THE USE OF DIGESTATE AS A REPLACEMENT OF MINERAL FERTILIZERS FOR VEGETABLES GROWING*

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The effect of anaerobically fermented pig slurry as a fertilizer on the quantitative parameters of two kinds of tomatoes and five kinds of peppers was assessed by the use of pot trials. These trials were carried out over a period of five years. Each trial involved four treatments, namely (a) control without fertilization, (b) fertilization with mineral fertilizers, (c) 50% nutrients in mineral fertilizers and 50% in fermented pig slurry, and (d) fertilization only with fermented pig slurry. Besides yield parameters in kg and in the number of fruit pieces, the dry matter content of vegetables was also monitored. A statistically significant influence of the year was found in the case of the yield and dry matter content parameters. The influence of cultivar was not found. The positive effect of the use of digestate was mainly seen in the case of combined method. The results showed that anaerobically fermented pig slurry can be a suitable alternative to the use of mineral fertilizer.

digestate; anaerobically fermented pig slurry; fertilization method; vegetables; quantitative parameters

INTRODUCTION

Bio-gas slurry as a digestate is a by-product from bio-gas stations resulting from the anaerobic fermentation of pig slurry during the bio-gas production. A common bio-gas plant with the power of 500 kW emits more than 10 000 t of digestate per year with a dry matter content of about 10% (Kratzeisen et al., 2010; Weiland, 2010). Such digestate is a significant biological product containing abundant nutrient elements and biologically active substances. Its main components are water, nitrogen in ammonium form, phosphorus, potassium, magnesium, calcium, and non-decomposed lignocelluloses. This heterogeneous mixture of compounds is an easily available and quick source of nitrogen with pH 7.6–8.5 (Pospíšil, Bitter, 2001). The digestate from anaerobic fermentation is also a valuable fertilizer due to the increased availability of nitrogen and the better short-term fertilization effect (Kratzeisen et al., 2010).

Anaerobically fermented pig slurry as an organic waste could be applied to soil, with or without mineral fertilizer, because it improves soil fertility, plant quality, and resistance to biotic and abiotic stress (Candráková et al., 2008; Mahmoud et al., 2009; Pospíšil, Mitrušková, 2009). Application of bio-gas digestate increased the yield and quality of sweet maize (Hanáčková et al., 2007; Hanáčková, 2009; Liu et al., 2009a). The result showed that maximum yield in sweet maize was obtained when treated with bio-gas digestate and chemical fertilizer. The same conclusion was obtained by Li et al. (2006) in the treatment of lettuce and by Liu et al. (2009b) in the treatment of grape with bio-gas digestate and chemical fertilizer. Fertilization with fermented bio-slurry positively affected quality and yield of sugar beet bulbs (Hanáčková et al., 2008; Babička et al., 2010). In addition, combination of organic and inorganic fertilizers increased plant growth, yield, quality, and soil fertility in experiments with cucumber, cabbage, and sweet pepper (Del Amor, 2007; Zahradník, Petříková, 2007; Mahmoud et al., 2009).

The aim of this study was therefore to determine the impact of the digestate application on the quantitative parameters (yield and dry matter content) of two kinds of commonly grown vegetables (tomatoes and pepper) in a long-term growing experiment.

MATERIAL AND METHODS

Vegetables cultivation and fertilization

Seeds of tomato (*Lycopersicon lycopersicum* L.) cultivars 'Start F1'and 'Tornádo F1' and seeds of pepper (*Capsicum annuum* L.) cultivars 'Amy', 'Folika',

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‘Ozarowska’, ‘Sluníčko F1’, and ‘Terezka’ were purchased from Semo Smržice Ltd. (Smržice, Czech Republic) and grown in greenhouses. Plants of tomato (30 cm) and pepper (20 cm) were then planted in 20 l pots in peat-bark substrate RKS I (Agro CS Inc., Říkov, Czech Republic). The substrate was enriched with fertilizers according to the fertilizing method. Ten plants were grown with each of the following fertilizing treatments: (a) control (marked N) – no added fertilisers; (b) mineral (M) – 15 g $(NH_4)_2SO_4$ and 9 g K_2HPO_4 added to each pot (20 l) prior to planting, and 7.5 g $(NH_4)_2SO_4$ added 30 days later; (c) organic (O) – 0.8 l of fermented pig slurry added to each pot prior to planting, and another 2 l of it added 30 days later; (d) combined (K) – 50% of mineral (7.5 g $(NH_4)_2SO_4$ and 4.5 g K_2HPO_4) and 50% of organic fertilizers (0.4 l of fermented pig slurry) added to each pot prior to planting, and 3.75 g $(NH_4)_2SO_4$ and 1.5 l of fermented pig slurry added 30 days after planting.

