Agronomic characterization of some *Crambe abyssinica* genotypes in a locality of the Po Valley

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Abstract

The use of oil with a high level of erucic acid in some industrial sectors appears to offer excellent prospects from a technological and environmental point of view. This study was carried out to determine the potential of *Crambe abyssinica* for producing high erucic acid oil seeds in the Po Valley environment (North Italy). The productive yield of 3-year trials using six different genotypes was generally satisfactory, even though significant differences were found between the years. The different weather patterns recorded during the trials showed how emergence, flowering and seed-filling stages are particularly important phases for obtaining good yields. The grain production in these years ranged between 2.3 and 3.2 t ha⁻¹ and were similar to that of other spring oilseed crops in our environment. The seed had an oil concentration of between 320 and 370 g kg⁻¹, with a fatty acid composition regularly characterized by a level of erucic acid higher than 53%. This paper also reports and discusses some other seed characteristics (protein content, weight per hectolitre, thousand kernel weight, hull/seed ratio and number of seed per plant). Amongst the genotypes tested, Mario gave the highest seed and oil yields followed by Belann and C-29, whereas Mejer and Belenzian gave lower yields, especially as a result of an insufficient emergence. © 1998 Elsevier Science B.V. All rights reserved.

Keywords: Non-food oilseed crops; *Crambe abyssinica*; Oil; Erucic acid; Biolubricants

1. Introduction

The replacement of mineral or synthetic products with compounds of natural origin will assume a marked expansion in the third millennium, in view of the increasingly more widespread use of so-called “green chemistry” in numerous industrial productions. Therefore, the ‘Community Regulations’ for set-aside lands (EEC Regulation 1765/92) envisaged subsidies for the cultivation of the so-called ‘alternative’ crops characterized by a non-food utilization of the products. For this reason, various European countries started up research programs on new starch, fibre, energy and oil-producing plants for non-food uses. In Italy, the Ministry of Agriculture, Food and Forestry Resources promoted and financed the PRisCA (Research Project on Alternative Crops) and, in the ambit of this project, some very interesting prospects and a wide market were highlighted for the vegetable oils
produced for industrial use, as an alternative to mineral and/or synthetic oils. The possible use of vegetable oils, in fact, has aroused great interest especially in the lubricant sector due to their renewal as well as their ecological, biodegradable and completely non-toxic nature (Floris and Pignatelli, 1991).

Amongst the new oil crops tested, *Crambe abyssinica* appears to offer excellent prospects not just for its good adaptation to the pedoclimatic conditions in central-northern Italy (Lazzeri et al., 1994) but also, above all, due to the particular fatty acid composition of its oil, characterized by a level of erucic acid (C22:1) around 55%. This level of long-chain fatty acids gives crambe oil a high viscosity and smoke point, making it particularly suitable for some lipochemical industrial preparations and in the lubricant sector (Lazzeri et al., 1997a). Crambe oil has in fact shown better technological features than medium-chain food oils currently available on the market, such as those of sunflower, rapeseed or soybean (Bondioli et al., 1998).

*Crambe* (*Crambe abyssinica* Hochst. ex R. E. Fries), a member of the *Brassicaceae* family, is an erect annual herb with large pinnately lobed leaves (White and Higgins, 1966). It has a moderately branched straight stalk (Fig. 1). The flowers are white, clustered in racemes and show the typical *Brassicaceae* structure. The spherical fruits are one-seeded and indehiscent. Despite indeterminate flowering, the fruits formed usually adhere until the later fruits mature and, even at harvest, the pericarp (hull) remains adherent to the seed. For all of these features, main seed yield components of crambe could be identified such as the number of plants per m$^2$, number of seed per plant and thousand kernel weight.

In Italy, after an initial stage of establishing the main cultivation techniques for crambe, experiments were carried out in the open field for a couple of years with results that confirm the productive potential of the crop (Lazzeri et al., 1995, 1997b). The genotypes currently available are mainly of USA origin, where the crop was widely cultivated in the 1960s, before being abandoned because of the poor food quality of the oil and the lack of interest at that time for the non-food vegetable oil market (White and Higgins, 1966). At present there are no European crambe varieties available, although in Holland, the CPRO-DLO at Wageningen (Mulder and Mastebroek, 1996) and the CEBECO company in Rotterdam are carrying out some breeding trials on crambe.

