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COMPARISON OF THE EFFECTIVENESS OF DIGESTATE AND MINERAL FERTILISERS ON YIELDS AND QUALITY OF KOHLRABI (*BRASSICA OLERACEA*, L.)

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Abstract

LOŠÁK, T., ZATLOUKALOVÁ, A., SZOSTKOVÁ, M., HLUŠEK, J., FRYČ, J., VÍTĚZ, T: *Comparison of the effectiveness of digestate and mineral fertilisers on yields and quality of kohlrabi* (*Brassica oleracea, L.*). Acta univ. agric. et silvic. Mendel. Brun., 2011, LIX, No. 3, pp. 117–122

In a one-year vegetation pot experiment we compared the effect of the digestate from a biogas station and mineral fertilisers on yield and quality parameters of kohlrabi, variety Seguza. Four treatments were used in the trial: 1) untreated control, 2) urea, 3) digestate, 4) urea, triple super phosphate, KCl, $MgSO_4$. The rate of N was the same in treatments 2–4, 1.5 g N/pot. In treatment 4 the rate of P, K and Mg corresponded with the rate of these nutrients in the digestate treatment (3).

The weight of single bulbs of the control unfertilised treatment were significantly the lowest (22.9%), as well as the nitrate (6.0%) and ascorbic acid content (66.2%) compared to the urea treatment (100%) and the other fertilised treatments. After the application of the digestate (treatment 3) and mineral fertilisers (treatment 4) the weight of single bulbs significantly increased by 27.9 and 29.2%, respectively, compared to the urea treatment (2). The content of ascorbic acid in the fertilised treatments did not differ (772–789 mg/kg) but it increased significantly compared to the unfertilised treatment (511 mg/kg). There were no significant differences between the two treatments fertilised with mineral fertilisers in the bulb nitrate content (678 and 641 mg NO_3^-/kg fresh matter, respectively). After digestate application their contents decreased significantly to 228 mg NO_3^-/kg fresh matter. Digestate treatment resulted in comparable or better yield and qualitative parameters compared to treatment with mineral fertilisers.

digestate, urea, mineral fertilisers, kohlrabi, yields, ascorbic acid, nitrates

In recent years we have seen a great expansion in the production and use of biogas in the Czech Republic namely for co-generation production of electricity and heat. For the farmers biogas stations (BGS) offer new and stable income for environmentally friendly energy; at the same time however this issue presents a number of new questions, including the subsequent use of anaerobic fermentation residues – the digestate (Cigánek *et al.*, 2010). Hitherto results of field or pot trials point out both the positive effects of the digestate in terms of yields (Gunnarsson *et al.*, 2010, Stinner *et al.*, 2008, Arthurson, 2009) as well as the insignificant effect (Ross *et al.*, 1989, Bath and Elfstrand, 2008).

If the digestate from biogas production comes exclusively from farm manure and roughage, Regulations No. 474/2000 Coll. characterise it as type organic fertiliser originating from anaerobic fermentation in the production of biogas with a minimal content of 25% of combustible (organic) matter and 0.6% of nitrogen. Each BGS will produce a digestate of a different composition, based namely on the sort, chemical composition and amount of raw matter entering the BGS and on the actual fermentation process (Cigánek *et al.*, 2010).

Based on the Government Decree No. 103/2003 Coll. (so-called Nitrate Directive) digestate is a fertiliser rapidly releasing nitrogen (C/N ratio less than 10); in vulnerable areas this fact limits or directly prohibits its use at a certain time and so makes higher demands on the storage capacities (Lošák, 2010).

Experts are divided in their opinions on the properties and possibilities of the practical use of digestate as an organic fertiliser. From the agrochemical point of view the principle problem is that the digestate contains only a small amount of degradable organic matter (Kolář *et al.*, 2010). Results of some experiments have shown that fermentation (digestion) reduces the content of labile organic fractions practically by one half, of medium-labile organic fractions by one fifth and that the content of stable organic fractions increases almost fourfold (Kolář *et al.*, 2010a). The digestion process results in the loss of great amounts of organic carbon; as much as 24–80% of dry matter of organic substances is transformed into methane (CH_4) and CO_2 (Möller, 2009). Primary labile organic matter is the source of energy for soil micro-organisms which in the process of mineralization transform into nutrients available to plants and into carbon dioxide; only a small part of the primary organic matter is transformed into humus substances (Lošák, 2010). The humus substances in the soil have a many-sided positive function and their sorption and ion-exchangeable capacity reduces the loss of nutrients (NO_3^-) from the soil by washing out – elution (Kolář *et al.*, 2008). In this way the presence and quality of organic substances has a significant effect on soil fertility. Although regulations define the digestate as an organic fertiliser, its composition and properties are closer to combined mineral fertilisers. When fertilising with digestates it is therefore necessary to apply to the soil at the same time other sources of primary (labile) organic matter of good quality – by ploughing down all post-harvest residues, fertilising with farm manure, compost and straw (Cigánek *et al.*, 2010, Lošák, 2010).

