Reducing agricultural inputs in high erucic *Brassicaceae*: preliminary results

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Abstract

Erucic acid is an unsaturated fatty acid (C22:1) having a large number of applications in the chemical industry because it confers desirable technological characteristics on oils and derived compounds. Among crops yielding large amounts of erucic acid, the *Brassicaceae* species are the most widely cultivated. The possibility of reducing agricultural inputs for these non-food crops may be an important future challenge in industrialised countries. Two high-erucic *Brassicaceae* species – *Brassica napus* var. *oleifera* and *Brassica carinata* – were chosen among various species as those best adapted to the north Italian environment, with the aim of testing yield responses in conditions of low input.

A large-scale split-plot experiment was set up at the experimental farm of the University of Padova in Legnaro (NE Italy) in 2005/06, and compared two different levels (high and low) of agricultural inputs. High input was characterised by conventional soil tillage, chemical weed control, and high N-P-K fertilisation, and low input by minimum tillage, mechanical weed control, and limited N-P-K fertilisation. The varieties Maplus (NPZ-Lembke) and Hearty (Monsanto) of *B. napus*, and BRK1 (Eurogen) of *B. carinata* were sown at the end of September 2005. Yield results of both species were encouraging, with HEAR values (High Erucic Acid Rapeseed) which were even higher than those of canola in the same location. Rapeseed yielded more than Ethiopian mustard, with different behaviour between varieties and significant interactions with input level. Maplus yielded the most, reaching 3.72 DM t ha^{-1} at high input and 3.12 t ha^{-1} at low. Instead, Hearty reached slightly higher yields at low input (3.4 vs. 3.2 t ha^{-1}), indicating its better adaptability to extensive agricultural management. The yield of *B. carinata* was not affected by input level, and satisfactory performance (2.9 t ha^{-1} on average) together with low predation by birds, suggests its profitable introduction into field rotations in Northern Italy. For this species, maturity was reached almost 2 weeks later than rapeseed, around on the end of June, a fact which should be carefully considered in order to avoid a harvest overlap with wheat.

Key words: Erucic acid, Ethiopian mustard, low input, rapeseed

Introduction

The use of erucic acid derived from "green feedstock" in several industrial applications has been increasing in the last ten years. The major industrial use for erucic acid (*cis* 13-docosenoic acid) is the production of erucamide, a slip agent for polyethylene and polypropylene. In the erucamide market, there are only a few large producers, some based in the EU and USA and only a few in the Far East (Temple-Heald, 2004). The market for slip agent derived from erucic acid is now put at approximately 30.000 t per year, and the consumption trend is expected to increase at a rate of 3-5% per annum. Erucic acid also has other interesting industrial uses, such as the production of behenic acid, behenic alcohol and their derived compounds (Sonntag, 1995, Gunstone and Hamilton, 2001, Temple-Heald, 2004).

Among botanical species yielding high quantities of erucic acid, *Brassicaceae* are the most interesting in terms of production per hectare, although some non-*Brassicaceae* species may reach higher percentages of erucic acid in their oil. In this regard, *Brassica napus* var. *oleifera* HEAR and *B. carinata* showed good adaptability to the environmental conditions of North-East Italy in autumn sowing, together with high oil production, as observed in previous field experiments (e.g., Zanetti et al., 2006).

As the cultivation of high erucic *Brassicaceae* is relatively recent in Italy and is becoming more interesting, there is a need to verify its most suitable agricultural management, with the aim of limiting the level of inputs for environmental and economic purposes. For canola, it has already been demonstrated that proper agronomic management (e.g., choice of variety, tillage system, amount of fertilisers and chemicals, seed dose) is strategic for real environmental benefits in terms of energy and CO_2 balances (Bona and Mosca, 1994; Bona et al., 1999).

In a large-scale field experiment at the University of Padova, two types of agricultural management with different levels of inputs were compared in order to optimise the cultivation of recently released high erucic varieties of rapeseed and Ethiopian mustard.