In Italy, in 1995, the Istituto Sperimentale per le Colture Industriali in Bologna submitted an application for the registration of a new genotype, Mario, selected for the cultivation conditions of central-northern Italy. The aim of this work was therefore to assess the agronomic performance of the genotype Mario as compared with some USA genotypes (Belann, Belenzian, C-29, 47112 and Mejer), over three cultivation cycles (1994–1996) performed in the Po Valley (central-northern Italy).
2. Materials and methods

2.1. Site, soil and climate

A field experiment was carried out in the environment of Budrio (Bologna-Italy) located in the Po Valley (latitude 44° 32' 13"N, longitude 11° 29' 40"E, altitude 29 m asl) during three seasons, from 1994 to 1996. The trials were performed on a loamy-clayey soil (clay 26%, silt 54%, sand 20%) with a high content in available potassium and a mean content in phosphate and organic matter. The climatic conditions were recorded daily in a meteorological station located at the experimental site and were reported as the rainfall and the mean temperatures over 10 days (Fig. 2).

2.2. Experimental design

Three crambe varieties from USA, Belann, Belenzian, Mejer, with registered germplasm (Campbell et al., 1986), two lines, C-29 and 47112, also from USA and a new genotype from Italy, Mario, were cultivated in a randomized block design with four replications in plots of 14 m². All the genotypes were cultivated with spring sowing (sowing date before 15 March), using a seed density of 10 kg ha⁻¹ (whole seed), in rows 35 cm wide, with the aim of obtaining around 100 plants m⁻². At sowing time, 80 kg ha⁻¹ of N (ammonium nitrate) were applied. Weeds were manually controlled, whereas protection treatment and irrigation were unnecessary in the three years of the trials.

2.3. Measurements

During cultivation, the length of the main phenological stages such as emergence, rosette, flowering, seed filling and ripening was measured. In addition, the emergence rate, the number of plants per m², plant height, root length and harvest index were recorded. The number of plants per m² was determined at the rosette phase, whereas the plant height and the main root length were recorded at harvest time, on a representative sample of 10 plants per replicate.

At maturity (seed moisture lower than 90 g kg⁻¹), the plants were cut with a standard mower, manually gathered and threshed with a fixed machine, using sieves suitable for small seeds. Impurities (less than 3%) were removed and the seed yield, thousand kernel weight, hull/seed ratio (ratio between the weight of the fibrous hull that

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Fig. 2. Average decade rainfall and temperatures recorded during the 3 years of trials at the experimental site (Budrio, Bologna, Italy).
surrounds the seed and the weight of the seed), weight per hectolitre, moisture, protein, oil and erucic acid content were determined from the whole seeds. The number of seeds per plant was calculated from the seed yield, number of plants per m² and thousand kernel weight values.

The moisture level was measured by oven-drying the seed at 105 °C for 24 h and the oil concentration with the NMR (Nuclear Magnetic Resonance) technique, using a specific calibration on an Oxford Newport 4000. The level of erucic acid, previously transformed into the corresponding methyl-ester by rapid transmethylation with basic catalysis (Christopherson and Glass, 1969), was determined with a Carlo Erba mod HRGC 5300 mega series gas-chromatograph with a flame-ionization detector (FID). The gas chromatograms and the calculation of the retention times were obtained using a Spectra Physic mod 4290 integrator, operating over a 10-mV range. The total protein level was determined with the Kjeldahl method and using an automatic titre distiller Vapodest 6 Gerhard (Germany) (conversion factor: 6.25).

2.4. Statistical analysis

Variance and correlation analyses were performed using the MSTAT-C (1990) software package, after an arcsine transformation of the percentage data. Then, after checking the error variance homogeneity with the Bartlett test, a combined analysis of variance over the years was performed. Mean values were compared according to the LSD test at a P≤0.05 significance level.

