Biogas nutrient *management* in organic cropping – not only a nitrogen issue

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Implications

Nutrient imbalance, mainly due to low K and high Ca and/or Mg concentrations, was a plausible explanation for low growth response to digestate fertilisation by beetroot following harvested grass-clover biogas ley. To derive the full benefit of a transition to a biogas nutrient management (BG) system, extra nutrients except for N may need to be added, especially if digestate supply is divided between many crop positions in the rotation. This is probably of extra importance on sandy soils such as that used in this experiment.

Background and objectives

Nitrogen is often mentioned as the most growth-limiting parameter in organic cropping, especially where farm manure is not available and green manure is the main nutritional instrument. However, in a BG system biodigestion of ley and use of the digestate as fertiliser instead of green manuring may reduce the N limitation. The objective of this study was to identify whether, in an organic BG system without supply of farm manure, nutrients other than N may limit beetroot growth in general and following harvested ley in particular.

Key results and discussion

Dry matter production in beetroot with barley as pre-crop responded linearly to plant-available N (PAN) in 2003, both 32 days after sowing (DAS) (Figure 1) and at final harvest. In 2004 the response followed a linear plateau function indicating no further increase in biomass 32 DAS for more than 139 kg PAN ha^{-1} and in biomass at final harvest for more than 145 kg PAN ha^{-1}. Beetroot generally had lower DM biomass at 32 DAS following ley than following barley, even when PAN was the same. The same pattern was seen in 2004 for final harvest of beetroot following ley harvested twice (2H-ley) and three times (3H-ley), but not following green manure ley (GrM). For final harvest in 2003, the response to PAN was equal for barley and ley pre-crops (not shown).

PAN was the most important variable explaining the amount of total biomass at final harvest of beetroot in 2003. However, PAN was of little importance at 32 DAS in both years and at final harvest in 2004. Compositional nutrient diagnosis (CND) imbalance index showed that K deficiency was significantly greater in beetroot following 2H- and 3H-ley than following barley both at 32 DAS and at final harvest (Table 1). The plants had compensated by increased uptake of Mg and/or Ca. At 32 DAS boron level was also lower following 3H-ley than following barley.

How work was carried out

Fertilisation, with digestate from biodigested plant material, of an organic beetroot crop, with barley, GrM, 2H- or 3H-ley as previous crops, was investigated in field experiments on a sandy soil in 2003 and 2004, including treatments without digestate supply. The beetroot crop following barley was fertilised with digestate according to four different N target values based on the sum of mineral N in soil and NH_4-N in digestate. For beetroot following the different leys only one digestate treatment was included, with supply according to a low N target value. The supply of digestate differed with ley pre-crop and barley at the low N-target value, but the sum of mineral N in soil and NH_4-N added with the digestate was equalized between pre-crops. The actual supply of NH_4-N with digestate to beetroot following barley was 43, 105, 156 and 202 kg ha^{-1} (mean of two years). The actual supply to the beetroot crop following ley were 26, 54 and 65 kg NH_4-N ha^{-1} (mean of two years) for GrM, 2H- and 3H-ley, respectively. The beetroot crop

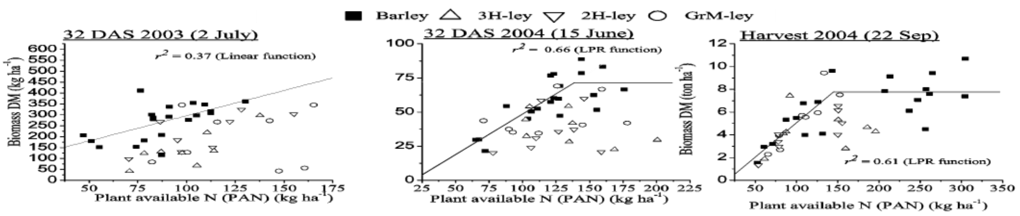

Figure 1. Biomass dry matter in beetroot plants with different pre-crops as a function of plant-available N. The regression lines refer to treatments with barley pre-crop only. DAS = Days after sowing.

without addition of digestate was supplied with 40 kg Na ha^{-1} (Besal, AB Hansson & Möhring) and 150 (after barley), 100 (after GrM) or 200 (after H-ley) kg K ha^{-1} (Kali vinasse). The nutrient concentrations (kg Mg^{-1} fresh weight) in the digestate were: 1.3 NH_4-N, 1.9 N_{org} (i.e. 3.2 total N), 0.4 P, 4.2 K, 1.0 Na, 0.4 Mg, 0.2 S, 0.141 Fe, 0.006 Mn, 0.005 Zn, 0.004 B and 0.001 Cu. The C:N_{org} ratio was 10.

PAN was defined as supply of effluent NH_4-N and apparent contribution of mineral N from soil, including mineralised N from pre-crop residues. Calculations of mineral N from soil was based on the 0-30 cm soil layer at 32 DAS and on the 0-60 cm layer at final harvest.

Partial Least Squares (PLS) (c.f. Magnusson 2002) and CND, calculating nutrient balance index, (Parent and Dafir 1992) were used to interpret nutrient status in plant biomass. In the PLS model, the explanatory variables were PAN and nutrient concentration (log-ratio) of 12 macro- and micronutrients. CND norms were derived from 22 aeroponic experiment treatments with dynamic nutrient supply further described in Gunnarsson (2012, Paper IV).

Table 1. Nutrient imbalance index[§] and, within brackets, nutrient concentration (% for K, Ca and Mg; ppm for B) in digestate-fertilised beetroot. All beetroot fertilised to the same N target value. Mean for 2003 and 2004. Different letters show significant difference (5% level, Dunnet) for the nutrient compared with barley pre-crop as a control[§§]

	32 DAS				Final harvest (total plant)			
Nutrient	Barley	GrM-ley	2H-ley	3H-ley	Barley	GrM-ley	2H-ley	3H-ley
K	-0.8a	-1.8a	-2.9b	-2.9b	-2.9a	-3.0a	-3.9b	-4.7b
	(6.82)	(6.11)	(5.54)	(5.31)	(2.65)	(2.73)	(2.39)	(2.20)
Ca	3.0a	4.1b	4.0b	3.6a	1.14a	2.32a	2.33b	1.0a
	(1.38)	(1.67)	(1.69)	(1.56)	(0.51)	(0.65)	(0.69)	(0.52)
Mg	0.1a	0.7a	1.2b	1.8b	no significant differences			
	(1.18)	(1.29)	(1.41)	(1.52)				
B	-2.7a	-3.3a	-3.5a	-3.8b	no significant differences			
	(29.9)	(27.8)	(27.5)	(26.3)				

[§] Imbalance calculated as described by Khiari *et al.* (2001). High negative value indicates deficiency and high positive value surplus compared with the norm. [§§]Only nutrients for which significant differences were found are included (P, Mn, Cu, N, Zn, Fe, Na and S were also tested)

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