Materials and methods

The trial was set up during 2005-06 in Legnaro (NE Italy) at the experimental farm of the University of Padova, following a split-plot experimental design with 3 replicates. Aiming at mimicking farm-scale cultivation as closely as possible, plot size was set at 400 m^2 surface area and agricultural practices were applied by means of farm-scale technologies. Two commercial varieties of *B. napus* HEAR – Maplus (NPZ Lemble-Germany) and Hearty (Monsanto-France) – and one variety of *B. carinata* (BRK1, Eurogen-Italy) were sown on 27 September 2005 in a silty-loam soil, by a cereal seeder. The seed dose was 4.5 kg ha^{-1}, roughly corresponding to a density of 100 seeds per m^2 for all varieties. Two contrasting levels of inputs, high and low, were tested, as described in Table 1.

Table1. Characterisation of two input levels.

	High input	Low input
Soil tillage	Ploughing to 0.35 m depth + grubbing + harrowing	Disc-harrowing + rotary tillage
Weed management	Metazachlor (Butisan-S, 500 g a.i. L^{-1}, BASF) 1250 g ha^{-1} (pre-emergence)	Mechanical weeding
Inter-row distance	0.3 m	0.45 m
Pre-sowing fertilisation (kg ha^{-1})	N: 30, P_2O_5: 90; K_2O: 90	N: 0, P_2O_5: 50; K_2O: 50

Spring nitrogen fertilisation was calculated following the method proposed by CETIOM (Centre Technique Interprofessionnel des Oléagineux Métropolitains) (1998), called "Réglette Azote". In brief, it recommends increasing doses of N to increase potential yield (i.e., revealed by higher shoot biomass at the end of winter). Within the same range of biomass, the lower the value, the higher the amount of N. According to this approach, at the end of winter (1 February 2006), the shoot biomass (fresh weight) of 1 m^2 for each plot (2 replicates per plot) was sampled. Biomass values were related to potential yields of 3.0 and 3.5 t ha^{-1}, chosen respectively for low and high input management, to calculate the N dose (Table 2). The resulting amount of N, applied as ammonium sulphate, ranged between 65 and 72 kg ha^{-1} for low input and between 83 and 100 kg ha^{-1} for high input.

Table 2. Amount of spring nitrogen calculated by following "Réglette Azote" method, in deep soil rich in organic matter (average: 2.5%).

Species	Cultivar	Input level	N (kg ha^{-1})
B. napus	Maplus	High	89
B. napus	Maplus	Low	72
B. napus	Hearty	High	100
B. napus	Hearty	Low	65
B. carinata	BRK1	High	83
B. carinata	BRK1	Low	67

During stem elongation and flowering stages (7 April to 5 May 2006), the nutritional status of the crop was monitored by a SPAD-502 chlorophyll meter (Konica-Minolta, Hong Kong), together with determination of Kjeldahl nitrogen content in shoots.

Harvest was on 16 June for *B. napus* and later, on 26 June, for *B. carinata*, in both cases by combine harvester (Claas, Harsewinkel, Germany) equipped with a wheat cutting bar. Oil contents were determined with Soxtec-Tecator equipment (FOSS Analytical, Höganäs, Sweden) on 2 g of milled seeds, with diethyl ether as solvent.

Results and discussion

Environmental conditions during the crop cycle were very similar to the 30-year average for the same location, apart from higher rainfall during autumn (almost double) and lower in March and April.

Except for some leaf damage due to noctuids, which occurred one month after sowing, especially in the low input plots (probably due to the presence of wheat residues on the soil surface), which required chemical control (Meteor, Chimiberg, 15.7 g l^{-1} a.i. deltamethrin, 15.7 g ha^{-1}) the growing conditions were very suitable to both rapeseed and Ethiopian mustard.

Flowering started at mid-April for *B. napus* and a couple of weeks later for *B. carinata*; since non-conspicuous rainfall occurred after this phase, the incidence of lodging in both species was very limited.

