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UNCOVER AND PROMOTE TOLERANCE TO TEMPERATURE AND WATER STRESS IN CAMELINA SATIVA

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D5.2
Optimized agronomic protocol for camelina as an autumn crop for double cropping

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Document Summary

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Datasets underlying: Data sets of the field trials collected at UNIBO experimental: BBCH, daily meteo data, final plant density, plant height, seed yield, total aboveground biomass, 1000-seed weight, seed oil and protein content, oil yield.

Communication level
☒ **PU** *Public*
☐ **CO** *Confidential, only for members of the consortium (including the Commission Services)*

Approved by:

☒ AIT (COO)	☒ CCE	☒ INRAE	☒ RRes
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Abstract

Deliverable 5.2 includes the main results obtained in a three-year field trial conducted by UNIBO aiming at identifying the best agronomic management for camelina grown as an autumn cover crop preceding summer crops in northern Italy. The studied factors were: sowing date (beginning of October vs. end of October), sowing density (6 kg/ha of seed with row-seeding vs. 8 kg/ha of seed with broadcasting), nitrogen fertilization (0 vs. 60 vs. 120 Kg N/ha) and harvesting method (conventional harvest vs. swathing).

In order to promote camelina productive performance while minimizing the inputs, in terms of both economic and environmental costs, the optimal combination of factors is as follows:

- ✓ Delayed sowing at the end of October/beginning of November
- ✓ A seed rate of 6 kg/ha with row-seeding
- ✓ N fertilization of 60 kg N/ha
- ✓ Conventional harvest

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1. Introduction

The introduction of a new crop in a new cropping system is not only fundamental but also strategic for its future acceptance by the farmers' community. Due its intrinsic characteristics camelina has been identified as a suitable crop to replace fallow autumn/winter period before the establishment of spring/summer crops in southern Europe. The shortness of its cycle and the high plasticity in terms of sowing dates easily permit to define camelina as a cover/intermediate crop. This is of great interest in southern European countries which mostly relay on cereals (autumn and spring) sole-cropping with indisputable environmental benefits related to increment of biodiversity, the better uses of available resources, and the break of some soil-borne diseases.
Obviously, the definition of an optimal and environmental sound agronomic management is one of the key issues for the future scale up of the crop.
In the framework of UNTWIST, UNIBO established a three-year study in open field aiming at identifying the optimal agronomic management for camelina in northern Italy, when grown as a cover/intermediate crop preceding typical summer crops.

2. Material and Methods

The trial was set up in the experimental farm of the University of Bologna (44°33'N, 11°23'E), during three growing seasons (2020/21, 2021/22 and 2022/23). The experimental design of the trial was a split-split plot with 4 replicates, with the main plot factor being the sowing time, the sub-plot factor being the sowing density, and the sub-sub plot factor being the nitrogen fertilization. A total of 96 plots were established in each growing season. The plot area was 18 m^2. Additionally, since the application of swathing can be a feasible option to anticipate camelina harvest when sowing is delayed in autumn, thus improving the feasibility of double cropping after camelina, the two harvesting techniques (conventional vs. swathing) were tested in the late sown plots, with row-seeding and intermediate nitrogen fertilization. Soil characteristics of the fields are reported in Table 1. Agronomic management was performed similarly during the three growing seasons, in particular seedbed was prepared with minimum tillage technique applying a 15 cm deep disking without ploughing. Fertilization was performed at the rosette stage, 0-60-120 kg ha^{-1} of nitrogen was applied as Urea (46%N) depending on the treatment. Sowing was performed in two different sowing times: anticipated sowing in the first decade of October and delayed at the beginning of November. Sowing and harvest dates are reported in Table 2. Sowing was carried out with a mechanic seeder, model Damax 17. Seeds were sown at 1 cm deep when drilling was used, while when broadcasted, the seeds were just left on the surface of the soil without being buried. Sowing density for row seeding was 6 kg ha^{-1}(=D1), while for broadcasted plots a sowing density of 8 kg ha^{-1} (= D2) was attested. The variety used in this trial was UNT5 (provided by CCE), a spring genotype with high germinating vigour, very drought tolerant and with high weed suppression effect.

