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YIELD AND QUALITY OF BUSH PROCESSING TOMATOES FERTILIZED WITH DRIED ORGANIC AND ORGANOMINERAL FERTILIZERS

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Abstract

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The effect of dried organic and organomineral fertilizers on the yield and quality of the bush processing tomatoes variety 'Proton' were explored in 2005–2006. Field experimental plots were established in Žabčice in the Czech Republic. The following variants of fertilizers were included: Agormin T, Agro, Dvorecký agroferm, farmyard manure, mineral fertilizers and unfertilized control. All plots, except the control, were fertilized with mineral fertilizers on the same nutrients level. Total yield, marketable yield, number of fruits and mean fruit weight were assessed. Total solids, carotenoids, ascorbic acid and nitrates (mg.kg^{-1} of fresh fruit weight) were analysed in fruits. Fertilizers did not significantly influence total yield and marketable yield. The highest yields were found at Agormin T (7.42 kg.m^{-2} and 6.73 kg.m^{-2}, respectively), the highest mean fruit weight was found at mineral fertilizers (82.9 g) and Agormin T (82.4 g). Fertilizing with Agro resulted in the highest number of fruits (81.0 pieces.m^{-2}). Dvorecký agroferm significantly increased ascorbic acid content in fruits compared to the control. The highest nitrates content was recorded for the control, the lowest for mineral fertilizers. There was not found significant effect of fertilizers on total solids and carotenoids. All tested dried organic or organomineral fertilizers were shown to be efficient alternatives to traditional farmyard manure. Only Agro significantly decreased ascorbic acid content in comparison to farmyard manure.

organic fertilizers, tomatoe, yield, fruit weight, total solids, ascorbic acid, nitrates, carotenoids

Tomatoes are one of the most frequently cultivated vegetables in the world. There are lots of studies dealing with optimal fertilization and using organic fertilizers in tomatoes crop (Quattrucci, 2000, Patil et al., 2004) to ensure high productivity and high quality of the product. Using conventional farmyard manure meets some hygienic and labour problems. Manure transportation over long distance is uneconomical, because of high bulkiness due to high water content (Bélec et al., 2003). Restructuring of agriculture concerns in the Czech Republic leaded to lack of manure in some areas with plant production specialization and, on the other hand, its surplus in other ones. Fermentation and modification of the raw manure into dried granular fertilizer is one of the possibilities how to solve this problem (Zahradník and Petříková, 2006).

Presented paper put the results of the study of the effect of some dried organic and organomineral fertilizers on the yield and qualitative fruit parameters of bush processing tomatoes. The aim is to explore possibility of utilization of these fertilizers as the alternative to conventional farmyard manure.

MATERIAL AND METHODS

The field experimental plots were established in the training agriculture enterprise of Mendel University of Agriculture and Forestry Brno (MUAF) in Žabčice (South Moravia, Czech Republic) in 2005–2006. The locality is characterized by average year temperature 9 °C and average year precipitation 490 mm, soil type is Arenic Cambisol. Nutrients level in the soil before plot foundation is presented in Tab. I. Nutrients P, K, Ca, Mg were extracted according to Mehlich III method and subsequently analysed by colorimetry (P) and atomic absorption spectrophotometry (K, Ca, Mg).

I: *Soil analyses before fertilizing (mg.kg^{-1})*

Year	pH/$CaCl_2$	N_{min} (mg.kg^{-1})	P (mg.kg^{-1})	K (mg.kg^{-1})	Ca (mg.kg^{-1})	Mg (mg.kg^{-1})
2005	6.73	19.54	218.3	326.7	2345.8	235.2
2006	6.85	22.33	316.7	251.7	2560.0	228.4

We used the bush processing tomato variety 'Proton' (SEMO Ltd., CZ). It is a medium early maturing variety with very firm, ovalround to round fruits of medium weight (80–90 g). It is suitable for hand picking and direct consumption as well, it is short-term storable. Maximum yield efficiency is 80 t.h^{-1}.