Regardless of level of input, *B. carinata* (BRK1) showed constantly lower values of SPAD and nitrogen contents in plants than the two varieties of *B. napus* (Figs. 1, 2) and this led to poorer final yields. The dynamics of SPAD and nitrogen contents were almost similar in all genotypes, except for Maplus (low input) whose nitrogen content unexpectedly remained high (around 2.8%), at least until initial pod formation (5 May).

SPAD was positively correlated with seed yield and could be considered as a good indicator of production. In particular, SPAD values measured at full flowering (27 April) showed the highest coefficient of determination ($R^2 = 0.56$).

Ethiopian mustard reached lower yields than HEAR varieties (Fig. 3), thus showing inferior productivity in the environment of Northern Italy, in contrast with past results obtained in Spain by Fernandez Martinez and Dominguez (1982) and Fereres et al. (1983). The yield of BRK1 did not vary with input level (high vs. low: 2.90 vs. 2.88 t ha^{-1} DM) (Fig. 3), thus confirming its stable behaviour observed for SPAD and shoot N contents. In terms of yield, rapeseed varieties showed contrasting responses to input level. Maplus was able to enhance higher input levels by increasing seed yield from 3.11 to 3.72 t ha^{-1} DM, whereas Hearty was almost indifferent (high vs. low: 3.26 vs. 3.45 t ha^{-1}), indicating that there is a significant interaction between varieties and input level ($P \leqslant 0.001$).

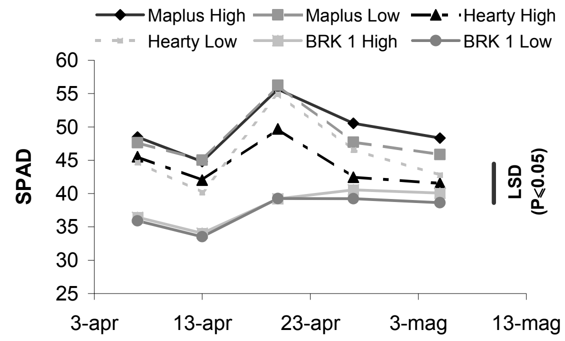

Fig. 1. Dynamics of SPAD values. Vertical bar: LSD for 'Treatment × Time' interaction (5.86).

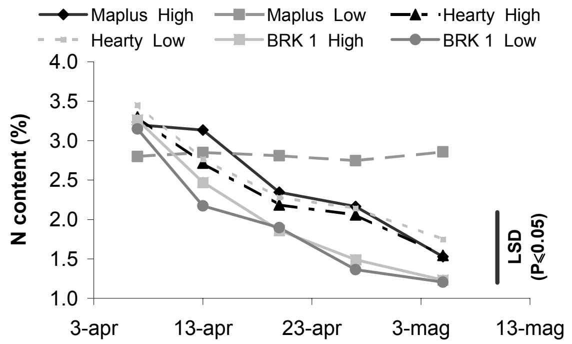

Fig. 2. Dynamics of plant nitrogen contents. Vertical bar: LSD for 'Treatment × Time' interaction (0.89).

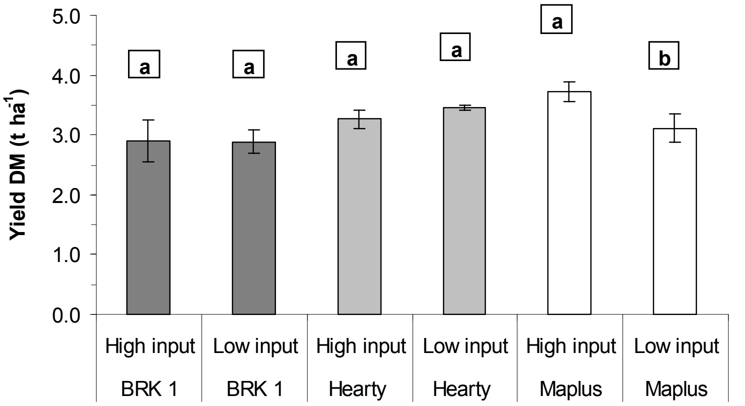

Fig. 3. Seed yield of three varieties at two input levels. Vertical bars: standard error. Letters: comparisons between input levels within same variety.