Table 1. Main soil characteristics of each field trial in the different growing seasons

Growing season	*Type of soil*	*pH*	*Organic matter*	*Total nitrogen*	*Assimilable phosphorus (P_2O_5)*	*Exchangeable potassium (K_2O)*	*C/N*
2020-2021	Loam	6.69	1.80% s.s	0.98 g/kg	55 mg/kg	201 mg/kg	10.63
2021-2022	Clay-loam	7.93	1.65 % s.s	1.02 g/kg	34 mg/kg	180 mg/kg	9.36
2022-2023	Loam	7.82	1.48% s.s	1.05 g/kg	40 mg/kg	134 mg/kg	8.17

Table 2. Sowing, nitrogen and harvesting dates in three growing seasons (2020-2022). GDD (growing degree days) accumulation is reported.

Growing season	Sowing date	Sowing density	Sowing date	Nitrogen application	Harvesting date	GDD*
2020-2021	S1	D1 D2	08/10/20	08/02/21	21/05/21	1166
	S2	D1 D2	28/10/20	05/03/21	14/06/21	1399
2021-2022	S1	D1 D2	12/10/21	09/02/22	01/06/22	1303
	S2	D1 D2	12/11/21	08/03/22	14/06/22	1334
2022-2023	S1	D1 D2	11/10/22	06/02/23	08/06/23	1664
	S2	D1 D2	08/11/22	08/03/23	12/06/23	1391

*t.base 4°C

During camelina growth cycle emergence rate was determined 30 days after sowing and winter survival was quantified as the ratio between plants emerged before the beginning of the winter and in March, right after

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the end of the season. Soil coverage (%) was defined by means of the Canopeo app (Minnesota University): three pictures of each plot were taken, and soil coverage was obtained as % of green pixels present in the photo. Plants were harvested at full maturity (seed moisture ~10%) when conventional harvesting was applied. When swathing was tested, plants were cut at 25 cm from soil with a mowing bar when seed moisture was attested around 35% humidity (14-17 days before conventional harvesting), then they were left on the standing residues and after one week they were threshed with a plot combine (Nursery Master, Wintersteiger, Austria). For conventional harvest, the central portion of each plot was manually harvested cutting the plants at soil level and total biomass was determined. Immediately before harvest, the final plant height was determined as the mean value of the plot. Finally, plants were threshed by means of a plot combine (Nursery Master, Wintersteiger, Austria) and seeds and straw were separated and weighted. Representative sub-samples of fresh biomass, straw and seeds were collected, and oven dried at 105°C until constant weight in order to determine the residual moisture of the different samples and adjust the productive parameters to dry matter (DM). In order to determine final plant density at harvest, plants in two adjacent rows per 1m length were counted in row-seeded plots. When broadcasting was performed two metal squares of 20x20 cm area were placed in each plot and plants grown inside of the area were counted. Harvest index (HI) was calculated as the ratio between the total aboveground biomass and the seed yield. 1000-seed weight was determined by averaging the weight of 3 replicates of 1000 seeds each. Seed oil content and protein was determined by NIRS (Near-infrared spectroscopy) in the laboratories of CCE. The oil yield, expressed as kg of oil/ha, was obtained by multiplying individual plot seed yield by the relative seed oil content determined by CCE.

The main meteorological data, i.e., air temperature (minimum and maximum) and daily precipitation were collected throughout the growing seasons by weather stations located nearby each experimental location. GDD (Growing Degree days) were calculated for each location, seeding time, and growing season, from sowing to harvest using the following equation:

$$GDD = \sum[(T_{max}+T_{min})/2 - T_{base}]$$

Where T_{max} and T_{min} are the maximum and minimum air temperature, respectively, and T_{base} for camelina was defined as 4°C (Gesch & Cermak, 2011).

2.1. Statistical analysis of the data

All collected data were subjected to a three-way ANOVA (Statgraphics Centhurion 18) in which the three considered main factors were: sowing date, sowing density, and nitrogen fertilization. Year was considered as a random factor in the analysis. When significant statistical differences emerged among means ($P \leq 0.05$), LSD (Least Significant Difference) test was used to separate means. For the evaluation of the effect of the harvesting strategies, a different two-way ANOVA was run comparing the two harvest methods and the effects of the years, mainly in relation to the meteorological conditions after the swathing, since for the rest the trials were in the same conditions as the other. When significant statistical differences emerged among means ($P \leq 0.05$), LSD (Least Significant Difference) test was used to separate means.