There were 10 plants for each cultivar and fertilizing method. The experiments were carried out over a period of five years in the case of tomatoes (2005–2009) and two years in the case of peppers (2007–2008), which represents a total of 400 tomato and 200 pepper plants.

Digestate characterization

The anaerobically fermented pig slurry was obtained from a bio-gas station (R.A.B. Ltd., Třeboň, Czech Republic) processing pig slurry from a swinery. The bio-gas station works continually with the same input. According to data from the supplier, the anaerobically fermented pig slurry consisted of (per l) 595 mg NH_4^+, 755 mg PO_4^{3-}, and 1.1–1.25 g K_2O. The pig slurry also fulfilled the limits for risk elements content (Collection of Laws, 2001, 2009).

Quantitative parameters determination

The mature tomato and pepper fruits were picked in their consumer maturity and immediately weighed on analytical balances Vibra AJ-2200CE (Shinko Denshi Co. Ltd., Tokyo, Japan) to two decimal places. Yield results were calculated as the total weight of all fruits from ten plants. For comparison of fertilizing methods, the yield of control samples was considered as 100%. Dry matter content was analyzed by drying (102 ± 2 °C, constant weight at difference less than 1 mg) (Davídek, Velíšek, 1992).

Table 1. Descriptive statistics of yield results from 10 tomato plants (in kg) according to fertilizing method

Fertilizing method	Minimum	Maximum	Mean	S.D.
Control	3.2	14.9	8.6	3.2
Mineral	7.4	34.4	18.8	9.5
Organic	4.1	36.6	17.0	9.9
Combined	10.4	34.7	21.1	8.2

S.D. = standard deviation

Table 2. Descriptive statistics of yield results from 10 tomato plants (in fruit pieces) according to fertilizing method

Fertilizing method	Minimum	Maximum	Mean	S.D.
Control	63	209	153	48
Mineral	167	444	274	94
Organic	86	483	244	112
Combined	219	403	303	55

S.D. = standard deviation

Table 3. Descriptive statistics of dry matter content of tomato fruit yield results (in %) according to fertilizing method

Fertilizing method	Minimum	Maximum	Mean	S.D.
Control	5.1	10.4	6.6	1.6
Mineral	4.1	7.4	5.8	0.8
Organic	5.0	20.4	8.3	4.8
Combined	5.0	16.4	7.7	3.8

S.D. = standard deviation

Statistical methods

To evaluate statistically significant differences between samples by the analysis of variance and Tukey's HSD test, and to determine correlation coefficients (*r*) between the data, the software STATISTICA (StatSoft, Version 8.0, 2007) was used. *P*-values < 0.05 were regarded as statistically significant (Currell and Dowman, 2009; Hendl, 2009). According to the correlation coefficients, the correlations were evaluated as weak ($|r| < 0.3$), moderate ($|r| = 0.3$ to 0.7), and strong ($|r| > 0.7$) (Elifson et al., 1998).

RESULTS AND DISCUSSION

The basic statistical characteristics (minimum, maximum, mean, and standard deviation (S.D.)) of the parameters analyzed according to the fertilization method are given in Tables 1–3 (tomatoes) and Tables 4–6 (peppers). Concerning tomato results for all five years, the year showed a statistically significant influence on the yield of tomatoes both in kg and in pieces. There were differences between the year 2005 and 2006 ($P_{kg} = 0.001$, $P_{pieces} = 0.002$), and between the year 2006 and 2007 ($P_{kg} = 0.002$, $P_{pieces} = 0.004$). The year also showed a statistically significant influence on the dry matter content of tomatoes ($P < 0.001$). The effect of cultivar on the yield and dry matter content was not found.

The highest yield of tomatoes and peppers (both in kg and in the fruit pieces) was reached with the combined fertilization method, while the lowest yield was obtained without fertilizer. Quantitative parameters for organic and mineral methods were not much different. Statistically significant differences in the yield of tomatoes in kg were proved between non-fertilized and combined method ($P = 0.013$), and in the case of fruit pieces between non-fertilized and combined method ($P = 0.002$) and non-fertilized and mineral method ($P = 0.017$) which showed the positive effect of the use of fertilizers on the tomatoes yield. In the case of pepper yield parameters no significant difference between organic and mineral or combined method was detected, too.