3. Results

The climatic conditions in the years 1994–1996 were different during the emergence, flowering and seed filling stages, and this had a significant impact on the results. Only in 1994 was the weather generally suitable for very good plant growth, whereas in 1995, the light rainfall following sowing led to the formation of a hard surface crust. In 1996, the mean temperatures recorded in the days following sowing were lower than 7 °C, and in the first 2 weeks of May and June, the temperatures were higher than in the other two years (Fig. 2).

The length of the phenological phases only revealed significant differences between the years (Table 1). The sowing–emergence interval (S–E) was markedly shorter in 1994 than in the other two years, whereas the rosette–flowering interval (C₁–F₁) was significantly shorter in 1996. The interval beginning of flowering–end of seed filling (F₁–G₄) and the length of maturity stage were also significantly different in the three years. All the genotypes tested always terminated their reproductive cycle within 120 days after sowing.

The emergence rate did not show a statistically significant years × genotypes interaction, whereas differences were found between the years and between the genotypes, as observed for the emergence rate (Fig. 3). In 1994, a mean emergence rate close to 60% was attained, which was significantly higher than in the other two years (around 30%). Amongst the genotypes, Mario and 47112 were found to be the best, with mean values of more than 50%, whereas Mejer was always the worst, with about 20%.

The number of plants per m² did not show a statistically significant years × genotypes interaction, whereas differences were found between the years and between the genotypes for the emergence rate (Fig. 4). In 1994, about 90 plants per m² were obtained, a number almost double as compared with the other two years. Amongst the genotypes, Mario and 47112 reached the highest number of plants per m², whereas Mejer yielded more than 30 plants per m².
The seed yield (t ha\(^{-1}\) of dry matter (DM)) did not show a statistically significant years × genotypes interaction, whereas differences were found between the years and between the genotypes (Table 2). Amongst the years, 1994 showed the highest, and 1995 showed the lowest yield. Amongst the genotypes, Mario gave the highest seed yield, followed by Belann and C-29. Seed yields of Mejer and Belenzian were significantly lower.

As observed for the seed yield, the oil yield (t ha\(^{-1}\)) did not show a statistically significant years × genotypes interaction, whereas differences were obtained between the years and between the genotypes (Table 2). 1994 was the year with the highest yield and 1995 with the lowest yield. Amongst the genotypes, Mario showed the highest production, whereas Belenzian and Mejer again gave the lowest production.

The oil concentration (g kg\(^{-1}\) of DM), showed a statistically significant years × genotypes interaction (Table 3). During the three years of the trials, however, the seeds of Mejer always had the highest oil concentration, whereas Mario was characterized by a medium to low concentration, and this tendency was found in the three years of cultivation. In 1994, the highest overall results...
Table 3

Oil concentration and harvest index: mean values of each genotype in the three years of trials

<table>
<thead>
<tr>
<th>Genotypes</th>
<th>Oil concentration (g kg(^{-1}) of DM)</th>
<th>Harvest index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belenzião</td>
<td>373 a</td>
<td>336 b</td>
</tr>
<tr>
<td>Belann</td>
<td>360 bc</td>
<td>321 c</td>
</tr>
<tr>
<td>Mejer</td>
<td>379 a</td>
<td>352 a</td>
</tr>
<tr>
<td>47112</td>
<td>372 ab</td>
<td>338 a</td>
</tr>
<tr>
<td>C-29</td>
<td>366 abc</td>
<td>334 b</td>
</tr>
<tr>
<td>Mario</td>
<td>358 c</td>
<td>334 b</td>
</tr>
<tr>
<td>Mean</td>
<td>368 a</td>
<td>339 c</td>
</tr>
</tbody>
</table>

Years *** *
Genotypes * ns
Years × genotypes ** ***

*\(P \leq 0.05\); **\(P \leq 0.01\); ***\(P \leq 0.001\); ns, not significant. DM, dry matter. Mean values with different letters in the same column vary significantly for \(P \leq 0.05\) according to the LSD test.

were obtained, whereas the lowest oil concentration was recorded in 1995.

The level of erucic acid (as a percentage of the total fatty acids) was very stable even with variations of the experimental factors (years and genotypes), yielding a proportion of 53–55% (data not shown).