2.2. Meteorological data

During the three-year trial, constant increment was observed for minimum temperatures (°C). In the first and second growing season, the mean minimum temperatures were 4.2°C along camelina cycle, while in the growing season 2022-23 the registered mean minimum temperature was 5.7°C. Regarding maximum temperatures (°C) no significant differences were observed. Going in depth in the dataset (Table 3), October 2022 was the warmest of the three growing seasons resulting in a mean minimum temperature of 11°C and mean maximum temperature of 24.5°C, regarding. Winter was the coolest during the second growing season with a mean minimum temperature of -0.1°C. During the last period of the growth cycle, temperatures were consistent across the years. Growing degree days, calculated from sowing to harvest in each trial, were consistent through the years reporting values in line with Zanetti et al. (2017). The anticipated sowing of the last growing season reported higher accumulation of GDD due to high temperatures in October together with very low precipitation (<1mm) that resulted in a delayed emergence.

Table 3. Main meteorological parameters surveyed during camelina growth cycle in the 3 consecutive years of trials.

Growing season	***Month***	***T.min (°C)***	***T. mean (°C)***	***T. max (°C)***	***Precipitation (mm)***	***GDD (*)***
2020-2021						
	October	8.1	12.9	18.2	54.6	226.4
	November	5.4	9.1	13.7	24.8	156.6
	December	3.0	5.8	9.1	116.8	68.5
	January	-0.6	2.7	6.6	44.2	11.2
	February	2.1	7.1	12.6	6.2	97.3
	March	1.0	8.7	16.2	5.8	144.9
	April	4.6	11.2	17.5	56.6	215.4
	May	10.8	17.1	23.2	31.2	407.3
	June	14.8	21.9	28.9	4.0	268.9
2021-2022						
	October	6.52	12	18.38	0.4	160
	November	6.8	9.7	12.9	78.8	171.9
	December	0.4	3.8	7.6	32	18.2
	January	-0.7	3.4	8.5	37	22.3
	February	0.0	6.2	12.9	14	63.6
	March	0.4	7.4	14.8	41	108.3
	April	5.7	12.3	18.6	91.8	248.3
	May	13.7	19.9	25.8	27.4	492.4
	June	17.4	24.8	31.4	12	624.5
2022-23						
	October	11.5	17.5	24.5	0.8	281.1
	November	5.9	10.0	14.3	111.4	179.5
	December	4.2	6.4	8.4	64.6	82.7
	January	2.8	5.8	9.2	51.8	63.3
	February	-0.5	5.4	12.4	14.2	59.7
	March	3.8	10.7	17.2	29	208.5
	April	6.0	12.2	18.6	31.4	246.1
	May	12.5	17.2	22.1	276.2	409.5
	June	15.5	21.2	27.6	46	206.5

*t.base 4°C

Concerning precipitation (Fig. 1), during the last growing season (2022-2023), very heavy rains were registered in May, resulting in prolonged flooding and doubled amount of precipitation compared to the first and second growing seasons (2020-21 and 2021-22, respectively).
The uneven distribution of precipitation in the months of May and June caused quite uneven results related to the application of the swathing technique at harvest, which allowed an anticipation of 5 to 7 d compared with conventional harvest.

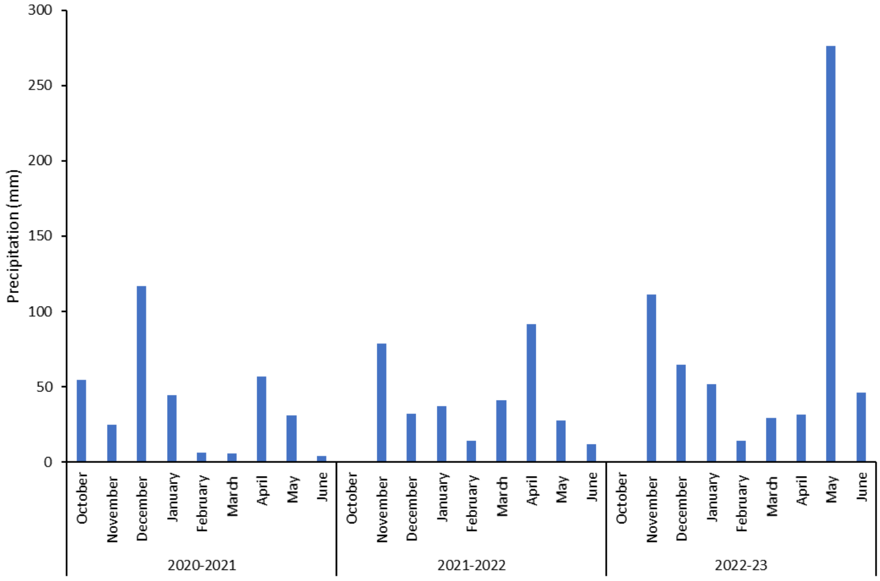

Fig. 1. Precipitation during camelina growth cycle in the 3 consecutive years of trials at UNIBO.

