Słowa kluczowe: pomidor, plon, sucha masa, barwniki fotosyntetyczne, masa owocu

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