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Nutrient supply for organic oilseed crops, and quality of potential organic protein feed for ruminants and poultry

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Abstract. The aim of organic farming husbandry is to be entirely based on an organically produced diet. Pea is the most commonly cultivated protein rich crop in organic agriculture in Norway. However other high protein crops with complementary properties are needed to meet the nutritional demands in feeds for ruminants, pigs and poultry. An ongoing study in Bioforsk aims to develop cultivation practices on nutrient supply for organic oilseed crops and to establish knowledge on the feed quality of organically grown oilseed crops used as protein feed. It appears that spring turnip rape (*Brassica rapa* L. var. *oleifera*) and Camelina (*Camelina sativa* L.) can both be successfully cultivated with different levels of supplied nitrogen and sulphur. The nutrient value of organic spring turnip rape seems to be equivalent to conventional protein crops. Camelina can be an alternative in organic production, due to fewer problems with harmful pests compared with the traditional oilseed crops rape and turnip rape. Oilseed cake of turnip rape has higher protein and mineral content than the seed, and can be an interesting addition in feed ration for both ruminants and poultry, especially in combination with field pea.

Key words: Oilseed crops, concentrates, oilseed cake, pea, rape, turnip rape, camelina

INTRODUCTION

Earlier studies have indicated that the content of crude protein is low in the herbage from an organic ley (Ebbesvik, 1998; Haglund et al., 2000; Johnsson, 2002), resulting in insufficient protein content to meet the nutritional demands of e.g. highly productive milking cows. Therefore feedstuffs with additional protein are normally added to the ration. Husbandry in organic farming should be based entirely on an organically produced diet (Council for The European Union, 1999). An obstacle in the production of concentrates for use in organic farming is that extracted soybean meal, which is the main protein source in conventional concentrates, is not permitted in organic husbandry. This is due to a general ban on the use of chemical extraction in fodder production in organic farming (www.debio.no). Fish meal has been a vital constituent in concentrates and has secured the need for high-quality proteins in organic husbandry. However, precautions to avoid contamination with meat and bone meal, in addition to a high price, have made it important to look for alternatives.

Currently, pea is the most commonly cultivated protein-rich crop in organic agriculture in Norway. However other high protein crops with complementary properties are needed to meet the nutritional demands in feeds for ruminants, pigs and poultry. Oilseed crops, which are rich in both fat and protein, will become a viable alternative if problems related to their cultivation are solved. The content of chemical constituents such as protein, fat, NDF (neutral detergent fibre) and amino acids varies among crops. In addition, nutritional quality parameters like fatty acid composition and rumen degradability of protein varies greatly among crops as well. High rumen degradability of protein results in a protein value of feeds for ruminants (Madsen et al., 1995). Moreover, turnip rape (*Brassica rapa* L. var. *oleifera*) and rape (*Brassica napus* L. var. *oleifera*) are rich in unsaturated fatty acids, which restrict the content of oilseeds that can be used in the daily feed ration for ruminants. However, the value of oilseeds in the rations for rumninants can be increased if fat is removed and protein value increased through processes like expelling. Moreover, the oilseeds are rich in S–containing amino acids, complementing the amino acids found in peas. Camelina (*Camelina sativa* L.) or gold of pleasure is another oilseed crop, which may have considerable interest for organic cropping in northern areas (Alen et al., 1999). It has a low nutrient requirement, no seed dormancy, less problems with insect damage than rape and turnip rape and the seed quality makes it interesting both for edible oil and animal feed (Vollmann et al., 1996). Experiments with conventionally grown oilseeds crops show great difference in protein and fat content according to the N–fertilization rate (Rathke et al., 2004; Asare & Scarisbrick, 1995). Currently, our experience with oilseed crops in organic agriculture in Norway is limited, and we do not know to what extent limitations in the nitrogen (N) supplement will influence the content of crude protein and fat. In addition, N and sulphur (S) application have increased the seed glucosinolate concentration (Asare & Scarisbrick, 1995). Different fertilization strategies may perhaps result in differences in the feed quality. Experiment with long–term cattle manure application to rape increased the total N–content and decreased the oil content in seed (Hao et al., 2004). The objective of the present study is to develop cultivation practices on nutrient supply for organic oilseed crops and establish knowledge on the feed quality of organically grown protein crops. Quality parameters of significance for the use of crops in the production of concentrate for ruminants and poultry are prioritized. The oilseed crops included in the study is winter rape, winter turnip rape, spring turnip rape and camelina. The trials are carried out at Bioforsk Arable Crops Division, Research Farm Apelsvoll in Norway and Swedish University of Agricultural Science, Lanna Research Station in Sweden. This paper presents results from the field experiments at Apelsvoll in 2007 and 2008.