The protein concentration (g kg\(^{-1}\) of DM) was not significantly influenced by the experimental factors, with mean values of around 210 g kg\(^{-1}\) (data not shown).

The harvest index showed a statistically significant years × genotypes interaction (Table 3). Over the three years, however, Mejer always showed the highest values (0.35) as compared with the other genotypes. The highest harvest indices were obtained in 1996.

The thousand kernel weight (g of DM) showed a highly statistically significant years × genotypes interaction (Table 4). Over the three years, however, 47112 always showed the highest TKW (mean 6.8 g), whereas C-29 always showed significantly lower values (around 5.7 g).

The seed weight per hectolitre showed a statistically significant years × genotypes interaction (Table 4). However, the highest values were obtained from Belann with 32 kg hl\(^{-1}\) and the lowest from C-29 with 30 kg hl\(^{-1}\). On average, the highest values were obtained in 1994 and the lowest in 1996.

The number of seeds per plant showed a highly significant years × genotypes interaction (Table 4). In 1994, the number of seeds per plant was significantly lower than in the other two years. Amongst the genotypes, Mejer showed always the highest number of seeds per plant.

The husk/seed ratio did not show a statistically significant years × genotypes interaction, although differences were observed between the years and between the genotypes (Fig. 5). In 1994, the lowest mean values (0.26) were obtained, and in 1996, the statistically highest values (0.39). Amongst the genotypes, 47112 showed significantly lower values, whereas Belann had the highest husk/seed ratio.

During the experimentation, some other parameters were determined, without showing any statistically significant differences (Table 4). However, the highest values were obtained from Belann with 32 kg hl\(^{-1}\) and the lowest from C-29 with 30 kg hl\(^{-1}\). On average, the
Table 4
Thousand kernel weight, weight per hectolitre and number of seeds per plant: mean values of each genotype in the 3 years of trials

<table>
<thead>
<tr>
<th>Genotypes</th>
<th>Thousand kernel weight (g of DM)</th>
<th>Weight per hectolitre (kg hl⁻¹)</th>
<th>Number of seeds per plant (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belenzian</td>
<td>6.58 bc</td>
<td>6.68 a</td>
<td>6.77 bc</td>
</tr>
<tr>
<td>Belann</td>
<td>7.07 a</td>
<td>6.49 ab</td>
<td>6.70 c</td>
</tr>
<tr>
<td>Mejer</td>
<td>6.29 cd</td>
<td>6.65 a</td>
<td>7.08 ab</td>
</tr>
<tr>
<td>47112</td>
<td>6.83 ab</td>
<td>6.52 a</td>
<td>7.16 a</td>
</tr>
<tr>
<td>C-29</td>
<td>6.00 d</td>
<td>5.50 c</td>
<td>5.52 d</td>
</tr>
<tr>
<td>Mario</td>
<td>6.25 cd</td>
<td>6.17 b</td>
<td>6.89 abc</td>
</tr>
<tr>
<td>Mean</td>
<td>6.50 ab</td>
<td>6.34 b</td>
<td>6.69 a</td>
</tr>
</tbody>
</table>

*P ≤ 0.05; **P ≤ 0.01; ***P ≤ 0.001; nd, not determined; DM, dry matter. Mean values with different letters in the same column vary significantly for P ≤ 0.05 according to LSD test.

4. Discussion
The overall results of the three years of trials confirm some previous observations concerning the good adaptability and the interesting productivity potential of crambe in the Po Valley pedoclimatic conditions (Lazzeri et al., 1995, 1997b). The growing cycle and the productivity of the six genotypes tested yielded significant variations with the different weather conditions in the three years of trials.

