Effects of crop management on fatty acid profile of low-linolenic varieties

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Abstract

Rapeseed oil, rich in alpha-linolenic acid (C18:3) is easily oxidized when heated and therefore not suitable for deep frying. New rapeseed varieties produce oil with low linolenic acid content, which can vary from 1.5 to 4.5% between fields and years. According to Everard (2004), a typical unpleasant odour appears above a threshold content of 2.5% C18:3 when rapeseed oil is heated. Understanding the causes of linolenic acid content variability is therefore necessary to produce optimal oil quality.

Fatty acid profile is affected by genotype and climatic conditions, especially temperature. However, crop management could also play a role, as there are differences among neighbour fields of the same cultivar, i.e. with similar climatic and genotypic background.

Sowing density, sulphur fertilization, insect and disease control had no direct effect on fatty acid profile in the experiments carried out in Changins, VD, Switzerland, in 2004 and in 2005. However, they showed interesting relationships between several quality parameters of grain harvested (oil and protein content, oleic and linolenic acid content). Oil and protein content were strongly negatively correlated (r=-0.96) and both could partly explain variability of linolenic acid content with correlation coefficients r=0.34 and r=-0.42 for protein and oil, respectively.

Nitrogen nutrition influenced oil content but its effect on fatty acid profile is not clear-cut. In 2004, one variety (Spiral) seemed to be sensitive to nitrogen fertilization with higher linolenic acid content at higher fertilization rates, whereas the cultivar Splendor did not show significant differences between 90, 130, 170 and 210 kg N/ha. This moderate direct effect of N fertilization can be perturbed by other indirect mechanisms mediated by temperature. High N fertilization may delay anthesis and consequently the period of high linolenic acid synthesis, which has been shown to be temperature sensitive (Baux *et al.*, 2007). If minimal temperatures change during this period, the final oil composition may be affected. It is concluded, that crop management practices have only limited effects on fatty acid composition.

Key words: alpha-linolenic acid, crop management, N fertilization, protein, oil, grain filling

Introduction

Rapeseed oil is an important source of linolenic acid, essential fatty acid of the omega-3 family, but it is not suitable for deep-frying as polyunsaturated fatty acids like linolenic acid are easily oxidized. When heated an unpleasant odour appears. New rapeseed varieties with low linolenic and high oleic acids content (HOLL) have been selected. Their fatty acid profile is better adapted to frying media production and healthier than more saturated fats. According to Everard *et al.* (2004), the typical "room odor" appears when linolenic acid content is above 2.5%. As this target content is not always met and large variations of fatty acid profile are often observed among fields of the same region, it is necessary to understand if farmers can influence linolenic acid content through adapted crop management practices. Kadar *et al.* (2001) tested various levels of NPK supplies on oil content and fatty acid composition of conventional oilseed rape. Higher nitrogen fertilization levels resulted in higher protein and linolenic acid content and lower oil and oleic acid content. Similar effects on oleic acid were observed by Pellet (2001) in N experiments repeated over three seasons with 3 conventional cultivars. The effect of nitrogen fertilization on oil and protein content is confirmed by many studies, but only a few ones did report some N impact on fatty acid composition. Most of them as Merrien (2005) could not show any effect of N fertilization on fatty acid profile. Possible effects of S fertilization, fungicide and insecticide treatments have not been reported.

The goal of the present work was to assess the influence of crop husbandry on fatty acid profile in low-linolenic oilseed rape varieties.

