Influence of preceding crop, site and nitrogen management on yield of organic oil seed rape (*Brassica napus* L.)

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Background

Plant nutrient supply is a key issue in production of organic winter oil seed rape (WOR). The variation in nitrogen (N) application and yield level varies greatly meanwhile there is lack of knowledge about crop N demand and profitability during different conditions, i.e. influence of the previous crop and other site specific conditions. The production of organic oil seed rape is often hazardous and the grower has to expect great variations in yield levels (Wallenhammar, 2005). WOR demands high amounts of available soil N to achieve an adequate yield. The N demand is large during the vegetative stages (Schultz, 1972), and variation in yield of WOR is due to availability of N during growth and development (Rathke et al., 2006). Recent investigations (Stenberg et al., submitted), showed that the effect on yields of WOR of different sources of organic fertilizers, application dates and distribution techniques varied greatly between years.

Farms with high yield levels were in a monitoring study found to use both large amounts of manure as well as no fertilizers at all (Wallenhammar, 2005). Soil N mineralization varies highly both within field and between fields. In a large number of field experiments in winter wheat and spring barley, the amount of N harvested in unfertilized plots ranged from 22 to 116 kg N ha^{-1} (Gruvaeus, 2007). This variation is large also within fields (Delin, 2005). Subsequently, there are large variations both within a field and between fields of the amount of N available from the soil mineral pool. This is an important issue for the farmer from an economical perspective as well as an environmental issue as N supplied but not used by the crop partly can be lost to the surrounding environment.

Recommendations of N application are today often based on results from single or very few field experiments and in practice. Large amounts of manure are often applied prior to establishment in August, which may cause large losses of N by leaching during late autumn and winter. Jensen et al. (1997) found in pot experiments with ^{15}N labelled fertilizer that at low N use rates, spring applied N fertilizer remained in the soil mineral N pool after harvest of the rape crop. Increased leaching after excess N rates in spring was found by others (e.g. Engström et al., 2011). There is a need to improve tools used by advisors and farmers to predict the N demand.

The objective of this study was to increase the knowledge of the possibilities to adjust the N application by organic fertilizers to the previous crop and site with the aim to develop N management strategies for N application in organic winter oil seed rape.

Materials and methods

This study was carried out in 12 field experiments in south Sweden during 2009-2010. The effects of different N levels under varying preconditions were determined by quantifying the yield and N demand in relation to different soil parameters. The experiments were fully randomized two factorial carried out with four replicates with two levels of N application in autumn (0 or 50 kg N ha^{-1}) and five levels in spring (0, 50, 100, 150 or 200 kg N ha^{-1}). N was supplied in autumn as Biofer 10-3-1 (10% N, 3% phosphorus and 1% potassium) and in spring as Vinasse, a by-product from yeast production with on average 4% N and 4% potassium. The experiments had four replicates.

The crops were scanned plot-wise for estimation of N content and biomass volume in autumn and in BBCH 51-57 (Lancashire et al., 1991) by a handheld N-sensor measuring the NIR reflectance from the crop. Plant density was also determined. Plants were sampled for analysis of dry matter yield and N content on the occasions for N-sensor scanning. Soil mineral N content in 0-90 cm was quantified at sowing, early spring and at harvest. Seed yield and quality including seed N content was determined in each plot at all sites. Economical optimum N fertilisation was determined as N rate at the highest net income assuming a seed price of 6 SEK kg^{-1}, N cost 22 SEK kg^{-1} and cost for transport and drying 0.2 SEK kg^{-1}. Each experimental site was characterized regarding crop rotation history and several soil characteristics as soil texture, organic matter content and soil electrical conductivity measured with EM38. Here we focus on seed yields in relation to N fertilisation and site.

Results and discussion

Seed yields differed between sites and years and ranged from very low yields, about 500 kg ha^{-1}, to 4080 kg ha^{-1} in plots without N fertilization (Table 1). Yield increases from the autumn application was on average 135 kg ($p=0.0012$) and in spring 700 kg at the highest N level compared with no N ($p<0.0001$). Pollen beetles (*Meligethes aeneus*) and cabbage stem flea beetles (*Psylliodes chrysocephala*) caused high yield losses at some of the experimental sites and in these cases the yield responses from N application was negligible. High variation within the experiments was noted, shown by high coefficients of variation (CV) and experiments with known damages and a CV value above 15% for the seed yield were excluded from further analysis of the yields. Yield increases were up to 1400 kg ha^{-1} at the highest spring N application rate recorded at a site with a long lasting set-aside as preceding crop.