1994 was the best year for the crop, during which no sign of stress was observed throughout the growing cycle. In 1995, instead, the insufficient and poorly distributed rainfall after sowing caused the formation of a hard surface crust that delayed and affected crop emergence and caused a signifi-
Table 5
Correlation coefficients among different characters in the six *Crambe abyssinica* genotypes tested

<table>
<thead>
<tr>
<th>Characters</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Seed yield</td>
<td>0.465***</td>
<td>0.975***</td>
<td>-0.066</td>
<td>0.593***</td>
<td>-0.108**</td>
<td>0.658****</td>
<td>-0.358*</td>
<td>0.721****</td>
<td>-0.574***</td>
</tr>
<tr>
<td>2. Oil concentration</td>
<td>-</td>
<td>0.625***</td>
<td>0.242*</td>
<td>0.642***</td>
<td>-0.362**</td>
<td>0.405***</td>
<td>-0.644***</td>
<td>0.392***</td>
<td>-0.136</td>
</tr>
<tr>
<td>3. Oil yield</td>
<td>-</td>
<td>-0.015</td>
<td>0.469***</td>
<td>-0.429***</td>
<td>0.677***</td>
<td>-0.454**</td>
<td>0.728***</td>
<td>-0.371***</td>
<td></td>
</tr>
<tr>
<td>4. Thousand kernel weight</td>
<td>-</td>
<td>0.235</td>
<td>0.182</td>
<td>0.031</td>
<td>0.080</td>
<td>-0.002</td>
<td>-0.042</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Weight per hectolitre</td>
<td>-</td>
<td>-0.708***</td>
<td>0.625***</td>
<td>-0.436*</td>
<td>0.659***</td>
<td>-0.490***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Hull/seed ratio</td>
<td>-</td>
<td>-0.446***</td>
<td>0.678***</td>
<td>-0.485***</td>
<td>0.308*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Harvest index</td>
<td>-</td>
<td>-0.399*</td>
<td>0.957***</td>
<td>-0.721***</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Number of plants per m²</td>
<td>-</td>
<td>-0.446*</td>
<td>0.317</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Number of seeds per plant</td>
<td>-</td>
<td>-0.733***</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*P ≤ 0.05; **P ≤ 0.005; ***P ≤ 0.001.

Significant reduction in the number of plants per m². Similar effects on emergence were also observed in 1996, but in this case, they were probably due to the low temperatures after sowing. The good seed germinability in laboratory (higher than 90%) as compared to that found in the field confirms the close link between weather conditions and germination, which was found to be a particularly critical phase within the cultivation cycle. Again in 1996, the high temperatures recorded in mid-May led to an early flowering thus reducing plant vegetative growth, as confirmed by the high harvest index values. Finally, the high temperatures recorded between the end of May and the beginning of June led to incomplete seed filling, as confirmed by the high hull/seed ratio values recorded in this year.

These different weather patterns influenced seed and oil yield of all the tested genotypes. In 1994, the mean seed yield was 3.25 t ha⁻¹, equal to 1.2 t ha⁻¹ of oil, but even in 1995, with the poor seed emergence, the seed yield was 2.3 t ha⁻¹, equal to 0.8 t ha⁻¹ of oil. For this reason, we can affirm that, in the Italian environment, the production of crambe seed was in the range of that of other spring oilseed crops (Baldoni and Giardini, 1982).

The composition of the whole seed was characterized by a mean oil concentration higher than 350 g kg⁻¹ and, even in the worst year, never fell below 320 g kg⁻¹. This is not a very high concentration but is similar to that of other oil crops. The level of erucic acid was extremely stable over the years and, amongst the genotypes tested, showed values around 54%, confirming the results reported in a previous paper (Lazzari et al., 1995). This uniform quality in the years is certainly a fundamental characteristic for the industrial use of the oil, since it makes it possible to obtain a standard quality of the derivative products. The whole seed also showed a protein concentration of around 210 g kg⁻¹, characterized by an interesting amino acid composition (Carlson and Tookey, 1983). The presence in crambe meal of a high level of goitrogenic products derived from the hydrolysis of glucosinolates makes the meal unsuitable for use as animal feed (Anderson et al., 1993) without a detoxifying process (Capelle, 1997). This aspect, which at the moment is a negative factor for the economic assessment of the crop, is currently being studied to identify other non-food applications for products with a high added value as proteins (Vereijken et al., 1997), as well as for glucosinolates (Aliano et al., 1997).