Materials and methods

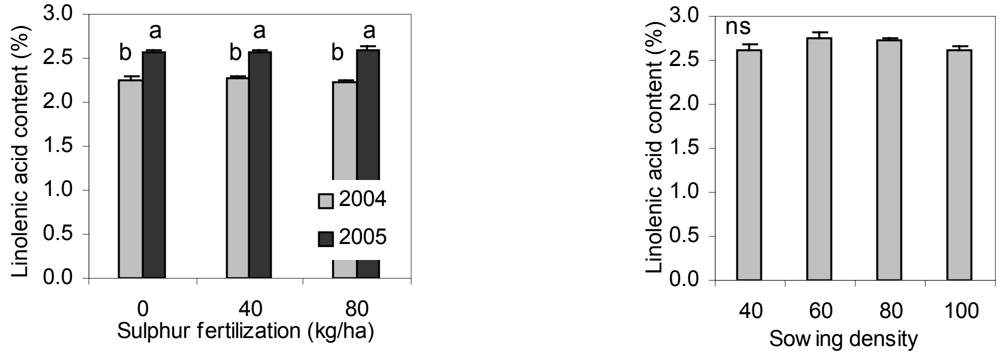
Crop management experiments

Sulphur fertilization experiments were carried out in Changins in 2004 and 2005 with 3 treatments (0, 40, 80 kg S/ha) and 4 replicates as randomized blocks. Plots were machine harvested at full maturity and grains were dried for 48 h at 60°C. Fatty acid composition was analysed by gas chromatography, oil and protein content by Near Infrared Spectrometry (NIRS). Fertilizer form was K2SO4 in S experiments with KCl used to balance K input. Various crop management experiments as sowing density, nitrogen and sulphur fertilization or fungicide use were carried out in Changins in 2005 and provided us with a pool of 120 data for Splendor's oil and protein contents as well as fatty acids profile, all of them coming from the same year and location.

N fertilization and grain filling

A nitrogen fertilization experiment was carried out in Changins in 2004, as a split-plot design with 4 nitrogen levels (90, 130, 170, 210 kg N/ha) in the main plots, and 2 varieties (Spiral, low-linolenic, and Splendor, low-linolenic and mid-oleic, Monsanto) in sub-plots, with 4 replicates. Fertilizer form was ammonium nitrate. Samples were processed as mentioned above. In a second N fertilization experiment with cultivar Splendor, *s*equential harvests were carried out from the beginning of grain filling until maturity on a volunteer-free well-isolated field at the Changins experimental station, in 2005-2006. Three nitrogen fertilization levels were applied (0, 130, 210 kg N/ha) in a randomized block design with three replicates. The first harvest occurred 473 degree-days (base O°C) (i.e. 35 days) after the onset of flowering. The next ones were performed every 7 days until full maturity on July 11th, after 1260 degree-days since the onset of flowering. One sample per plot was taken each time. Pods were harvested by hand and grain dried at 60°C before analysis of fatty acid composition by gas chromatography. Sub-samples were used to determine grain dry matter content (100 °C, 24 hours) and thousand seed weight. Oil content was analysed by nuclear magnetic resonance (NMR) and total N content determined by the Kjeldahl method.

Results and discussion



(A) (B)

Fig 1: Influence of crop management on final linolenic acid content of rapeseed oil. A- 3 levels of sulphur fertilization, 2 years of experiment. B- 4 levels of sowing density. Error bars = standard error, n=4. Treatments with the same letters are not statistically different (Duncan's Range test)

The experiments carried out in Changins could not demonstrate any direct effect of crop management practices (sulphur fertilization, sowing density, plant protection, data not shown) on oil composition (Fig 1).

Tab. 1: Correlation coefficients (r) between several parameters describing seed quality- Pool of 120 values, Changins, 2005

	Oil	Proteins	1000 seed weight	Oleic acid content	Linolenic acid content
Oil content	1	-0.96	0.74	0.56	-0.42
Protein content		1	-0.70	-0.54	0.34
1000 seed weight			1	0.37	-0.31
Oleic acid content				1	-0.62
Linolenic acid content					1

Note: correlations significant with 1% error

Despite the lack of direct effects between cropping techniques and final oil composition, interesting relationships between linolenic acid content and other parameters of seed quality (Tab. 1) were noticed in Changins in 2005 when pooling data from various crop husbandry experiments performed with variety Splendor. Seed final linolenic acid content was negatively correlated with oil and oleic acid and positively with protein content.

