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The impact of culture system and fertilization type on yield and fruit quality of greenhouse tomatoes

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Abstract. This paper presents the results of research regarding the influence of some technological inputs on greenhouse tomatoes yield and fruit quality. In order to establish how the fertilization and system of culture can influence the greenhouse tomatoes yield and quality, two systems of culture (in soil and in organic substrate) and different types of fertilization (basic and additional) were analyzed. Maximum early and total yields were obtained in case of organic substrate culture. Vitamin C, acidity and total sugar content of fruit increased with radicular+foliar additional fertilization. None of the nitrate values over passed the accepted limits of permission for greenhouse tomatoes.
Key Words: Tomatoes, fertilization, organic substrate, fruit quality.

Rezumat. În această lucrare sunt prezentate rezultatele cercetării privind influenţa unor inputuri tehnologice asupra producţiei şi calităţii fructelor la tomatele de seră. Pentru a stabili modul în care fertilizarea şi sistemul de cultură pot să influenţeze cantitatea şi calitatea producţiei de tomate de seră au fost studiate două sisteme de cultură (în sol şi pe substrat organic) şi diferite metode de fertilizare (de bază şi fazială). Cele mai mari producţii timpurii şi totale au fost obţinute în cazul sistemului de cultură pe substrat organic. Conţinutul fructelor în vitamina C, aciditatea şi conţinutul fructelor în zahăr total au înregistrat valori mai ridicate în cazul fertilizării radiculare+foliare. Conţinutul în nitraţi al fructelor de tomate nu a depăşit limitele admise pentru cultura tomatelor de seră.
Cuvinte cheie: Tomate, fertilizare, substrat organic, calitatea fructelor.

Introduction. Greenhouse tomatoes production involves a number of complex interactions between cultivar, environment and management of the crop, each of which plays a role in fruit yield and quality determination. Since many experiments have not revealed real differences between the product quality of vegetables grown in soil or hydroponically, soilless culture in greenhouse may be an alternative to soil culture for high-value vegetable crops including tomatoes (Schnitzler & Gruda 2003). Better tomato fruit quality can be obtained by direct measures such as an increase in the concentration of the nutrient solution, or a reduction of nitrate application rates. It is also necessary to adopt appropriate nutrient management practices (use of slow-release fertilizers, split applications, combining of radicular and foliar fertilization) which help to supply nutrients in quantities adequate to just meet crop demand and minimize losses, thereby increasing the nutrient use efficiency. The objective of the present study was to evaluate greenhouse tomatoes grown in soil and in organic substrate in order to establish how the system of culture and the management of technological inputs can influence yield and chemical properties of tomato fruit.

Material and Method. The experiment was carried out in 2008 at the greenhouses of vegetable growing Department of University of Agricultural Sciences and Veterinary Medicine from Cluj-Napoca. The research was organized as a poly-factorial experience with three experimental factors: 1. system of culture: soil and organic substrate (made from 80% peat and 20% long duration follow soil + well decomposed manure); 2. basic fertilization of soil and organic substrate with two treatments (simple doze and double doze); 3. additional fertilization consisted of radicular and radicular + foliar treatments.

Cronos F_1 was used as biological material. The planting of transplants in soil was done at the end of January and the installation of plants at the final growing place, in case of organic substrate culture system, was done in the second decade of February. Organic substrate was placed in small capacity (8 L substrate/plant) polyethylene bags. Each bag was planted with one plant and drainage slits below each plant in the bag were cut to assure the drainage. Plant spacing was 0.40 m between plants and 0.80 m between rows for both system of culture, the plants density being about 32.000 plants ha^{-1}. Two treatments of basic fertilization expressed as kg ha^{-1}, in case of soil culture, and as kg m^{-3} of substrate, in case of organic substrate culture, were added to establish the simple doze (300 kg ha^{-1} Complex III – N:P:K 15:15:15 for soil culture respectively 3 kg m^{-3} Complex III for organic substrate culture) respectively the double doze (300 kg ha^{-1} Complex III + 300 kg ha^{-1} Multicote IV N:P:K 12:0:43 for soil culture respectively 3 kg m^{-3} Complex III + 3 kg m^{-3} Multicote IV for organic substrate culture). Additional fertilization was done with 1% Complex III (15:15:15) solution applied once at two weeks for all of experimental variants in case of radicular fertilization and with 0.5% Ferticare (10:5:26) solution, applied once weekly for half of the variants, which were supplementary foliar fertilized. The experiment was arranged in a complete randomized block design with three replications. The production system was managed following conventional technology for greenhouse tomatoes production in case of soil culture, respectively the technology established by Carpenter (1982) and adapted to our local conditions by Indrea (1990) in case of organic substratum culture. Fruit were harvested periodically, from 5 of May up to 10 of July, at full red stage, and classified as early yield (that one recorded till 31 of May) and total yield. Samples of whole fruit were used to determine the titratable acidity, total soluble solids, total sugar, vitamin C content and nitrates content. Recorded yield data were subject to analysis of variance.