MATERIALS AND METHODS

Fields with peas, spring sown green manure and barley were established as pre–crops for turnip rape and camelina in the spring of 2006, 2007 and 2008 on the organic research area at Research Farm Apelsvoll. The green manure crop consists of white clover (*Trifolium repens*), ryegrass (*Lolium spp*.) and phacelia (*Phacelia tanacetifolia*). The spring turnip rape ('Petita') and camelina ('unknown') field trials were fully randomized experiments with four levels of N-fertilization; 0, 40, 80 or 120 kg total N ha^{-1} (chicken manure pellets). Each experiment has three replications. Trials on pre–crop barley had in addition sulphur fertilization ($CaSO_4$+$2H_2O$ –powdered gypsum) as an added factor. Levels of S-fertilization are 0 and 20 kg total S ha^{-1}. In order to prevent yield loss, the turnip rape trials were covered by nets, efficiently keeping birds out. Samples of spring turnip rape from the respective fields in 2007 and 2008 at Apelsvoll were sampled and analysed chemically for ash (method EU DIR 71/250), starch (method AOAC 996.11), protein (method EU DIR 93/28), fibre (method EU DIR 92/89), NDF (method Ankom), fat (method EU DIR 98/64), amino acids (method SS-EN ISO 13903:2005) and the minerals Ca, P, Mg (minerals method NS-EN ISO 11885) and S (method NMKL161 mod; ICP-AES). The samples were from the experimental plots with maximum and minimum N– and S–fertilization. One sample of camelina from Apelsvoll in 2007 was analysed to get an impression of the chemical composition compared with turnip rape. In the autumn 2006 samples of field pea (varieties Faust, Integra and Pinochio) from six different farms, including Apelsvoll, were analysed chemically for ash, starch, protein, NDF, fat, fibre, calcium (Ca), phosphorus (P) and magnesium (Mg). In 2008 one pea sample from Lanna and one sample from Apelsvoll (variety Faust) was also analysed for the same compounds in addition to amino acids. To evaluate the effect of different N– and S–fertilization on the chemical composition of the feed samples, data were analysed using GLM analysis of variance in Minitab. Multiple comparisons was accomplished with the Tukey-Kramer method (P = 0.05).

DISCUSSION AND RESULTS

The results presented include data from field trials in 2007 and 2008 examining the effect of different levels of fertilizing for turnip rape and camelina. Results from pea analyses from 2006 and 2008 are also included.

The results from the analyses of spring turnip rape were comparable to results from conventional studies as shown in table 1. The amino acid profile is also quite comparable with values from the feed tables (Feed table, 2008). Based on these results, organic manure and mineral fertilizer do not seem to result in differences in feed quality of organically grown spring turnip rape compared to spring turnip rape from conventional farming. The results from the pea analyses were quite comparable to results from conventional studies (Table 1). This was an expected outcome as very little fertilization is recommended on field peas in general.The chemical composition of camelina was comparable with spring turnip rapeseed, but camelina seems to have higher content of S (0.66% DM), lower content of Ca (0.30% DM) and higher content of protein (24.0% DM). The amino acid composition of the single camelina sample is also comparable with the amino acid composition in spring turnip rape, except content of Arginine and Aspartate that were higher (8.19 and 9.19 g/100g CP compared with 6.54 and 8.61 g/100 g CP) and Leucine, Lysine and Proline were lower (6.50, 4.96 and 4.91 g/100 g CP compared with 7.53, 6.12 and 5.78 g/100 g CP respectively).

The variety of turnip rape (‘Petita’) in the trial was low in glucosinolates and eruca acid, which are anti-nutritional compounds. In the camelina seeds, the content of glucosonolates was 24 μmol g^{-1}, and within the acceptable level of 25 μmol g^{-1} for rape seeds.

Table 1. Chemical composition of organic field pea and spring turnip rapeseed, and pea and rape/ turnip rape from the 2008 feed table.

	Pea, *n* = 8 *% of DM (St.Dev)*		**Conventional Pea** *% of DM*	**Spring turnip rapeseed, *n* = 13** *% of DM (St.Dev)*		**Conventional rape- and turnip rapeseed** *% of DM*
DM	89.9	(5.5)	89.7	94.5	(0.29)	93.5
Ash	2.9	(0.2)	3.0	4.8	(0.48)	4.7
Fat	2.2	(0.3)	1.9	45.7	(2.48)	45.2
Protein	22.4	(2.1)	24.2	20.6	(3.32)	21.8
Fibers	6.4	(1.0)	6.7	9.7	(2.35)	13.3
P	0.36	(0.05)	0.47	0.86	(0.05)	0.76
Ca	0.09	(0.01)	0.14	0.53	(0.04)	0.49
Mg	0.13	(0.01)	0.13	0.29	(0.02)	0.30
S	–	–	–	0.31	(0.03)	0.28

Table 2. The effect of different levels of spring applied fertilizer on yield, kg seed ha^{-1} and oil% in dry matter in turnip rape and camelina 2007–2008 (*n* = 6).