Dry matter contents of both kinds of vegetable samples observed in this study were in the following descending order: organic > combined > control > mineral

Table 4. Descriptive statistics of yield results from 10 pepper plants (in kg) according to fertilizing method

Fertilizing method	Minimum	Maximum	Mean	S.D.
Control	2.4	4.9	3.7	0.9
Mineral	2.6	6.1	4.6	1.2
Organic	2.7	6.2	4.4	1.1
Combined	3.8	6.2	5.4	0.8

S.D. = standard deviation

Table 5. Descriptive statistics of yield results from 10 pepper plants (in fruit pieces) according to fertilizing method

Fertilizing method	Minimum	Maximum	Mean	S.D.
Control	53	88	67	15
Mineral	43	107	76	21
Organic	63	83	74	8
Combined	58	94	82	13

S.D. = standard deviation

Table 6. Descriptive statistics of dry matter content of pepper fruit yield results (in %) according to fertilizing method

Fertilizing method	Minimum	Maximum	Mean	S.D.
Control	5.9	9.8	7.2	1.4
Mineral	6.2	8.1	7.1	0.8
Organic	5.5	8.7	7.8	1.2
Combined	4.1	8.9	7.4	1.7

S.D. = standard deviation

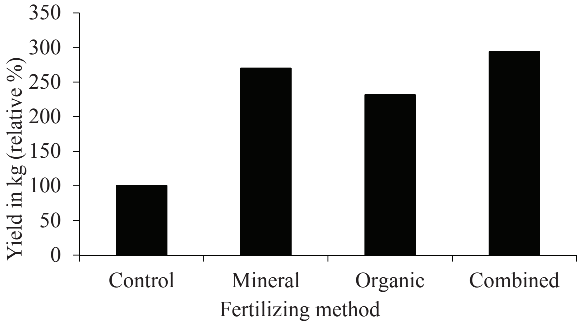

Fig. 1. Effect of digestate reuse on the yield parameters (kg) of tomatoes

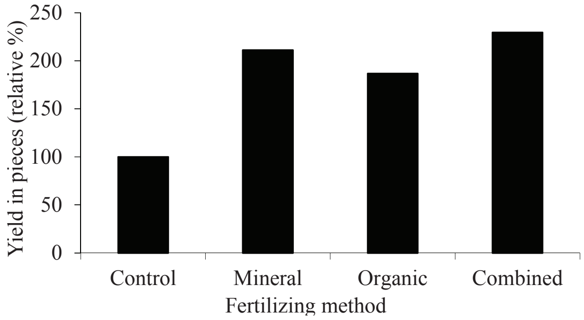

Fig. 2. Effect of digestate reuse on the yield parameters (fruit pieces) of tomatoes

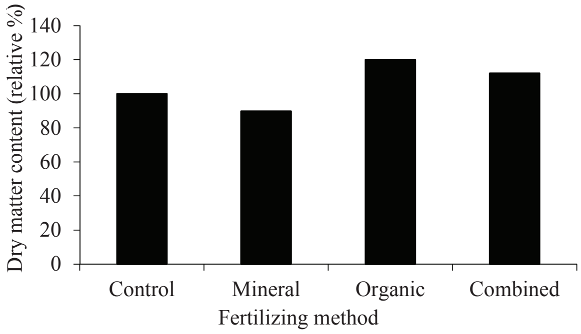

Fig. 3. Effect of digestate reuse on the dry matter content of tomatoes

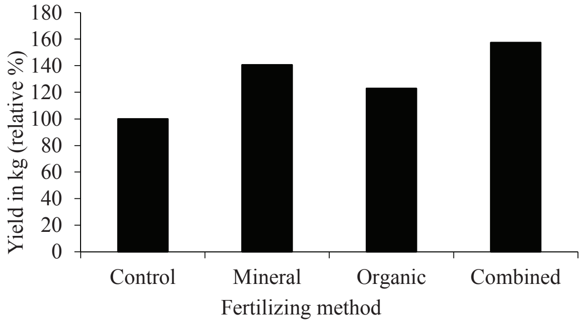

Fig. 4. Effect of digestate reuse on the yield parameters (kg) of peppers

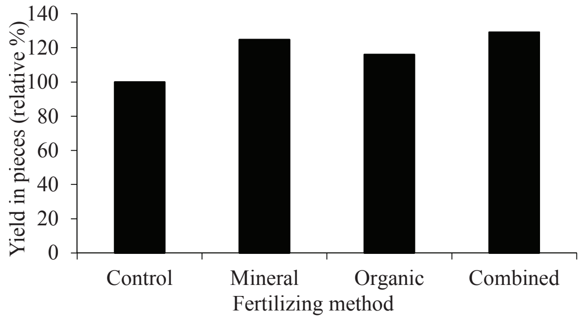

Fig. 5. Effect of digestate reuse on the yield parameters (fruit pieces) of peppers