Table 1. Seed yield (kg ha^{-1} at 9 % water content) of eight of the field experiments in the study in 2009 (L) and 2010 (M)

Experimental site and region	**L005 Gotland**	**L006 Skåne**	**L007 Skåne**	**L008 West**	**M001 Skåne**	**M002 Skåne**	**M007 West**	**M008 SWest**
Preceding crop	Pasture	White clover	White clover	Ley	Set-aside (14 year)	White clover	Green manure	Ley II
Soil	Silt	Silt	Sand	Silt	Sand	Sand	Silty clay	Sand
Sowing	15 Aug.	1 Sep.	1 Sep.	25 Aug.	20 Aug.	27 Aug.	20 Aug.	19 Aug.
Fertilisation autumn	4 Sep.	17 Sep.	11 Sep.	-[1]	3 Sep.	16 Sep.	8 Sep.	18 Sep.
Fertilisation spring	8 Apr.	8 Apr.	8 Apr.	-[1]	31 Mar.	8 Apr.	15 Apr.	28 Apr.
Variety	Cadillac	Carousel	Calypso[2]	Calypso[2]	Calypso[2]	Hornet[2]	Calypso[2]	Hornet[2]
F1: 0 kg N autumn	2750	4021	2875	2822	2795	2361	1828	2947
F1: 50 kg N autumn	2889	4061	3004	2745	3116	2420	1987	3361
F2: 0 kg N spring	2808	4079	2713	2281	2239	2060	1441	2340
F2: 50 kg N spring	2904	4049	2778	2580	2502	2360	1830	3177
F2: 100 kg N spring	2793	3991	2894	2733	2971	2386	1888	3520
F2: 150 kg N spring	2926	4079	3103	3116	3391	2504	2153	3430
F2: 200 kg N spring	2668	4005	3209	3208	3674	2641	2224	3303
CV (%)	7.2	5.4	8.5	4.2	7.4	12.6	14.8	13.2
F1	0.0393	n.s.	n.s.	0.0522	0.0001	n.s.	n.s.	0.0170
F2	n.s.	n.s.	0.0018	<0.0001	<0.0001	0.0096	0.0002	0.0011
F1*F2	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Optimum N level	0	0	0	163	190	41	61	68
Seed yield at optimum N level	2824	4086	2716	3118	3640	2304	1833	3376
Net income at optimum N level	16376	23698	15755	14497	16934	12462	9287	18084
Yield increase at optimum n level	0	0	0	824	1393	238	390	1057

[1] Missing data, [2] Hybrid varieties.

There was no response from spring N application in three of the experiments (L005-L007; Table 1) when white clover and pasture constituted the preceding crops. These crops most likely contributed to high soil N availability during growth of WOR, thus explaining the high yield level in unfertilised WOR. A small N response was obtained at two sites (M002 and M007) with white clover or green manure as preceding crop. The weak N response at M007 may be due to a dry period in spring reducing mineral N availability in the soil.

The highest responses from spring N fertilisation were recorded in experiments with ley (mixed grass and clover; L008 and M008) or a set-aside (M001) as preceding crops. Here, optimum N rate ranged from 68 to 190 kg N ha^{-1} and the yield increase ranged from 824 to 1393 kg ha^{-1}. The highest N response was recorded after a 14 year old grass set-aside. Here the soil profile was likely depleted from mineral N and N immobilisation was considerable due to incorporation of crop residues with low N content. The high N response after the grass/clover leys may be caused by N leaching losses from the sandy soils and high rainfall as at M008. Also dry weather in spring, as in the experimental years, reducing N mineralisation might have contributed to the response as at L008 and M007.

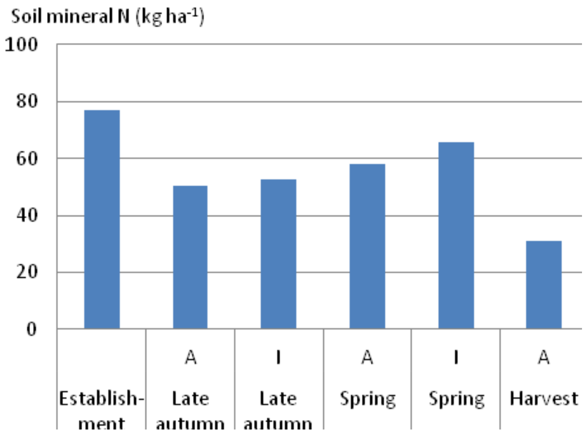

Fig. 1. Soil mineral N as averages for all sites 2009-2010. Treatment A=0+0 kg N and I=50+150 kg N.