Tab2: Seed quality parameters and resulting linolenic acid content in a pool of data ordered by increasing linolenic acid content – Pool of 120 values, Changins, 2005

	Protein content (%)	Oil content (%)	1000 seed weight	Linolenic acid content (%)
Average - all values Changins 2005 (n= 120)	21.8	46.4	4.2	2.45
Average - C18:3 content<2.36 (first quartile)- N=32	21.0	47.7	4.4	2.32
Average - C18:3 content>2.50 (last quartile)- N=32	22.2	45.6	4.1	2.63

() Standard error of the mean, n=15

The data were classified by increasing linolenic acid content. Mean protein content, oil content and 1000-seed weight were calculated for the whole set, the lowest, and the highest linolenic acid contents (first and last quartiles) (Tab.2). The lowest linolenic acid contents were related to the highest oil and seed weight, and the lowest protein contents. The opposite was also true for high linolenic acid contents. This could explain part of the variability around the average value of 2.45% linolenic acid content of this data set. However, the differences observed between the lowest and highest linolenic acid content was only about 0.30% C18:3, which does not have any dramatic consequence on oil quality. These correlations suggested that crop management methods could have an effect on linolenic acid content as well, when they affect oil or protein content. The effect of N supply was investigated separately.

Impact of N nutrition on fatty acid composition.

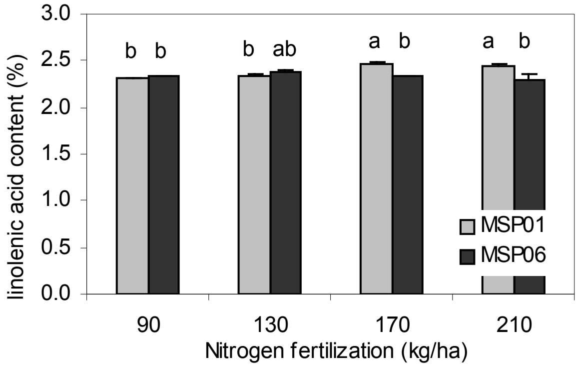


Fig 2 Effects of nitrogen fertilization on seed linolenic acid composition. Error bars = standard error, n=4. Treatments with the same letters are not statistically different (Duncan's Range test)

Slight but statistically significant N effect on linolenic acid content was observed in variety Spiral: high N fertilization levels increased linolenic acid content. In variety Splendor, however, this was not the case (Fig 2). Concurrently, nitrogen fertilization had more effect on proteins, oil content, and seed yield in variety Spiral than in Splendor (data not shown).

Sequential harvests were performed with Splendor from the beginning of grain filling until full maturity. At the beginning of grain filling, higher linolenic acid content was observed in the high N treatment as compared to the lowest one. After a 40 degree-day delay, values of the high-N treatment were similar to those of other treatments (Fig 3). Linolenic acid content was similar among treatments at maturity. Growth analysis was used to characterize the grain filling period. Linolenic acid synthesis, as well as oil synthesis, happened over a short period of time, lasting for about 20 days, at the beginning of grain filling (Fig 4). The peak of oil or linolenic acid synthesis was only reached a few days later in the high N treatment as compared to other treatments (Fig. 4 A and B). As linolenic acid content has been shown to be sensitive to minimal temperature during the peak of seed growth (Baux et al., 2007) and nitrogen fertilization appears to delay this peak, it can happen that meteorological conditions change during this period. In those conditions, higher nitrogen fertilization could result in a change in linolenic acid content, depending on the change in minimal temperature over the period. Furthermore, it is possible that these changing climatic conditions could balance the slight direct effect of an increased N supply on linolenic acid content and result finally in no effect at all.