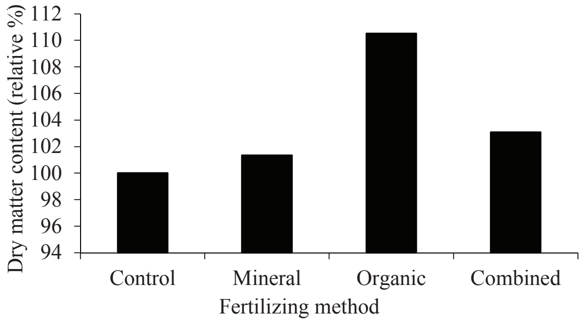

Fig. 6. Effect of digestate reuse on the dry matter content of peppers

method. The highest dry matter content of the monitored vegetable was obtained with the organic fertilization method, which shows that anaerobically fermented pig slurry matches the nutritional needs of the plants in the most suitable way. The higher dry matter content of vegetables fertilized by organic fertilizer compared to the lower content of dry matter in the case of mineral method can be an important information and factor for vegetable products (ketchups, dry products, puree etc.) industry. Dry matter content also significantly affects the shelf life of agricultural products. Lower water content inhibits the growth of undesirable microorganisms, especially fungi, which cause decay of the products.

In order to eliminate the effect of the year, the results were recalculated. The values from non-fertilized method for each year and cultivar were regarded as 100%, and all parameters from other methods were related to them. Comparison of these relative results is shown in Figs. 1–3 for tomatoes and Figs. 4–6 for peppers. The positive effect of the use of anaerobically fermented pig slurry as an organic fertilizer on the yield parameters is prominent mainly in the case of the combined method. This statement is in agreement with sweet maize, cucumber, sweet pepper, and cabbage experiments (Del Amor, 2007; Zahradník, Petříková, 2007; Hanáčková et al., 2008; Liu et al., 2009a; Mahmoud et al., 2009) where the combination of digestate and mineral fertilizer showed the highest yields as well. Concerning the dry matter content, fermented pig slurry seems to be the most effective fertilizer. Its power of the mineral fertilizer substitute is mainly seen in peppers results (Fig. 6).

The advantage of this study was its long-term duration (5 years) which enabled us to eliminate the effect of the year (weather conditions differences) on the monitored parameters. As the effect of cultivation was not statistically significant, the effect of fertilizing method was the main factor influencing the yield and the dry matter content of the studied tomatoes and green peppers.

CONCLUSION

This study confirmed that the use of fermented pig slurry as a replacement of mineral fertilizer for tomato and red pepper increased the dry matter content of these vegetable fruits. Digestate combined with application of mineral fertilizer was the best management system for increasing tomatoes and green peppers yields and decreasing of applied mineral fertilizer amount.

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Použití digestátu jako náhrady minerálních hnojiv při pěstování zeleniny

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Vliv použití anaerobně fermentované prasečí kejdy na kvantitativní parametry dvou odrůd rajčat a pěti odrůd paprik byl sledován za podmínek nádobových pokusů. Experimenty byly prováděny po dobu pěti let. Každý pokus zahrnoval (a) kontrolní variantu bez hnojení, (b) hnojení minerálním hnojivem, (c) kombinované hnojení 50% minerálním hnojivem a 50% fermentovanou prasečí kejdou a (d) hnojení pouze fermentovanou prasečí kejdou. Kromě výnosových parametrů v kg a počtech plodů byl také sledován obsah sušiny pěstované zeleniny. Byl zjištěn statisticky významný vliv ročníku na výnos a obsah sušiny. Vliv odrůdy nebyl prokázán. Pozitivní vliv použití digestátu byl sledován hlavně při aplikaci kombinovaného způsobu hnojení. Výsledky ukazují, že anaerobně fermentovaná prasečí kejda je vhodnou náhradou minerálních hnojiv.

digestát; anaerobně fermentovaná prasečí kejda; způsob hnojení; zelenina; kvantitativní parametry

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