	Spring turnip rape		**Camelina**	
Fertilization	**Yield, kg seed ha^{-1}**	**Oil, % DM**	**Yield, kg seed ha^{-1}**	**Oil, % DM**
0 kg N ha^{-1}	1266a	47.03a	1504a	40.91a
40 kg N ha^{-1}	1493ab	47.69ab	1858b	40.99a
80 kg N ha^{-1}	1604ab	48.37b	1928b	40.71ab
120 kg N ha^{-1}	1903b	47.84ab	1996b	40.5b
P	0.013	0.057	0.000	0.002

The mean results of N–fertilization on crop yield and oil content, for all spring oilseed trials from 2007 and 2008 (*n* = 6) are presented in Table 2. The results for turnip rape indicate a steady increase in yield as the level of N–fertilization increases. There are only significant differences between 0 and 120 kg N ha^{-1}, with 50% increased yield. Camelina seems less affected by increased levels of N, and the yield increase from 0 to 120 kg N ha^{-1} was 30%. Camelina also showed a significant yield increase at 40 kg N ha^{-1} compared to 0 kg N ha^{-1}.

N–fertilization in spring does not seem to affect the amino acid composition of the oilseeds. The N–fertilization reduced the NDF–content in oilseed cake of spring turnip rape with barley as pre-crop (*P* = 0.052). Effect of N–fertilization on both content of NDF (*P* = 0.075) and crude protein (*P* = 0.032) differed between years. There was a tendency for larger increase in protein content with the N–fertilization with pea as pre-crop compared with pre-crop barley (*P* = 0.064). The effect of N–fertilization on the Ca content in spring turnip rapeseed differed between years (*P* = 0.007).

The results indicate an acceptable yield both in turnip rape and camelina. Average oilseed yields in Norway from 1999 to 2002 were 164 kg daa^{-1} (Statistics Norway). During these years mainly conventionally produced spring turnip rape was grown. The yield presented in table 2 indicates that there is a compatible yield potential for organically produced oilseed crops with sufficient N–fertilization. Camelina has a slightly higher yield level than turnip rape, and seems to require lower levels of nitrogen. The oil yield in camelina is lower than in spring turnip rape, which corresponds to the lower oil content in the seed. The chemical composition seems to vary between years. S–fertilization did not significally affect yield or oil content of the oilseeds. According to Fismes et al. (1999) a balance in N– and S–fertilization is required for optimal yield and seed quality. S–fertilization is also of interest due to the high content of sulphurous amino acids in oilseed crops (Uhlen et al., 2004). These amino acids are essential for sufficient feed quality, and additional S–fertilization is thought to increase the content of sulphurous amino acids. Application of S did not significally affect the amino acid composition of spring turnip rape, but increased the fat content in oilseed cake (P = 0.038), and decreased the protein content in oilseed cake dependent on year (P = 0.001). The field trial was on moraine soil. One reason for modest effect of S–application might be that the S–content in the soil may have been sufficient for the crops. There is also S in the chicken manure (Zublena et al., 1993*)*. The seed yield level of turnip rape in 2007 was affected by pollen beetle (*Meligethes aeneus* F.) attack, reducing the yield. In 2008 striped flea beetle, *Phyllotreta striolata* (F.) were observed gnawing on the emerging turnip rape, but the yield did not seem to be substantially affected. No detectable damage from either pollen beetle of striped flea beetle was observed in the camelina trials. Another challenge in the field trials was birds feeding on the ripe turnip rape. The camelina did not seem to attract the birds. Combination of turnip rape/rape and pea in feed rations for dairy cows has shown to give acceptable yield and positive nutritional composition in the milk (Harstad et al. 2007). There was however observed a negative effect of the oilseed on the protein content of the milk compared with a ration with soybean meal. Higher protein content and lower fat content in oilseed cakes than in oilseeds makes it possible to increase the protein content of the feed without getting the problems with reduced milk quality. Regarding poultry, they cannot synthesize important essential amino acids like lysine, methionine and tryptophan. The amino acid analyses show that turnip rape and rape have high content of cysteine and methionine, where field peas have high content of lysine and low content of cysteine and methionine. Thus, field pea and turnip rape/rape can be complementary as protein sources for poultry.

CONCLUSIONS

The results in the study so far indicate nutritional composition of turnip rape and field pea and crop yield comparable to conventionally grown protein crops. Turnip rape and field pea is promising organic crops for both ruminants and poultry. Oilseed cake of turnip rape has higher protein and lower fat content than the seed, and is of interest in rations for both ruminants and poultry, especially in combination with field pea. Camelina can be an alternative in organic production, due to comparable yields and fewer problems with harmful pests compared with the traditional oilseed crops rape and turnip rape, but further investigations are needed.

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