We used the following fertilization treatments: Agormin T (an organomineral granulated fertilizer made from peat, with added basic nutrients), Agro (an organic granulated fertilizer made from poultry bedding and molasses), Dvorecký agroferm (an organic granulated fertilizer made from fermented and dried cow-dung, granulated), cattle farmyard manure, solo mineral fertilizers and unfertilized control. Cattle farmyard manure came from the training agriculture enterprise of MUAF Brno in Žabčice. We applied 35 t.h^{-1} of manure in the middle of October in 2004 and 2005, respectively. Dried organic fertilizers were applied two weeks before planting (4th of May 2005 and 6th of May 2006, respectively). Chemistry and doses of organic fertilizers are presented in Tab. II.

We used calcium ammonium nitrate (27% N) and potassium sulphate (50% K_2O) for mineral fertilization. Phosphorus fertilizers were not applied, because of very high level of P in the soil. All plots, except the control treatment, were fertilized by mineral fertilizers with regard of nutrients content of the applied organic fertilizers, soil level and supposed target yield (60 t.h^{-1}). Thus all variants of fertilizers had the same nutrients level of nitrogen and potassium: 129 kg.ha^{-1} N and 129.3 kg.ha^{-1} K (Malý et al., 1998).

II: *Chemistry (% in dry matter) and applied doses (t.ha^{-1}) of used fertilizers*

Fertilizer (producer)	N (%)	P (%)	K (%)	Dose (t.ha^{-1})
Agormin T (AGRO CS Inc., CZ)	1.14	0.21	3.55	2.5
Agro (MeM. B.V., NL)	3.87	0.97	5.72	1.0
Dvorecký agroferm (AGRO Dvorce Ltd., CZ)	1.70	0.47	2.99	1.0
Farmyard manure (MUAF Brno, Žabčice, CZ)	2.00	0.46	2.13	35

Tomatoes were sown in greenhouse on the 4th of March 2005 and the 6th of March 2006, respectively. After 18 days they were pricked out into multiplots (sizes 0.6 x 0.4 m with 96 cellpots per plot). Seedlings were planted out in space 0.6 x 0.5 m on the 23rd of May 2005 and on the 22nd May in 2006, respectively. The experimental plot design was a randomized block with 3 replications and plots of 16 m^2. Herbicide Sencor 70 WG was applied 14 day after planting. Later the soil surface was kept free of weeds by manual hoeing. Watering was applied by overhead sprinklers. Fungicide Acrobat MZ was applied preventively against late blight (*Phytophtora infestans*) on 10th of July 2005 and on 1st July 2006, respectively. Later the fungicide Kuprikol 50 was used, firstly on 27th July 2005. In 2006 there was signalised high infection pressure of the fungus *Phytophtora infestans*, therefore, we applied the Kuprikol 50 twice preventively (22nd July, 3rd September). Later it was applied repeatedly after every other harvest. Altogether 7 harvests were done weekly in 2005, the first one on the 10th of August, the last one on 20th the September. In 2006 due to severe *Phytophtora infestans* infection period in August we gained only 5 harvests, the first one on the 17th of August, the last one on the 13th of September.

Overall yield (kg.m^{-2}), marketable yield (kg.m^{-2}), number of fruits (pieces.m^{-2}) and mean fruit weight (g) were assessed in every harvest. Market fruit quality was classified according to Commission regulation (EC) No. 790/2000 (common marketing standard for tomatoes). Unmarketable yield was represented mainly by cracked fruits or fruits with late blight (infected by *Phytophtora infestans*). Total yields were expressed as the sum of all harvests. Fruits were sampled by plot replications during the third harvest and submitted to analysis for nutritional values. We used a mixture of 6 randomly chosen fruits per one replicate for analyses of total solids and carotenoids. Total solids (%) were determined by weight measurement after drying to a constant weight at 105 °C. Carotenoids (mg.kg^{-1} of fresh mass) were extracted with acetone and analysed by colorimetry according to Holm (1954). We used 6 randomly chosen fruits from each treatment plot for analyses of ascorbic acid and nitrates. Ascorbic acid and nitrates (mg.kg^{-1} of fresh mass) were measured with Reflectoquant® test strips in RQflex 2 reflectometer (Merck KGaA, Germany). Ascorbic acid reduces yellow molybdophosporic acid to phosphormolybdenum blue that is determined reflectometrically. By a reducing agent nitrate ions are reduced to nitrite ions, which react with an

aromatic amine to form a diazonium salt, which in turns react with N-(1-naphtyl) ethylene-diamine to form a red-violet azo dye that is determined reflectometrically. Measurement error of the apparatus is ±1.0 mg.kg^{-1}.