The objective of the vegetation pot experiment was to compare the effectiveness of the digestate and mineral fertilisers on yield and qualitative parameters of kohlrabi.

MATERIALS AND METHODS

The vegetation pot experiment was established on 7 June 2010; Mitscherlich vegetation pots were filled with 6 kg of medium heavy soil characterised as fluvial soil; Tab. I gives the agrochemical properties. The experiment involved 4 treatments given in Tab. II.

The digestate (C/N ratio 4/1) was obtained from a biogas station which uses pig slurry as the input raw material (ca 10 t a day) and maize silage from hybrid KWS 1393 (ca 16 t a day). Tabs. III and IV give the analysis of the digestate for the content of nutrients and hazardous elements. The contents of all the hazardous elements were below the limit specified in Regulations No. 271/2009 Coll.

Mineral fertilisers and digestate were applied in the form of watering and were thoroughly mixed with the entire amount of soil in the pot. Two

I: *Agrochemical characteristics of soil prior to trial establishment (Mehlich III)*

pH/ $CaCl_2$	mg/kg			
	P	K	Ca	Mg
7.5	34	159	6262	303
alkali	low	satisfactory	very high	good

II: *Treatments of the experiment*

Treatment No.	Scheme	Doses of nutrients (g/pot): N-P-K-Mg	Fertiliser
1	untreated control	0	–
2	N	1.5	urea
3	digestate	1.5-0.18-0.69-0.08	digestate
4	NPKMg	1.5-0.18-0.69-0.08	urea, triple superphosphate, KCl, $MgSO_4$

III: *Chemical analysis of the digestate for nutrient content*

%	nutrients				
	N	P	K	Ca	Mg
in dry matter	11.4	1.37	5.2	2.02	0.62
in fresh matter	0.72	0.09	0.31	0.13	0.04

IV: *Chemical analysis of the digestate for the content of hazardous elements and maximally admissible amounts*

	mg/kg dry matter								
	Cd	Pb	Hg	As	Cr	Cu	Mo	Ni	Zn
content	0.1	2.4	0.2	0.2	9.1	99	4.6	8.6	481
max.*	2	100	1	20	100	250	20	50	1200

*maximal admissible amount pursuant to Regulation No. 271/2009 Coll.

seedlings of kohlrabi variety Seguza were planted 10 days after fertilisation. The pots were watered to a level of 60% of the maximal capillary capacity and were kept free of weeds. The bulbs were harvested at full maturity on 2 August 2010. Immediately after harvest the individual bulbs without leaves were weighed. Nitrate concentration (mg NO_3^-/kg) was determined in the fresh matter of bulbs with a potentiometer using ion selective electrode (ISE). The content of ascorbic acid was determined in fresh matter using the capillary izotachoforesy method.

The results were processed statistically using variance analysis followed by testing according to Scheffe (P = 95%).

RESULTS AND DISCUSSION

a) Weight of single bulbs

Characteristic of kohlrabi is the high uptake of N from the soil (Feller and Fink, 1997) and in the process the deficiency of NO_3^--N in the soil reduces yields (Steingrobe and Schenk, 1991). Sharof and Weir (1994) studied the minimum amount of N required for vegetable crops including kohlrabi in relation to components of N balance in the soil and calculated that N requirement values were invariably lower than values from field trials.

As early as the first stages of growth a difference between the fertilised treatments (treatments 2–4) and unfertilised control (treatment 1) was visible; the colour of the latter was lighter and growth of the aboveground biomass was markedly slower. At harvest symptoms of phosphorus deficiency were detected on the bulbs of the control treatment (the bulbs turned violet in colour) which was the result of a low phosphorus supply in the soil and high pH value for its uptake.