Results and Discussion. Greenhouse vegetables can be grown in various types of soilless media, as long as proper irrigation and fertilization is provided (Cantliffe et al 2003). The same authors reported three times greater yields for muskmelon cultivated in soilless media than those obtained under field conditions. According to our previous studies (Apahidean 1998; Ganea 2003), peat and other growing media (mixture with perlite, volcanic tuff) which consisted of 50% peat, placed in big polyethylene bags (12 L substrate/plant), can be suggested to be used in tomatoes growing under greenhouse conditions with great influence on total yield (16-18 kg/m^2). Organic substrate culture also provided total yields about 25-27 kg/m^2 at greenhouse cucumbers (Măniuţiu 1998) and total yields about 7-7.5 kg/m^2 at greenpeppers cultivated in polyethylene greenhouses (Bobăilă 2005). In this experiment the influence of organic substrate culture system on both early and total yield of tomatoes was very significant, the obtained yield efficiencies varying between 34.7% in case of early yield and 38.1% in case of total yield (Table 1).

A balanced nutrient supply is important for both yield and quality of greenhouse tomato, irrespective the nutrient source and system of culture. A combination of radicular and foliar fertilizers should be applied in order to prevent salt buildup, nutrient deficiency and excessive fertilizer runoff. Using of slow-release fertilizers respect better these goals and hold great promise for the production of solanaceous, especially tomatoes. Gezerel & Donmez (1988) comparing slow-release fertilizer (Plantacote) and conventional fertilizers at 100:80:90 kg/ha NPK have found that slow-release fertilizers produced 92 t/ha of tomato, compared to only 42 t/ha when ordinary commercial fertilizers were used. With respect to the influence of basic fertilization on yield of greenhouse tomatoes, grown in soil and in organic substrate (Table 2), the doubling of applied nutrient doze determined very significant total yield efficiencies (0.83 kg/m^2) while the early yield didn't swell spectacular, maybe even due to the using of a slow-release fertilizer (Multicote). Fruit development in tomato is often accompanied by the depletion of foliar potassium to the detriment of both the yield and the fruit quality. The foliar fertilization, done with a fertilizer with a high K ratio (10:5:26), determined distinct significant efficiencies of both early yield (0.27 kg/m^2) and total yield (0.32 kg/m^2) in comparison with the variants which were radicular additionally fertilized (Table 3). Măniuţiu et al (2008) also reported that root and foliar fertilization determined positive significant yield differences (1.47 kg/m^2) comparative with root fertilization at greenhouse cucumbers.

Table 1

The early and total yield of greenhouse tomatoes as influenced by system of culture

System of culture	*Early yield*				*Total yield*			
	Kg/m^2	%	$\pm$D	Signification	Kg/m^2	%	$\pm$D	Signification
Soil – Control	4.19	100.0	0.00	-	8.41	100.0	0.00	-
Organic substrate	5.64	134.7	1.45	***	11.61	138.1	3.20	***
LSD 5%			0.14				0.30	
LSD 1%			0.32				0.70	
LSD 0.1%			1.00				2.21	

Table 2

The early and total yield of greenhouse tomatoes as influenced by basic fertilization of soil and organic substrate

Basic fertilization	*Early yield*				*Total yield*			
	Kg/m^2	%	$\pm$D	Signification	Kg/m^2	%	$\pm$D	Signification
simple doze	4.79	100.0	0.00	-	9.59	100.0	0.00	-
double doze	5.04	105.3	0.25	*	10.42	108.6	0.83	***
LSD 5%			0.16				0.24	
LSD 1%			0.26				0.39	
LSD 0.1%			0.49				0.74	

Table 3

The early and total yield of greenhouse tomatoes as influenced by additional fertilization

Additional fertilization	*Early yield*				*Total yield*			
	Kg/m^2	%	$\pm$D	Signification	Kg/m^2	%	$\pm$D	Signification
radicular fertilization	4.78	100.0	0.00	-	9.85	100.0	0.00	-
radicular + foliar fertilization	5.05	105.5	0.27	**	10.17	103.2	0.32	**
LSD 5%			0.15				0.18	
LSD 1%			0.22				0.27	
LSD 0.1%			0.33				0.40	

Today, the orientation in horticulture world wide is geared to quality instead of quantity. Since many experiments have not revealed any real differences between the product quality of vegetables grown in soil or hydroponically, both high yield and good quality fruit could be obtained by using of soilless culture systems. Besides, Schnitzler & Gruda

(2002) reported that taste of some vegetable fruit such as tomatoes, cucumbers, melons etc., may be substantially improved in hydroponics by manipulating the nutrients concentration in the supplied nutrient solution.