Data were statistically processed by analysis of variance and multiple range Tuckey HSD test ($P \leq 0.05$) using software Unistat 5.1.

RESULTS AND DISCUSSION

Fertilizers did not significantly influence total yield, marketable yield, number of fruits and fruit weight (Tab III). Total yield, marketable yield and number of fruits were significantly higher in 2005 compared to 2006. Lower yields in 2006 were caused mainly by unfavourable weather conditions: long lasting rain period in August resulted in high crop damage by late blight and shorter harvesting period.

III: *Analysis of variance for yield in 2005–2006*

Source of variability	d.f.	Total yield (kg.m^{-2})	Marketable yield (kg.m^{-2})	Number of fruits (pieces.m^{-2})	Fruit weight (g)
Fertilizer	5	0.57	0.72	99.9	16.812
Year	1	21.46**	21.79**	3130.2**	5.361
Fertilizer x Year	5	1.63	1.12	320.1	36.926
Residual	24	1.84	1.82	234.7	37.991

** $P \leq 0.01$

In 2005 the average total yield varied between lowest values in farmyard manure (7.16 kg.m^{-2}) to the highest value in mineral fertilizer (8.18 kg.m^{-2}). In 2006 the lowest total yield was recorded with mineral fertilizers (5.08 kg.m^{-2}), the highest with Agormin T (7.06 (kg.m^{-2}). Average values of yield indexes are presented in Tab IV. Total yield varied between 6.63 kg.m^{-2} (mineral fertilizers) and 7.42 kg.m^{-2} (Agormin T). The result of marketable yield corresponded with total yield. There were not found significant differences between fertilizers. The highest marketable yield showed Agormin T (6.73 kg.m^{-2}) and Agro (6.68 kg.m^{-2}).

IV: *Fertilizers influence on total and marketable yield (kg.m^{-2}) in 2005–2006*

Fertilizer	Total yield (kg.m^{-2})			Marketable yield (kg.m^{-2})		
	2005	2006	2005–2006	2005	2006	2005–2006
Agormin T	7.79 a	7.06 a	7.42 a	7.15 a	6.30 a	6.73 a
Agro	7.63 a	6.91 a	7.27 a	7.15 a	6.20 a	6.68 a
Farmyard manure	7.16 a	6.65 a	6.91 a	6.58 a	5.88 a	6.23 a
Dvorecký agroferm	7.86 a	5.69 a	6.78 a	6.98 a	5.13 a	6.06 a
Control	7.81 a	5.79 a	6.80 a	7.07 a	4.96 a	6.02 a
Mineral fertilizers	8.18 a	5.08 a	6.63 a	7.36 a	4.49 a	5.93 a

Different letters between rows indicate significant differences at $P \leq 0.05$ (Tuckey HSD test)

Toor et al. (2006) also did not observed significant fertilizers influence on the yield of greenhouse grown tomatoes. In contrast, Quattrucci (2000) reported significantly higher yield in tomatoes fertilized with mineral NPK fertilizers compared to organic and organomineral ones and unfertilized control. Fruit size was similar in all fertilizer treatments and was better than in the controls. Non significant differences between control and fertilized variants in our study could be explained by high natural N_{min} level in the soil before fertilizing (Tab. I). By multiplicating numbers 19.54 and 22.33 mg.kg^{-1}, respectively (N_{min} levels in the soil in 2005 and 2006, respectively) with index 4.5 (according to Malý et al., 1998) we gain high level of N_{min} – 87.93 kg.ha^{-1} in 2005 and 100.33 kg.ha^{-1} in 2006, respectively. According to the results obtained by De Luca et al. (2006), mineral fertilization increased tomato yields up to 90 kg ha^{-1}, suggesting that the maximum yield could be reached with lower N supplies. The authors also found that yields obtained after green manure management and mineral fertilization were not significantly different. Gianquinto and Borin (1990) found different fertilizer influence on yield of tomatoes in dependence on the soil type. On the clay and sandy soils the higher yields were obtained with 20 t.h^{-1} of farm-