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3. Results

3.1 Sowing dates x sowing density x N fertilization trial

The main results of the three-way ANOVA are included in table 4. Interestingly, only sowing date and N fertilization played a role on camelina productivity, while sowing density only affected final plant density as obviously expected. The interaction between the considered factors was never significant.

Table 4. Main results of the ANOVA carried out on the data collected on the 3-year-trial at UNIBO comparing 2 sowing dates, 2 sowing density and 3 N fertilization rates. Statistically significant differences (P≤0.05, LSD Test) are highlighted in red.

Measurement	Term	F-ration	P-value
Final plant height (cm)	Sowing date (A)	2.90	0.0912
	Sowing density (B)	0.02	0.8871
	N fertilization (C)	3.03	0.0521
	A x B	0.74	0.3928
	A x C	0.08	0.9187
	B x C	0.09	0.9155
Final plant density (plants/m^2)	Sowing date (A)	0.20	0.6572
	Sowing density (B)	7.96	0.0057
	N fertilization (C)	0.13	0.8744
	A x B	0.98	0.3246
	A x C	0.11	0.8935
	B x C	0.38	0.6843
Total aboveground biomass (Mg DM/ha)	Sowing date (A)	0.10	0.7527
	Sowing density (B)	2.61	0.1091
	N fertilization (C)	16.14	0.0000
	A x B	0.20	0.6545
	A x C	0.70	0.4974
	B x C	0.50	0.6103
Seed yield (Mg DM/ha)	Sowing date (A)	6.16	0.0145
	Sowing density (B)	0.25	0.6211
	N fertilization (C)	18.15	0.0000
	A x B	1.32	0.2527
	A x C	0.68	0.5068
	B x C	0.19	0.8283
Harvest Index	Sowing date (A)	6.12	0.0148
	Sowing density (B)	1.48	0.2258
	N fertilization (C)	0.61	0.5446
	A x B	0.38	0.5366
	A x C	0.93	0.3967
	B x C	0.12	0.8874

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1000-seed weight (g)	Sowing date (A)	3.70	0.0567
	Sowing density (B)	1.10	0.2960
	N fertilization (C)	0.37	0.6915
	A x B	1.05	0.3077
	A x C	0.12	0.8835
	B x C	0.24	0.7886
Oil content (% DM)	Sowing date (A)	0.17	0.6824
	Sowing density (B)	1.95	0.1656
	N fertilization (C)	12.30	0.0000
	A x B	2.46	0.1196
	A x C	0.39	0.6757
	B x C	2.02	0.1375
Protein content (% DM)	Sowing date (A)	4.08	0.0457
	Sowing density (B)	0.49	0.4846
	N fertilization (C)	11.92	0.0000
	A x B	1.48	0.2265
	A x C	0.35	0.7059
	B x C	0.02	0.9780
Oil yield (Kg DM/ha)	Sowing date (A)	5.87	0.0170
	Sowing density (B)	0.01	0.9162
	N fertilization (C)	11.28	0.0000
	A x B	1.91	0.1693
	A x C	0.92	0.4032
	B x C	0.29	0.7453

In detail, final plant height was not influenced by the considered factors (Table 4). Despite non-significant difference, it was possible to separate the mean values in response to N fertilization, with significant taller plants in the 120N (84.4 cm) compared with 0N (76.5 cm, Fig.2).