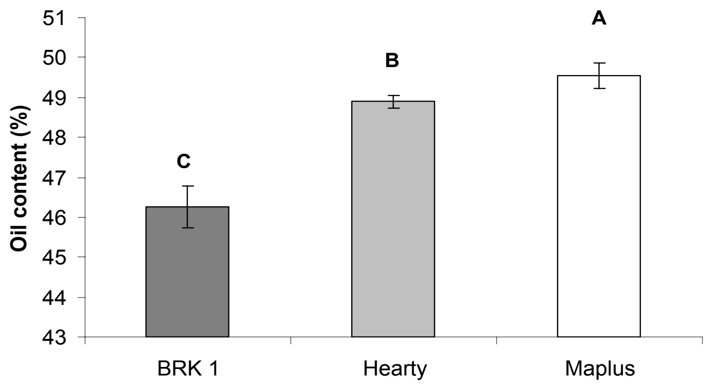

Fig. 4. Oil content (%) of varieties in trial (main effect). Vertical bars: standard error. Letters: represent statistically different values ($P \leq 0.01$).

In terms of oil content, *B. carinata* was also less promising than *B. napus*, having average contents of 45.5% compared with 48.9% for Hearty and 49.7% for Maplus (Fig. 4). For this parameter, input level had a general positive effect, as all varieties increased the oil contents in their seeds by 1.5% on average ($P \leq 0.05$), confirming the results of Arup and Subhendu (2004). The positive correlation between input level and oil contents may be explained by the modification of photosynthate partitioning within the plant. As lipids synthesis is a costly process in terms of energy, when limited amounts of inputs are applied, we may expect a more proportional decrease in oil accumulation than in yield, due to partial inhibition or delay in the fatty acid pathway.

Oil yields (data not shown) were encouraging, and higher than those obtained in previous experiments for older HEAR genotypes in the same location (Zanetti et al., 2006), with values ranging between 1.53 t ha^{-1} (Maplus low input) and 1.87 t ha^{-1} (Maplus high input), both of which are above the threshold level of 1.5 t ha^{-1} required by industry.

From oil characterisation, which is still in progress, the erucic acid contents were very high in both *B. napus* (49.1%) and *B. carinata* (47.0%). When analysis is completed, the role of agricultural management on this parameter can be evaluated.

Conclusions

The best choice of input level in the cultivation of high erucic *Brassicaceae* is relatively difficult and environmental conditions must also be considered. The choice of variety may play an important role, as different varieties may show opposite behaviour toward input levels. In this regard, only the HEAR variety, Maplus, was able to take advantage of high input, indicating that, in most cases extensive agricultural management may be properly applied to these crops.

The possibility of mechanical weed control is feasible, by adopting wider rows and may be cheaper than chemical control, although at present very few active ingredients are registered on the Italian market (i.e., Metazachlor, Trifluralin).

Considering the high nitrogen requirement of some *Brassicaceae*, over 200 kg ha^{-1} in canola, the use of the French "Réglette Azote" leads to rational N fertilisation (savings ranged between 36 and 50%), even in Northern Italy, and good yields.

The only cold tolerant variety of *B. carinata* suitable for Northern Italy yielded less than *Brassica napus*, suggesting that much effort remains to be done by breeders in the near future. Cultivation of Ethiopian mustard should also be carefully considered in the Italian environment because of a possible harvest overlap with wheat: in cases of delayed harvest this may lead to considerable pod shattering and yield losses.

These preliminary results derive from one year of research, and a new trial is ongoing.

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