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# WHAT IS MORE SUITABLE FOR KOHLRABI FERTILIZATION – DIGESTATE OR MINERAL FERTILIZERS?

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## Abstract

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In a one-year vegetation pot experiment, we compared the effect of digestate from a biogas station and mineral fertilisers on yield and quality parameters of kohlrabi, variety Moravia. Four treatments were used in the trial: 1) untreated control, 2) urea, 3) digestate, 4) urea, triple superphosphate, KCl, $MgSO_4$. The N dose was the same in treatments 2–4, 1.5 g N/pot. In treatment 4 the P, K and Mg doses corresponded to those supplied in the digestate treatment (3).
The weight of single kohlrabi bulbs in the unfertilised control was significantly lower (39.2%) than in the urea treatment (100%) and the other fertilised treatments. After application of digestate (treatment 3) and mineral fertilisers (treatment 4), the weight of single bulbs significantly increased by 18.6 and 25.2%, respectively, compared with the urea treatment (2). The content of ascorbic acid did not differ among the all four treatments (274–291 mg/kg). There were significant differences between all fertilised treatments (2, 3, 4) in bulb nitrate content (792, 327, 776 mg $NO_3^-$/kg fresh matter, respectively). The content of nitrates was the lowest in the unfertilised treatment – 135 mg $NO_3^-$/kg fresh matter. After digestate application the nitrate content decreased significantly, to 327 mg $NO_3^-$/kg fresh matter. We recommend the use of digestate to kohlrabi as it results in comparable or better yield and qualitative parameters of kohlrabi compared with mineral fertilizers.

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

## INTRODUCTION

Manures from stables, crop residues, wastes from food industry, municipal wastes, and dedicated energy crops are the main feedstocks for anaerobic digestion (AD) in biogas plants. The residual product of AD, called digestate (= biogas effluents = biogas residues, or biogas slurry, when animal manures are digested), is usually used as fertilizer (Möller and Müller, 2012). Biogas and digestate are the end-products of anaerobic digestion of organic raw material, which is an important source of renewable energy. Anaerobic digestion has been known for centuries, but rising prices of fossil fuel and increasing atmospheric pollution have boosted the interest in this process over recent years (Holm-Nielsen *et al.*, 2009; Weiland, 2010) and have made anaerobic digestion attractive to investors and consumers (Midillia *et al.*, 2006; Angelidaki *et al.*, 2011).

However, wide-scale biogas production raises a number of new questions, including the subsequent use of anaerobic fermentation residues – digestate (Cigánek *et al.*, 2010). Field and pot trials to date report positive effects of digestate application to arable land in terms of yield (Stinner *et al.*, 2008; Arthurson, 2009; Gunnarsson *et al.*, 2010) or no significant effects (Ross *et al.*, 1989; Bath and Elfstrand, 2008). Expert opinion is divided on the properties and possibilities for practical use of digestate as an organic fertiliser (Odlare *et al.*, 2008; Kolář *et al.*, 2008, 2010; Möller *et al.*, 2010, 2011; Lošák *et al.*, 2011). Digestion is associated with large losses of organic C (Möller, 2009). During the digestion process, 24–80% of organic dry matter is transformed to methane and carbon dioxide (Amon and Döhler, 2004). Möller and Müller (2012) reported that as much as 95% of the feedstock organic matter is degraded, depending on feedstock composition. However, the digestate produced is rich in N and has a high $NH_4^+$–N/total N ratio, making it potentially suitable as a fertiliser.

The aim of this study was to compare the effectiveness of digestate and mineral fertilisers on yield and qualitative parameters of kohlrabi.

## MATERIALS AND METHODS

The vegetation pot experiment was established on 27 May 2014 in the outdoor vegetation hall of Mendel University in Brno. 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 dry matter content of the digestate was 6.99%, pH 8.16 a C:N ratio 4.8:1. Tab. III gives the analysis of the digestate for the content of nutrients.

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 seedlings of early kohlrabi variety Moravia were planted 8 days after fertilisation. The pots were watered to a level of 60% of the maximal capillary capacity (demineralized water) and were kept free of weeds. The bulbs were harvested at full maturity on 18 July 2014. 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 a 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

A deficiency of $NO_3$–N in the soil reduces yields (Steingrobe and Schenk, 1991), because a characteristic of kohlrabi is high uptake of N from the soil (Feller and Fink, 1997). Sharof and Wier (1994) studied the minimum amount of N required for vegetable crops, including kohlrabi, in relation to components of N balance in the soil and found that N requirements were invariably lower than values from field trials.

As early as the first stages of growth in this pot study, there was a visible difference between the fertilised treatments and the unfertilised control. The plants in the latter had a lighter colour and growth of the aboveground biomass was markedly slower. At harvest, symptoms of P deficiency (violet discolouration) were detected on bulbs of the control treatment, which was the result of low P supply to the soil and unsuitable pH value for P uptake.