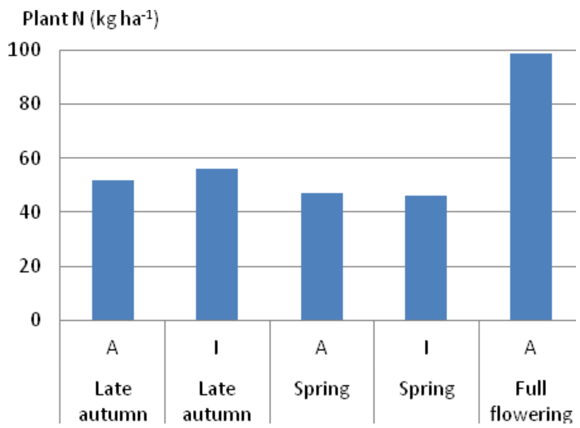

Fig. 2. Above ground plant N as averages for all sites 2009-2010. Treatment A=0+0 kg N and I=50+150 kg N.

Soil mineral N showed large variation between sites with on average almost 80 kg N in the control treatment at establishment of the crops (Fig. 1). In late autumn there was on average a small difference in soil N as well as above ground plant N (Fig. 2) depending on autumn fertilisation or not, indicating a large uptake during autumn even if there still were considerable amounts of N in the soil profile in late autumn. Measurements by N-sensor indicated higher N uptake in plots fertilised in autumn on sites with a well-developed crop cover (data not shown).

Total N as soil mineral N at 0-90 cm depth along with above ground plant N, in late autumn (Fig. 3) as well as in spring (Fig. 4) showed correlation with seed yields in the 0 N treatment. Sites with high N delivery, depending on preceding crop and management history, during autumn were also the highest yielding as shown by the seed yields at the different N application rates. Soil N availability in spring, expressed as N-uptake in crop and soil mineral N (0-90cm), was negatively correlated to optimum N rate in spring ($y = -1.0x + 204$, $R^2 = 0.67$).

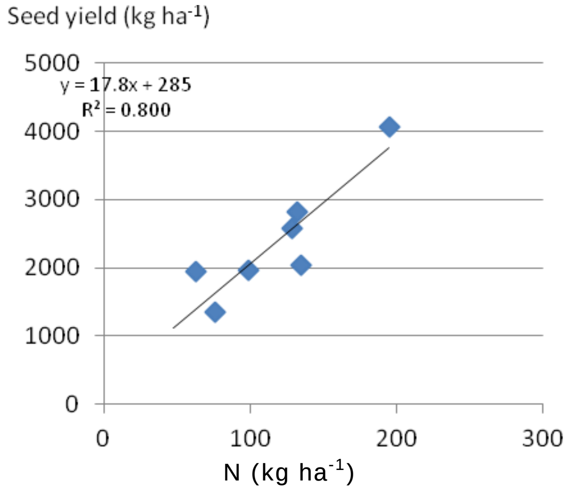

Fig. 3. Late autumn soil mineral N and above ground plant N vs. seed yield in the 0N treatment.

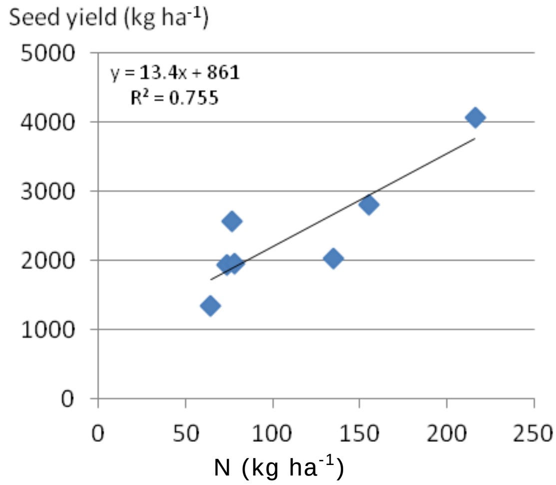

Fig. 4. Spring soil mineral N and above ground plant N vs. seed yield in the 0N treatment.

Since the N response of spring N fertilisation varies depending on both preceding crop and on soil type as well as weather conditions recommendations cannot be generalised and has to be determined specifically for a site. The results indicate that N uptake and soil mineral N in spring should be considered when calculating optimum N-rate in spring. Autumn N fertilisation can only be recommended to organic WOR when the preceding crop is causing N immobilisation or N losses are expected.

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