yard manure with combination 100 kg N + 50 kg $P_2 0_5$ + 150 kg $K_2 0$. On the peaty clay soil the best results gave only mineral fertilization (100 kg N + 50 kg $P_2 0_5$ + 140 kg $K_2 0$). The study of Parisi et al. (2006) indicated that high nitrogen doses increased total tomato yield but not marketable yield, because of a strong increase of unmarketable yield. The results are difficult to be compared with our experiment, because they used much higher nitrogen doses in their study. Gianquinto and Borin (1990) also reported, that high nutrients doses (200 kg N + 100 kg $P_2 0_5$ + 280 kg $K_2 0$) caused reduction of marketable yields.

The used fertilizers did not significantly influence total number of harvested fruits and mean fruit weight. Average values are presented in Tab. V. The highest number of fruits was observed with Agro (81.0 pieces.m^{-2}), the lowest one with mineral fertilizers (69.4 pieces.m^{-2}). The lowest fruit weight was observed with farmyard manure (78.7 g) and the control (79.6 g), the highest one with mineral fertilizers (82.9 g) and Agormin T (82.4 g), but the differences were not significant.

V: *Fertilizers influence on fruit number (pieces.m^{-2}) and fruit weight (g) in 2005–2006*

Fertilizer	Total fruit number (pieces.m^{-2})			Fruit weight (g)		
	2005	2006	2005–06	2005	2006	2005–06
Agormin T	87.3 a	70.1 a	78.7 a	78.8 a	86.0 a	82.4 a
Agro	84.1 a	77.9 a	81.0 a	82.6 a	77.1 a	79.9 a
Dvorecký agroferm	82.6 a	60.9 a	71.8 a	80.0 a	77.7 a	81.4 a
Farmyard manure	79.3 a	72.7 a	76.0 a	79.1 a	78.3 a	78.7 a
Mineral fertilizers	87.2 a	51.6 a	69.4 a	80.5 a	85.2 a	82.9 a
Control	82.9 a	61.5 a	72.2 a	81.5 a	82.7 a	79.6 a

Different letters between rows indicate significant differences at $P \leq 0.05$ (Tuckey HSD test)

Fertilizers had significant effect on ascorbic acid content and nitrates content in tomato fruits. Both traits were not significantly influenced by year (Tab VI). Regarding two years average values, the level of ascorbic acid varied between 168.3 mg.kg^{-1} (Agro) and 251.8 mg.kg^{-1} (Dvorecký agroferm). The average values correspond with data published by Kopec (1998) which mentioned 224 mg.kg^{-1} of ascorbic acid in tomato fruits.

VI: *Analysis of variance for ascorbic acid and nitrates (mg.kg^{-1}) in 2005–2006*

Source of variability	d.f.	MS	
		Ascorbic acid (mg.kg^{-1})	Nitrates (mg.kg^{-1})
Fertilizer	5	9687.51***	178.99***
Year	1	1005.01	14.22
Fertilizer x Year	5	1376.11	4.32
Residual	60	1580.18	35.85

*** $P \leq 0.001$

Dvorecký agroferm significantly increased ascorbic acid content in fruits compared to the control (Tab. VII). Zahradník and Petříková (2006) carried out analogous experiment with cucumber and, on the contrary to our results, they revealed the lowest ascorbic acid content in tomatoes fertilized with Agormin T and Dvorecký agroferm. But the differences were not significant. Audisio et al. (1995) showed that tomatoes treated with organic fertilizer had higher ascorbic acid content compared to mineral fertilizers. Elkner and Rumpel (1995) found that treatment with farmyard manure provided higher content of ascorbic acid compared to mineral fertilization and combination of mineral and organic fertilizers. Toor et al. (2006) observed that tomatoes fertilized with chicken manure and grass-clover mulch produced ascorbic acid 17.6% and 29% higher, respectively, compared to the tomatoes fertilized with mineral nutrient solutions. Patil et al. (2004) found the highest ascorbic acid content 267.6 mg.kg^{-1} in the variant treated with 50% recommended mineral fertilizers combined with the same rate of farmyard manure.