In this experiment the tomato fruit quality was assessed by some chemical components as: soluble solids, total sugar content, malic acid and C vitamin content. Among fruit constituents, with potential hazard to consumer's health, nitrates were determined. High dry matter or low water content of the tomato has been reported to affect fruit taste positively because the major components of tomato taste, especially sugars and acids, are more concentrated (Hobson 1988). The soluble solids content (SSC) represents approximately 75% of the total dry matter and they are comprised primarily of the reducing sugars and of 10% to 15% of citric and malic acids, being the major constituents which assure the nutritional value of tomatoes. The doubling of basic fertilization doze increased the SSC content in case of both culture systems but, as a whole, the SSC values recorded in case of organic substrate culture where lesser maybe because of the higher obtained yields and due to the reverse correlation between the yield and dry matter content of fruits (Table 4). Many studies have shown that tomato flavor is related to the balance between total sugars and organic acids (sugars:acids ratio) in the fruit (Auerswald et al 1999). Other studies have shown that K nutrition has a positive effect on fruit's sugar and acid content. Of the nutrition factors, the soil K content most affects the total acid content in the fruit (Lacatuş et al 1994). Significant responses to high K rate of the foliar fertilizer, which was weekly applied, were observed for total sugar content of fruit in case of both systems of culture. Fruit titratable acidity was increased with the foliar fertilization and mainly due to the high K rate of applied fertilizer. Tomato fruit are also rich in anti-oxidant compounds that have been recognized as beneficial for human health. Among these, vitamin C is a health-promoting factor with antioxidant properties. Even if the antioxidant content of tomatoes may depend on genetic factors in case of a given variety it can varies according to the culture system. Vitamin C content in the fruit is also influenced by K supply. Higher vitamin C content was recorded in case of variants cultivated in organic substrate (19.42 – 24.28 mg/100 g fresh matter) and vitamin C content increased in case of foliar fertilized variants both for soil culture and for organic substrate culture (Table 4). The root-media temperatures in the organic substrate which were slightly higher (2ºC), especially in the beginning of culture, compared with the soil, may have increased the growth, yield and chemical constituents in the tomato fruits from this system of culture.

Table 4

The chemical features of greenhouse tomato fruit as influenced by system of culture and fertilization

Variant			*Fruit quality*				
System of culture	Basic fertilization	Additional fertilization	Soluble solids %	Total sugar %	Titratable acidity %	Vitamin C mg/100g fresh matter	Nitrates mg/kg
Soil culture	simple doze	radicular	6.05	3.7	0.42	18.65	52.23
		radicular+foliar	6.48	3.9	0.47	22.33	54.56
	double doze	radicular	6.10	3.8	0.42	19.36	49.87
		radicular+foliar	6.55	4.1	0.54	22.88	53.68
Organic substrate culture	simple doze	radicular	5.72	3.6	0.48	19.42	65.59
		radicular+foliar	5.86	4.1	0.55	23.64	70.26
	double doze	radicular	5.90	4.1	0.54	22.04	79.41
		radicular+foliar	6.11	4.3	0.58	24.28	83.44

The major potential hazard to consumer health linked to fertilizers is the quantity of absorbed nitrogen and the way in which it is utilized in plant metabolism, mainly with respect to the nitrates content of edible plant tissues. However, both these factors are better managed in hydroponics, since in the small volume of rooting medium the nutrient supply is more efficiently controlled through the composition of the nutrient solution. Nitrates can be reduced to nitrites which then react with secondary amines to produce nitrosamines under the influence of acids in the stomach (Craddock 1983). At greenhouse cucumbers production a positive effect of high K fertilization doze (0.30 mg ml^{-1}) on uptake, translocation and reduction of NO_3 in leaves as well as on translocation of amino acids towards the fruit was reported, thereby perhaps enhancing the maximal commercial yield (Ruiz et al 2002). High vitamin C levels in vegetables can also prevent the nitrosation reaction. In our experiment the recorded values of nitrates content of fruit were situated under normal accepted limits and they varied between 49.87 mg/kg and 83.44 mg/kg even if they were a little bigger in case of organic substrate culture than in soil culture (Table 4). Nitrate ratios in the fruit increased with the foliar fertilization, even if they decreased with doubling of basic fertilization doze, in case of soil culture, maybe because from soil an important part of applied nitrogen is leached.

Conclusions. Greenhouse tomatoes production in hydroponics system could be an alternative to the soil culture because it allows the possibility of improving yields and provides better direct inputs adapted to specific conditions of the system or substrate. The best result of experience with greenhouse tomatoes cultivated in comparative culture in soil and in organic substrate is that on organic substrate they can be obtained earlier yields than in soil, even for later set up cultures. Product quality is a complex issue. As well as visual characteristics, properties such as the soluble solids, total sugar, acidity and C vitamin content of fruit, which count for fruit flavor, must be considered. The total sugar content and acidity are the most important characteristics of tomatoes taste. Both characteristics recorded higher values in case of foliar fertilization and in organic substrate culture as response to high K rate of the applied foliar fertilizer and to a better management of nutrition. High vitamin C content was recorded in case of variants cultivated in organic substrate and it increases in case of foliar fertilization both for soil culture and for organic substrate culture. Nitrate contents of tomato fruits were a little bigger in case of organic substrate culture for all the variants but none of them over passed the accepted values for greenhouse tomatoes.

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