V: *Weight of single bulb*

Treatment No.	Scheme	Weight of one bulb	
		g	rel. %
1	untreated control	37 a	22.9
2	N	161 b	100.0
3	digestate	206 c	127.9
4	NPKMg	208 c	129.2

Different letters (a, b, c) indicate significant differences among treatments

Weight of single bulbs is shown in Tab. V. The weight of the unfertilised bulbs (treatment 1) were by 77.1% lower than the treatment fertilised with nitrogen only (2). This means that N is the decisive element in terms of yields, as Hlušek *et al.* (2002), Feller and Fink (1997) pointed out. The weight of single bulbs fertilised with the digestate (treatment 3) and with mineral fertilisers (treatment 4) were significantly higher, i.e. by 27.9 and 29.2% respectively, than those fertilised with nitrogen only (treatment 2). Obvious is the positive synergic effect of additional nutrients (especially P, K, Mg) on yield formation in treatments 3–4. No significant differences were discovered between treatments 3–4. In experiments lasting several years Stinner *et al.* (2008) also reported positive effects of three different digestates (fermented clover-grass mixture, cover crops and post-harvest residues) on wheat yields. In the same way Bath and Elfstrand (2008) reported that yields of leek were the highest after the application of the digestate compared to fertilisation with compost. On soil with a low or satisfactory supply of available nutrients Cigánek *et al.* (2010) discovered that grain yields of winter wheat increased by 30.0–63.9% and seeds of winter rape by 38.5–57.7% compared to the unfertilised control.

b) Content of ascorbic acid and nitrates in bulbs

Vitamin C, including ascorbic acid and dehydroascorbic acid, is one of the most important nutritional quality factors in many horticultural crops and has many biological activities in the human body. The content of vitamin C in vegetables can be influenced by various factors such as genotypic differences, pre-harvest climatic conditions and cultural practices, maturity and harvesting method, and post-harvest handling procedures (Lee and Kader, 2000). Mozafar (1993) reported that nitrogen fertilisers, especially at high rates, seem to decrease the concentration of vitamin C in many different vegetables. By contrast Nilsson (1980) reported that nitrogen fertilisation did not affect the content of vitamin C in cauliflower.

Tab. VI shows the contents of ascorbic acid and nitrates. The lowest content of ascorbic acid was detected in the unfertilised control. The conclusions of a number of authors that adequate nutrition and fertilisation helps to increase yields and quality of production were confirmed (Hlušek *et al.*, 2002, Mengel and Kirkby, 2001). Maurya *et al.*

VI: *Content of ascorbic acid and nitrates in kohlrabi bulbs*

Treatment No.	Scheme	Content of ascorbic acid		Nitrate content	
		mg/kg FM	rel. %	mg/kg FM	rel. %
1	control	511 a	66.2	41 a	6.0
2	N	772 b	100.0	678 c	100.0
3	digestate	778 b	100.8	228 b	33.6
4	NPKMg	789 b	102.2	641 c	94.5

FM – fresh matter; Different letters (a, b, c) indicate significant differences among treatments

(1992) showed that, with a higher dose of nitrogen, cauliflower contained significantly more vitamin C. No significant differences in the ascorbic acid content were detected among the fertilised treatments (2–4).

Kohlrabi is a vegetable prone to a higher risk of nitrate accumulation in tissues (Hlušek *et al.*, 2002). The concentration of NO_3^- in plants is affected primarily by the vegetable species, level of N fertilisation, the respective plant organ, growth stage and the S concentration in the tissues (Lošák *et al.*, 2008, Marschner, 2002).

The lowest nitrate content was monitored in the unfertilised treatment (Tab. VI). The second lowest nitrate content was observed after digestate fertilisation (treatment 3). The reason could be that the digestate contains a specific proportion of organic N (25–50%) which is subject to mineralization after a certain time period (Kirchmann and Witter, 1992). It can be assumed that during the short period of kohlrabi vegetation (ca 7 weeks) only part of the organically bound nitrogen was mineralised. Therefore mineral N-NH_4^+ from the digestate (or after its nitrification N-NO_3^-) was available to the plants and was sufficient for yield formation and did not increase the nitrate content in the bulbs. In both treatments fertilised with nitrogen in urea (treatments 2 and 4) the nitrate content was the highest (Tab. VI) and exceeded their content almost threefold compared to the digestate-fertilised treatment (3).

SUMMARY

From the results of one-year trials it is obvious that digestate fertilisation resulted in weight of kohlrabi bulbs comparable to a similar rate of nutrients (N, P, K, Mg) applied in mineral fertilisers. In terms of qualitative parameters no significant differences in ascorbic acid contents were detected between the fertilisation treatments. The nitrate content in bulbs was almost three times lower in digestate-fertilised bulbs than in both mineral-fertilised treatments. Digestate application resulted in comparable or better yield and qualitative parameters than when mineral fertilisers were applied. The application of digestates can therefore save considerable costs for the purchase of mineral fertilisers. However digestates are poor in labile organic substances and the soil must be supplied from other sources.

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