VII: *Fertilizers influence on ascorbic acid and nitrates (mg.kg^{-1}) in 2005–2006*

Fertilizer	Ascorbic acid (mg.kg^{-1})			Nitrates (mg.kg^{-1})		
	2005	2006	2005–2006	2005	2006	2005–2006
Agormin T	207.5 a	186.5 ab	197.0 ab	21.67 a	23.17 a	22.42 a
Agro	173.5 a	163.0 a	168.3 a	23.50 a	25.33 abc	24.42 a
Dvorecký agroferm	238.2 a	265.3 c	251.8 c	27.17 a	28.33 abc	27.75 b
Farmyard manure	207.7 a	227.3 bc	217.5 bc	27.67 a	28.83 bc	28.25 ab
Mineral fertilizers	205.2 a	236.0 bc	220.6 bc	22.50 a	21.00 a	21.75 a
Control	195.5 a	194.2 ab	194.8 ab	31.17 a	32.33 c	31.75 b

Different letters between rows indicate significant differences at P ≤ 0.05 (Tuckey HSD test)

The highest nitrates levels were found in the control and farmyard manure. The absolute values were deeply under the hygienic limit. Tomatoes fertilized with solo mineral fertilizers produced fruits with the lowest content of nitrates. Zahradník and Petříková (2006) reported similar results. On the contrary, Elkner and Rumpel (1995) found that farmyard manure only induced lower content of nitrates than other fertilizer variants (pure mineral, mineral and farmyard combination).

Fertilizers did not significantly influence total solids and carotenoids content in fruits in 2005–2006 (Tab. VIII). We found statistically significant differences between fertilizers for both traits only in 2006 (Tab. IX).

VIII: *Analysis of variance for total solids and carotenoids in 2005–2006*

Source of variability	d.f.	MS	
		Total solids (%)	Carotenoids (mg.kg^{-1})
Fertilizer	5	0.256	6.838
Year	1	23.072***	0.070
Fertilizer x Year	5	0.101	1.179
Residual	24	0.108	2.751

*** P ≤ 0.001

There was found significantly higher total solids content in fruits in 2005 compared to 2006. Average values of total solids in fruits are presented in Tab. IX. In 2006 the highest value was determined in Dvorecký agroferm (5.07%), which significantly differed to the control (4.49%) and Agormin T (4.37%). Over the 2-year period of assessment, fertilization with Dvorecký agroferm resulted in the highest total solids contents (5.78 mg.kg^{-1}) in fruits, the control showed the lowest value (5.29 mg.kg^{-1}). According to Parisi et al. (2006) very high nitrogen doses (250 kg.ha^{-1}) could decrease total solids content, but we worked with much more lower doses.

IX: *Fertilizers influence on total solids (%) and carotenoids (mg.kg^{-1}) in 2005–2006*

Fertilizer	Total solids (%)			Carotenoids (mg.kg^{-1})		
	2005	2006	2005–2006	2005	2006	2005–2006
Agormin T	6.42 a	4.37 a	5.40 a	20.38 a	20.31 a	20.35 a
Agro	6.13 a	4.55 ab	5.34 a	22.09 a	20.94 a	21.51 a
Dvorecký agroferm	6.49 a	5.07 b	5.78 a	18.81 a	18.78 a	18.80 a
Farmyard manure	6.56 a	4.89 ab	5.73 a	19.47 a	19.92 a	19.70 a
Control	6.09 a	4.49 a	5.29 a	18.69 a	20.24 a	19.47 a
Mineral fertilizers	6.18 a	4.90 ab	5.54 a	21.40 a	21.18 a	21.30 a