The whole seed was also characterized by a high amount of fibre, the main component of the hull that surrounds the seed. Despite the significant differences between the years, the hull, even in the
best year as in 1994, represented more than 25% of seed production. In 1996, this value increased to 39%, very likely due to incomplete filling of the seed following the high number of seeds per plant and the high temperatures recorded during the seed-filling stage. This finding may be of practical interest since the hull only contains traces of oil (Lazzeri et al., 1994). Therefore, not only may the dehulling of the seed following harvest make it possible to recover hull for use in the production of cellulose derivatives (Capeotti et al., 1997), but also a marked increase in the weight per hectolitre is obtained that is very low for the whole seed. This operation, also simple to mechanize (Del Papa, pers. commun.), would also offer marked savings, especially in the transport, storage and seed extraction costs. The correlation coefficients evidenced the emergence rate, the number of plants per m², the weight per hectolitre and the hull/seed ratio as four important traits correlated with seed and oil yield. The first two were positively correlated with seed and oil yield because they characterize the final crop stand. They also showed a high correlation with each other due to the absence of plant mortality after emergence. It is interesting that a poor crop stand was associated with a higher number of seeds per plant, and lower seed and oil yield. A high degree of seed filling therefore is a crucial point for obtaining higher seed and oil yield. The thousand kernel weight, usually considered as a yield component, was not correlated to seed and oil yield, unlike the weight per hectolitre. The latter not only describes the seed weight, but also takes into account its volume, and hence is an indicator for the degree of the seed filling. In addition, the hull/seed ratio was negatively correlated with seed and oil yield and the weight per hectolitre. Finally, seed and oil yield and the weight per hectolitre were negatively correlated with the harvest index, since the latter, referring to the whole seed, also includes the hull.

Within these general patterns, the genotypes tested showed significantly different responses. Mario gave the highest seed and oil yield in the three years of trials, even if the seed showed a mean oil concentration. These results can be attributed not just to a significantly higher germination in the field, but also to a balanced plant growth, as confirmed by the high harvest index values and the low number of seeds per plant. The poorest yields were obtained with Mejer and Belenzian, also due to lower emergence rates that reduced the number of plants per m², causing low yields.

5. Conclusions

The interesting technological and environmental features of high erucic acid oilseeds have aroused interest in numerous European private lipochemical and biolubricant industries, indicating market prospects that might, in Italy alone, account for 10 000 tons a year. In our trials, *Crambe abyssinica* has been confirmed as a crop that can be cultivated in central-northern Italy for the production of high erucic acid oil. Its excellent adaptability to spring sowing under these pedoclimatic conditions and the shortness of its reproductive cycle (120 days) would allow the crambe crop to be included in the normal rotation, since the Community allows its cultivation on set-aside land as a non-food crop. The cultivation techniques used in our trials were suitable for good plant development, even if we cannot exclude the possibility that some variations of the agricultural techniques, such as the reduction of the inter-row distance to 25–30 cm, could allow a further increment in the production potential of the crop.

The emergence rate and consequently the number of plants per m², generally found to be insufficient in such trials, should be improved by specific breeding researches to lead to a more uniform crop stand, with positive effects on crop yields and stability. Moreover, a higher number of plants per m² should lead to a lower number of seeds per plant, and therefore to higher yields, as demonstrated by the correlation data obtained in our trials. They showed also that a low number of seeds per plant led to a better seed filling, characterized by a better hull/seed ratio. The number of seeds per plant were negatively correlated with the weight per hectolitre and positively with hull/seed ratio, two parameters that were indicative of the degree of seed filling.
In addition, our trials evidenced that the thousand kernel weight was not correlated with yields and therefore should not be considered as a yield component for crambe, whereas it could be more useful to substitute it by the weight per hectolitre for an evaluation of seed quality.

Finally, it should be emphasized that some genotypes tested in our trials gave yields that in our pedoclimatic conditions are similar to those of other spring oilseed crops, such as the '00' rapeseed confirming the applicatory perspectives of this crop. Amongst the genotypes tested, Mario showed a good adaptation to the pedoclimatic conditions in central-northern Italy, obtaining, although with a medium-low oil content, the best production results, followed by Belann and C-29. The Mario genotype, registered by the ISCI in Bologna, will be used, therefore, in the open field cultivation trials planned for the next years.

Acknowledgment

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References


