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Precision Nitrogen Management In Camelina: Preliminary Results From A Case Study In Central Italy

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Introduction

Nowadays, the use of advanced technologies in agriculture is mandatory in order to increase cropping system sustainability and quality. To guarantee a higher yield, farmers need to ensure the best health of their crops with, at the same time, the least environmental impact. Particular attention is generally paid to nitrogen fertilization since nitrogen use efficiency in modern agriculture is very low. It means that a lot of synthetic chemicals are wasted rather than utilized by crops with consequent environmental issues. The use of spectral reflectance indices, such as the normalized difference vegetation index (NDVI) and chlorophyll index (Dualex), are reliable indicators to determine N status of crop plants. In this contest, very scarce knowledge is available about the response of camelina - a promising oilseed crop for food, feed, and the bio-based industry - to different N rates as well as on the use of remote/proximal sensing. So, this study aimed to evaluate the effect of N fertilization rate and timing on camelina seed yield and quality. At the same time, biochemical parameters and NDVI by using proximal sensing techniques were assessed with the aim to optimise camelina agronomic management.

Materials and Methods

A field experiment was conducted in 2021 at the experimental Centre of the DiSAAA-a, located in San Piero a Grado (Pisa, central Italy, 43°40′ N; 10°19′ E, 5 m above sea level). The commercial variety Calena was used and different nitrogen levels (applied as ammonium nitrate, NH_4NO_3) and timing (basal and top dressing) have been compared. The tested treatments were: (i) control: no N application; (ii) basal dressing: 60 kg N ha^{-1} at sowing (60N+0); (iii) basal+top dressing combination: 60 kg N ha^{-1} at sowing + 60 kg N ha^{-1} before stem elongation (60N+60N); (iv) top dressing: 60 kg N ha^{-1} before stem elongation (0+60N). A completely randomized block design has been adopted with three replications for each treatment (plot size: 8m x 6m). Camelina sowing was performed in spring (08/03/2021) at the rate of 6.5 kg ha^{-1} considering percent seed germination as well as 1000-seed weight (TSW), in order to reach a target of 500 plants m^{-2} . The crop growth cycle was monitored and the achievement of the main phenological phases was registered according to the BBCH scale (Martinelli & Galasso, 2011). To assess seed yield, at seed full ripening (89 BBCH), camelina plants were harvested manually (24/06/2021) sampling 7 rows from the central portion of each plot (~2.0 m^2). Seed protein content was also determined by multiplying the total nitrogen percentage by 6.25 and total N content was determined by mini-Kjeldahl method. Furthermore, a preliminary evaluation of biochemical parameters and NDVI was carried out on the 26th of May 2021 when camelina was at full flowering (65 BBCH stage). In detail, chlorophylls (µg cm^{-2}) and flavonols index, and crop health status related to nitrogen uptake (Normalized Difference Vegetation Index, NDVI), were estimated by using a field-portable leaf-clip sensor (Dualex ® Scientific Force A) and a FieldSpec 4 Hi-Res spectroradiometer (spectral range: vis-NIR, 350-2500nm), respectively.

Results

Nitrogen fertilization significantly influenced plant density, seed yield, harvest index, and seed protein content (Table 1). In particular, significantly higher seed yields were observed under N fertilization (60N+0 = 2.55 Mg ha^{-1}; 60N +60N = 2.32 Mg ha^{-1}; 0+60N = 2.19 Mg ha^{-1}) compared to the control (1.57

Mg ha^{-1}) faced with a higher plant density at harvesting. A significant effect of nitrogen fertilization on harvest index was also observed with the highest values obtained at basal dressing N fertilizer (60N+0; 0.28) and at basal+top dressing combination (60N+60N; 0.30), followed by the control (0.24) and top dressing N fertilizer (0+60N; 0.22). A positive relationship between seed yield and seed N uptake was obtained with a highly significant correlation coefficient (R^2= 0.9948), confirming that N in the crops is generally positive associated with seed yield. Seed protein content was also significantly influenced by nitrogen fertilization (~ 24%) compared to the control (~ 22%).

Table 1. Effect of N fertilization on camelina plant density, seed yield, harvest index, and seed protein content.

N fertilzer application	Plant density (no. m^{-2})	Seed yield (Mg ha^{-1})	Harvest Index (HI)	Seed Protein Content (%)
Control	92.22 ± 3.3 c	1.57 ± 0.07 b	0.24 ± 0.003 b	22.32 ± 0.06 b
60N+0	197.78 ± 13.3 a	2.55 ± 0.22 a	0.28 ± 0.02 a	24.15 ± 0.88 a
60N+60N	198.00 ± 13.5 a	2.32 ± 0.28 a	0.30 ± 0.03 a	24.28 ± 0.56 a
0+60N	126.17 ± 13.8 b	2.19 ± 0.28 a	0.22 ± 0.002 b	24.28 ± 0.48 a
Significance	***	**	**	**

Data are means ± standard deviations. Means followed by the same letters are not significantly different at P < 0.05 according to LSD post-hoc test. **=P<0.01; ***=P<0.001.

The content of chlorophylls and flavonols, estimated by Dualex, as well as the NDVI, estimated by FieldSpec 4 spectroradiometer, were significantly influenced by N fertilization (Table 2). Chlorophylls and flavonols showed the same trend with the best values obtained in all fertilized theses, compared to the control. The NDVI was significantly higher when plants were under basal-top dressing combination (60N+60N; NDVI = 0.79) compared to the other N doses and timing and to the control, indicating a high level of crop vigor when camelina was subjected to the highest N dose split in two applications (at sowing and before plant stem elogantion).

Table 2. Estimation of chlorophylls, flavonols and NDVI under different N fertilizer application at camelina full flowering (65 BBCH stage).

N fertilzer application	Chl (μg cm^{-2})	Flav (Abs unit)	NDVI
Control	23.32 ± 1.03 b	1.03 ± 0.06 b	0.72 ± 0.01 b
60N+0	25.03 ± 1.23 a	1.19 ± 0.07 a	0.74 ± 0.01 b
60N+60N	26.28 ± 0.13 a	1.20 ± 0.04 a	0.79 ± 0.02 a
0+60N	25.10 ± 0.46 a	1.16 ± 0.07 a	0.73 ± 0.04 b
Significance	*	*	*

Data are means ± standard deviations. Means followed by the same letters are not significantly different at P < 0.05 according to LSD post-hoc test. *=P<0.05.

Conclusions

This study represents the first approach regarding the use of proximal sensing techniques to estimate N needs of camelina under the Mediterranean climatic conditions of Central Italy. The obtained results showed the positive influence of N fertilization on camelina seed yield and quality as well as on the content of chlorophylls, flavonols and NDVI. In particular, our findings suggested that the best health crop status was reached with 60N+60N, even if the highest seed yield could be achieved with the application of only 60 kg N ha^{-1} (distributed either in pre-sowing or in stem elogantion). Consequently, other levels of N could be not economically viable and environmentally friendly as N can be easily lost by leaching. Although preliminary, these results can help in developing, for camelina, proper strategies for N application rates and for site-specific recommendations for its cultivation in Central Italy.

Literature

Martinelli T. and Galasso I. 2011. Phenological growth stages of *Camelina sativa* according to the extended BBCH scale. Ann. Appl. Biol., 158: 87-94.