Different letters between rows indicate significant differences at P ≤ 0.05 (Tuckey HSD test)

The highest levels of carotenoids were found after using fertilizer Agro (21.51 mg.kg^{-1}), the lowest one with Dvorecký agroferm (18.80 mg.kg^{-1}). The average values of all tested fertilizers are presented in Tab. IX. Bímová and Pokluda (2006) analysed carotenoids in cucumber and cabbage. In cucumber they found the highest carotenoids content in the unfertilized control, the lowest one in Dvorecký agroferm, but the differences were not significant. On the contrary, in cabbage, they found the highest values in tomatoes treated with Dvorecký agroferm. The differences between fertilizers were not significant as well. We can conclude that fertilizers did not influence the level of carotenoids in tomato fruits.

SOUHRN

Výnos a kvalita keříčkových průmyslových rajčat hnojených sušenými organickými a organominerálními hnojivy

Ve dvouletém polním pokusu vedeném na Školním zemědělském podniku Mendelovy zemědělské a lesnické univerzity v Brně, v Žabčicích, byl v letech 2005–2006 hodnocen vliv tří alternativních sušených organických a organominerálních hnojiv na výnos, kvalitu a nutriční hodnotu keříčkových průmyslových rajčat, odrůdy 'Proton'. Pokus sestával z následujících variant hnojení: Agormin T, Agro, Dvorecký agroferm, chlévský hnůj, minerální hnojiva a nehnojená kontrola. Všechny varianty, kromě kontrolní, byly dohnojeny minerálními hnojivy na stejnou hladinu dusíku a draslíku (obsah fosforu v půdě byl velmi vysoký). Při sklizni byl hodnocen celkový výnos (kg.m^{-2}), tržní výnos (kg.m^{-2}), celkový počet plodů (ks.m^{-2}) a průměrná hmotnost 1 plodu (g). V plodech byl ihned po sklizni stanoven obsah dusičnanů a kyseliny askorbové (mg.kg^{-1} čerstvé hmoty) a následně byla hodnocena celková sušina (%) a obsah karotenoidů (mg.kg^{-1}).
Hnojiva statisticky významně neovlivnila celkový výnos, tržní výnos, počet sklizených plodů ani průměrnou hmotnost plodu. Nejvyšší celkový i tržní výnos vykázala varianta hnojená Agorminem T – celkový výnos 7,42 kg.m^{-2}, tržní výnos 6,73 kg.m^{-2}. Nejvíce plodů bylo sklizeno z varianty hnojené organickým hnojivem Agro (81,0 ks.m^{-2}). Hnojení pouze minerálními hnojivy a Agorminem T se projevilo v největším nárůstu průměrné hmotnosti plodu (82,9 g u minerálního hnojení, 82,4 g u Agorminu T). Dvorecký agroferm statisticky významně zvýšil obsah vitaminu C v porovnání s kontrolou. Také obsah dusičnanů byl statisticky průkazně ovlivněn hnojením, ovšem obecně byl velmi nízký. Nejvyšší obsah dusičnanů obsahovaly plody z kontrolní varianty, nejnižší z varianty hnojené pouze minerálními hnojivy. Hnojení nemělo statisticky významný vliv na obsah celkové sušiny ani na obsah karotenoidů v plodech. Nejvyšší obsah sušiny vykázala varianta hnojená Dvoreckým agrofermem (5,78 %), nejnižší kontrola (5,29 %). Nejvyšší obsah karotenoidů zaznamenala varianta hnojená Agrem – 860,5 mg.kg^{-1}, nejnižší Dvoreckým agrofermem – 751,9 mg.kg^{-1}. Všechna zkoušená alternativní hnojiva nesou potenciál vhodné náhrady chlévského hnoje. Pouze hnojení Agrem statisticky významně snížilo obsah kyseliny askorbové v plodech rajčat v porovnání s chlévským hnojem.

organická hnojiva, rajče, výnos, hmotnost plodu, celková sušina, kyselina askorbová, dusičnany, karotenoidy

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