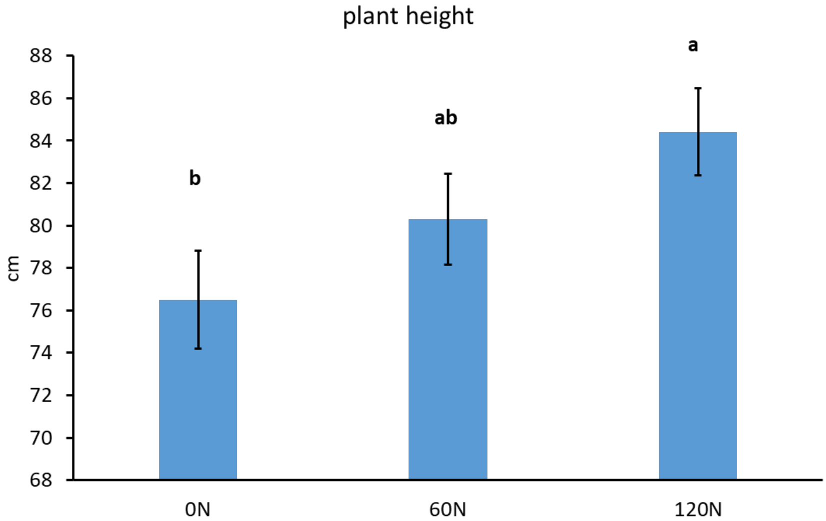

Fig. 2. Final camelina plant height at harvest in response to Nitrogen fertilization. Vertical bars: standard error. Different letters correspond to significant different means for P≤0.05, LSD Test.

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When considering the final plant density, as expected it was influenced by the sowing density, and plots sown at higher rate with broadcasting showed an almost double density (192 vs. 100 plants/m^2, *P≤0.05*). Unfortunately, this was the only parameter surveyed at harvest for which better performance of camelina was found in response to increased seeding rate, while no differences were found for all the other parameters. Thus, increasing the seeding rate of camelina probably only increases production costs in terms of higher seed costs, without any beneficial effect on the final productivity.
The total aboveground biomass and the seed yield were both significantly affected by the N fertilization, and the latter, also, by the sowing date (Fig. 3). In particular, aboveground biomass and seed yield were increased by 44% and 47%, respectively, when 120 kg of N/ha was applied compared with unfertilized plots. The differences between 60N and 0N were of 27% and 29% for total aboveground biomass and seed yield, respectively.

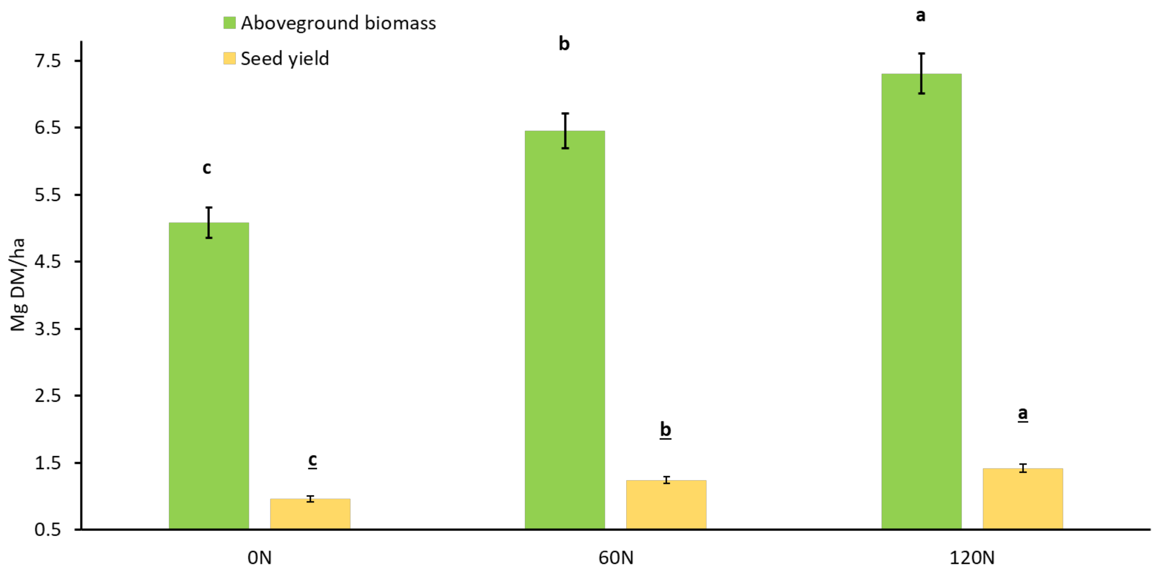

Fig. 3. Camelina total aboveground biomass and seed yield in response to Nitrogen fertilization. Vertical bars: standard error. Different letters correspond to significant different means for aboveground biomass (P≤0.05, LSD Test). Different underlined letters correspond to significant different means for seed yield (P≤0.05, LSD Test).