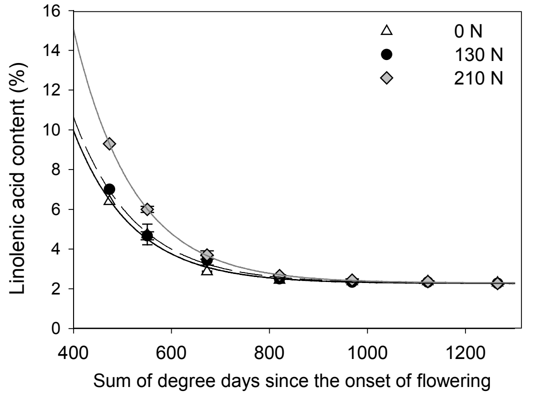


Fig.3: Effect of N fertilization on linolenic acid content from flowering to maturity. Error bars = standard error, n=3

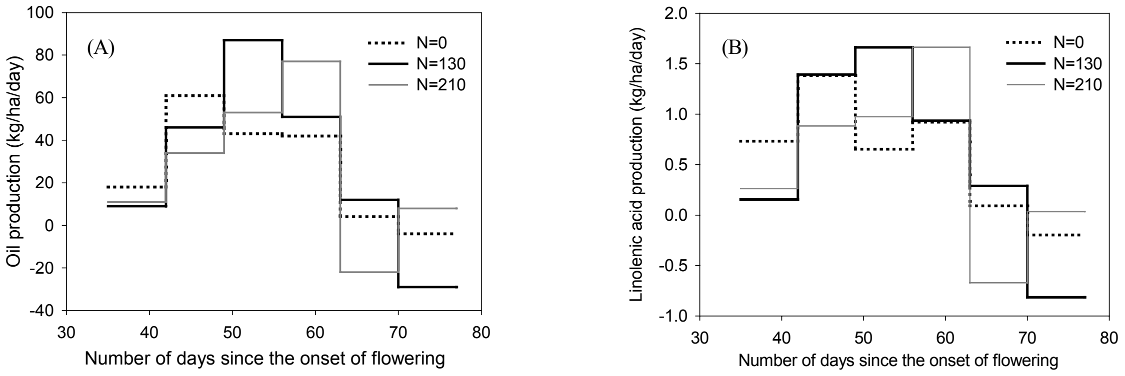


Fig.4: Oil (A) and linolenic acid production (B) per day.

Conclusions

Our studies suggested that in some cases a slight increase of linolenic acid content (about 0.30%) was due to higher nitrogen fertilization and therefore correlated positively to final protein content (and negatively to oil content, as a result of the strong negative relationship linking oil and protein content). However, we presented the hypothesis that nitrogen fertilization could affect this parameter to a greater extent through the delay in oil and linolenic acid peak of production. However, these differences depend on the changes in climatic conditions within about 10 to 15 days. Therefore, a change in nitrogen fertilization level, which will delay the peak of oil production, can increase, decrease, or have no effect on linolenic content, according to the minimal temperatures during the peak of oil and linolenic acid production. These two effects of nitrogen supply on final linolenic acid content can balance each other and finally result in an apparent absence of visible effects. This hypothesis could explain why some authors do find that N fertilization affects oil composition and others don't. Modulating linolenic acid content through nitrogen fertilization seems therefore difficult. However, it is necessary to understand the possible effects of crop management practices on oil synthesis to control linolenic acid content of oilseed rape.

Acknowledgements

This research was co-funded by the Swiss Confederation's Innovation Promotion Agency.

References

Baux A., Hebeisen T. & Pellet D. (2007). Effects of temperature on rapeseed oil fatty acid composition. CGIRC. 12th Intetrnational Rapeseed Congress, Wuhan, China.

Everard J. (2004): Acides linolénique et oléique: les clés pour diversifier les usages de l'huile de colza, Oléoscope 75: 23-25.

Kadar I., Nemeth T. and Lukacs D. (2001). Mineral fertilization of winter rape (Brassica napus L.) on calcareous chernozem soil. II. Novenytermeles 50 (5): 575-591

Merrien A. (2005). Contribution à l'explication de la variabilité de la teneur en acide linolénique chez le colza d'hiver culture en France. Rencontres annuelles du Cetiom, décembre 2005. 75-90.

Pellet D. (2001). Oilseed rape varietal response to N fertilization. Proceedings of the GCIRC technical meeting in Poznan, Poland, June 2001.