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

| $pH/CaCl_2$ | mg/kg | | | |
|---|---|---|---|---|
| | P | K | Ca | Mg |
| 7.6 | 49 | 166 | 12,111 | 342 |
| alkali | low | satisfactory | very high | good |

II: *Experimental set up to study the effect of digestate and mineral fertilization on kohlrabi*

| Treatment No. | Description | Dose of nutrients (g/pot): N–P–K–Mg | Fertiliser used |
|---|---|---|---|
| 1 | Untreated control | 0 | - |
| 2 | N | 1.5 | urea |
| 3 | Digestate | 1.5–0.24–1.35–0.14 | digestate |
| 4 | N, P, K, Mg | 1.5–0.24–1.35–0.14 | urea, triple superphosphate, KCl, $MgSO_4$ |

III: *Nutrient content of the digestate used for studying responses of kohlrabi*

| % | Nutrients | | | | |
|---|---|---|---|---|---|
| | Ntot | P | K | Ca | Mg |
| in fresh matter (FM) | 0.537 | 0.087 | 0.483 | 0.108 | 0.051 |

Content of N-$NH_4^+$ was 0.300% and content of Norg was 0.237% from the Ntot (0.537%)

IV: *The effect of digestate and mineral fertilizer on kohlrabi bulb weights*

| Treatment No. | Description | Weight of one bulb | |
|---|---|---|---|
| | | g | rel. % |
| 1 | Untreated control | 42 a | 39.2 |
| 2 | N | 107 b | 100.0 |
| 3 | Digestate | 127 c | 118.6 |
| 4 | N, P, K, Mg | 134 c | 125.2 |

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

Weight of single bulbs is shown in Tab. IV. The weight of the unfertilised bulbs (treatment 1) was 60.8% lower than in the treatment fertilised with nitrogen only (2). This confirms that N was the decisive element in terms of yield, as reported previously by Hlušek *et al.* (2002) and Feller and Fink (1997). The weight of single bulbs fertilised with the digestate (treatment 3) and with mineral fertilisers (treatment 4) was significantly higher, by 18.6 and 25.2% respectively, than the weight of those fertilised with nitrogen only (treatment 2). There was thus an obvious positive synergistic effect of additional nutrients (especially P, K, Mg) on yield in treatments 3 and 4. No significant differences were observed between treatments 3 and 4. In their previous experiment with kohlrabi of a different variety Lošák *et al.* (2011) came to the same conclusions; after the application of mineral fertilisers and/or digestate the yields increased by 17.9–19.4% as compared with nitrogen treatment only. In experiments lasting several years, Stinner *et al.* (2008) also reported positive effects of three different types of digestate (fermented clover-grass mixture, cover crops and post-harvest residues) on wheat yields. Similarly, Bath and Elfstrand (2008) reported higher yields of leek after the application of digestate compared with fertilisation with compost. On soil with a low or satisfactory supply of available nutrients, Cigánek *et al.* (2010) discovered that grain yield of winter wheat increased by 30.0–63.9% and seed yield of winter rape by 38.5–57.7% compared with the unfertilised control.

## b) Content of Ascorbic Acid 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 climate conditions and cultural practices, maturity and harvesting method, and post-harvest handling procedures (Lee and Kader, 2000).

Tab. V shows the contents of ascorbic acid in the kohlrabi bulbs. The content of ascorbic acid did not differ among the four treatments (274–291 mg/kg). However, in a previous experiment with the same kohlrabi variety (Lošák *et al.*, 2014) the content of ascorbic acid was found to be higher in all the fertilised treatments (441–458 mg/kg) as compared to the unfertilised treatment (398 mg/kg). Previous studies differ in their conclusions regarding the effect of nitrogenous fertilisation on the content of vitamin C. Mozafar (1993) reported that nitrogen fertilisers, especially at high rates, seem to decrease the concentration of vitamin C in many different vegetables. Similarly, according to Smatanová *et al.* (2004), the content of ascorbic acid in spinach decreased from 57.5 to 51.9 ppm when the rate of nitrogen increased from 0.6 to 0.9 g N/pot. In contrast, Nilsson (1980) reported that nitrogen fertilisation did not affect the content of vitamin C in cauliflower, while Maurya *et al.* (1992) showed that with a higher dose of nitrogen, cauliflower contained significantly more vitamin C.

## c) Content of Nitrates in Bulbs

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 species-specific factors, level of N fertilisation, the plant organ in question, growth stage and the S concentration in the tissues (Marschner, 2002; Lošák *et al.*, 2008).

The lowest nitrate content was observed in the unfertilised control (135 mg/kg FM) and the second lowest in the digestate treatment (327 mg/kg FM) (Tab. V). The reason could be that the digestate contains a specific proportion of organic N (25–

V: *The effect of digestate and mineral fertilizer on content of ascorbic acid and nitrate in kohlrabi*

| Treatment No. | Description | Content of ascorbic acid | | Nitrate content | |
|---|---|---|---|---|---|
| | | mg/kg FM | rel. % | mg/kg FM | rel. % |
| 1 | Untreated control | 281 a | 96.5 | 135 a | 17.0 |
| 2 | N | 291 a | 100.0 | 792 c | 100.0 |
| 3 | Digestate | 274 a | 94.1 | 327 b | 41.2 |
| 4 | N, P, K, Mg | 283 a | 97.2 | 776 c | 97.9 |

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

50%), which is subject to mineralisation after a certain period (Kirchmann and Witter, 1992). It can be assumed that during the short period of kohlrabi growth (approx. 6 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, but did not increase the nitrate content in the bulbs. The nitrate content was highest in the two treatments fertilised with nitrogen in the form of urea (792 mg/kg of FM in treatment 2 and 776 mg/kg of FM in treatment 4). Urea is a readily soluble mineral fertiliser and plants can take up N from urea in the form of whole molecules or after decomposition as $NH_4^+$ or $NO_3^-$ (Mengel and Kirkby, 2001).

## CONCLUSION

The results of one-year trials showed that there were no differences in bulb yields between the application of digestate and mineral fertilisers (NPKMg). The nutrients from the digestate were more useful in terms of quality parameters (nitrates content) of kohlrabi than urea. Digestate application and incorporation in the soil prior to planting out kohlrabi can be recommended. 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 – farmyard manure, straw, green manure, compost.

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