When analyzing the effect of sowing date (Fig. 4), the latest sowing (=S2) at the end of October/beginning of November confirmed to be the optimal one for camelina in northern Italy, as previously stated by (Righini et al., 2019). Nevertheless, the increase in seed yield was more modest than for N fertilization, with an increase of only 14% between late (S2) and early sowing (S1).

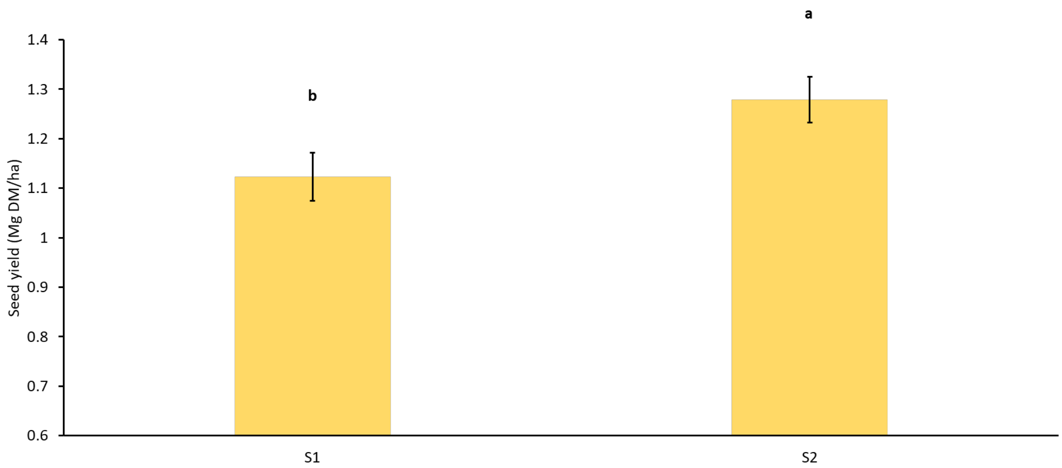

Fig. 4. Camelina seed yield in response to sowing date (S1 = early October, S2= late October/early November). Vertical bars: standard error. Different letters correspond to significant different means (P≤0.05, LSD Test).

The sowing date had also a significant effect on the camelina harvest index, a productive trait related to incidence of seeds on the total biomass production; in general the higher the better. As evident in Fig. 5, the later sowing date (S2) not only promoted seed yield, but also increased the ratio between seed biomass and total biomass. This trait is often associated to better allocation of resources, indicating that plants promote resource use and storage in productive organs (seeds) rather than in leaves, stems, etc.

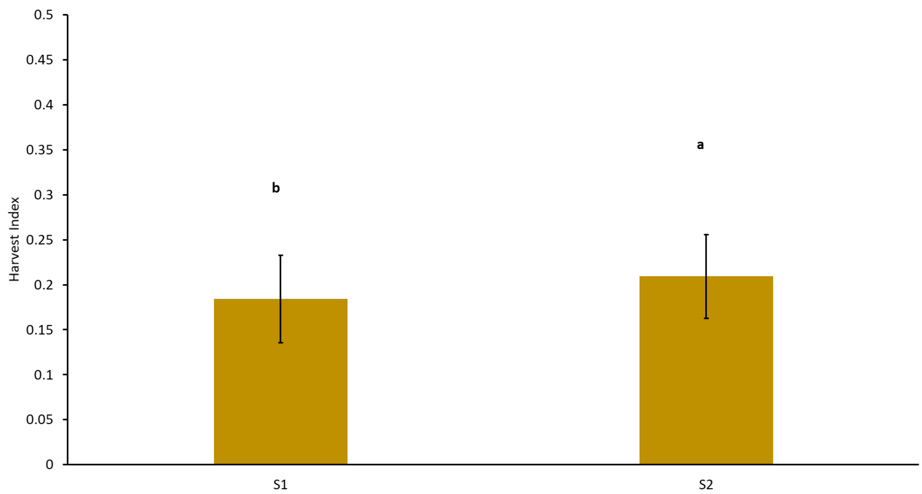

Fig. 5. Camelina harvest index in response to sowing date (S1 = early October, S2= late October/early November). Vertical bars: standard error. Different letters correspond to significant different means (P≤0.05, LSD Test).

Nitrogen fertilization and sowing date also played a role on camelina seed quality in terms of oil and protein content, with nitrogen in particular significantly influencing both parameters, while sowing date only affected seed protein content. As expected, oil and protein content were inversely related, and nitrogen fertilization promoted protein content while lowering oil content (Fig. 6).

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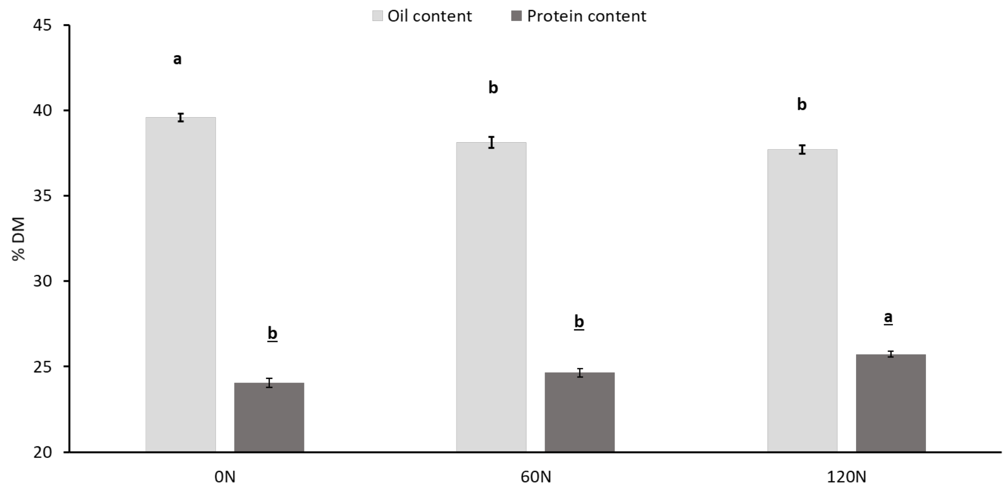

Fig. 6. Camelina seed oil and protein content in response to Nitrogen fertilization. Vertical bars: standard error. Different letters correspond to significant different means for seed oil content (P≤0.05, LSD Test). Different underlined letters correspond to significant different means for seed protein content (P≤0.05, LSD Test).

Sowing date also affected the seed protein content (Fig. 7), and the later sowing date promoted seed protein accumulation without significantly affecting oil content, which is of great interest for the overall performance of the crop.

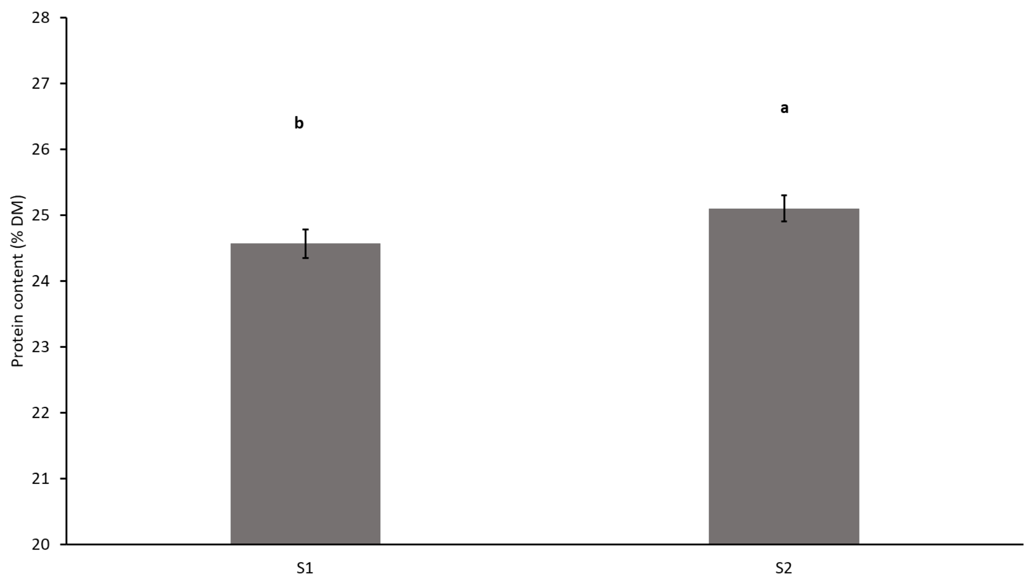

Fig. 7. Camelina seed protein content in response to sowing date (S1 = early October, S2= late October/early November). Vertical bars: standard error. Different letters correspond to significant different means (P≤0.05, LSD Test).

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The thorough analysis of the productive data obtained from this study can be summarized with the analysis of the oil yield, which combines both seed yield and oil content, and is certainly the most interesting parameter from a productive point of view, able to summarize the productivity of camelina in northern Italy. Seed yield was significantly affected by sowing date and N fertilization (Table 4).

As shown in Fig. 8, the later sowing (S2) increased oil yield by almost 13%. The higher N dose also promoted this parameter, but the increase was 21% and 36% when comparing 60N and 120N respectively with the unfertilized control. However, the differences between 120N and 60N were only +13%, which is too low to justify the additional economic and environmental costs related to doubling the nitrogen fertilization rate.

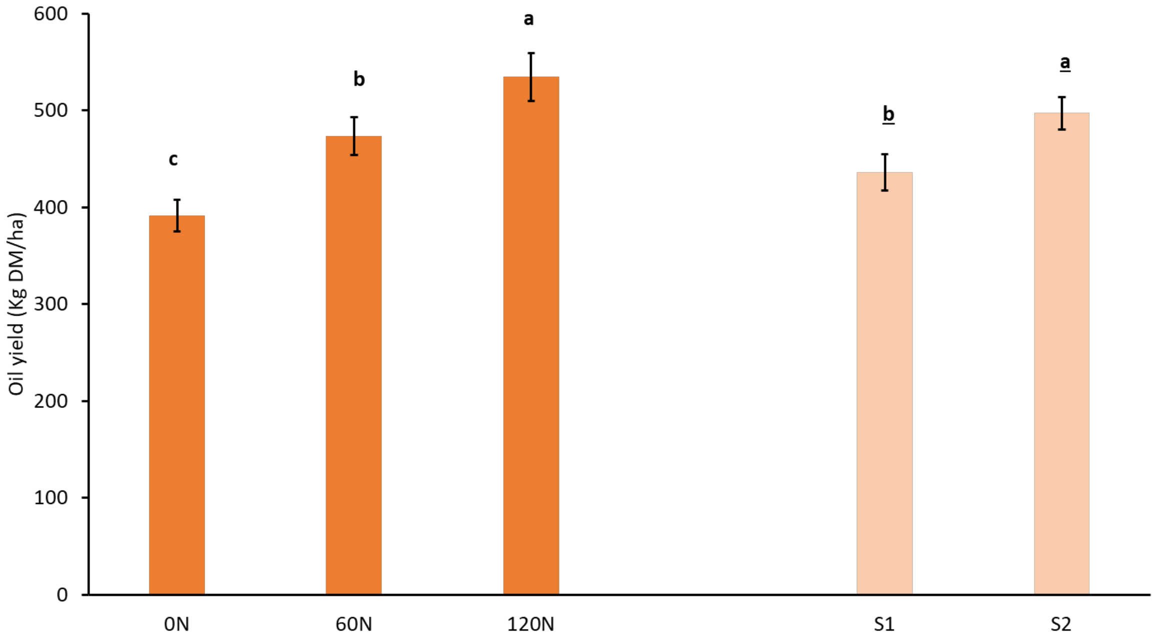

Fig. 8. Camelina oil yield in response to Nitrogen fertilization and sowing date. Vertical bars: standard error. Different letters correspond to significant different means in response to N fertilization (P≤0.05, LSD Test). Different underlined letters correspond to significant different means in response to sowing date (P≤0.05, LSD Test).

3.2 Harvesting technique trial

The results of the ANOVA carried out on the data collected in the harvesting strategy trial are shown in Table 5.

Table 5. Main results of the ANOVA carried out on the data collected on the 3-year-trial at UNIBO comparing 2 harvesting strategies across three growing seasons. Statistically significant differences (P≤0.05, LSD Test) are highlighted in red.

Measurement	Term	F-ration	P-value
Total aboveground biomass (Mg DM/ha)	Harvesting strategy (A)	11.52	0.0034
	Growing season (B)	5.26	0.0166
	A x B	3.83	0.0423

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Seed yield (Mg DM/ha)	Harvesting strategy (A)	0.00	0.9756
	Growing season (B)	5.55	0.0132
	A x B	6.72	0.0066
Harvest Index	Harvesting strategy (A)	2.99	0.1018
	Growing season (B)	0.49	0.6232
	A x B	9.11	0.0020
1000-seed weight (g)	Harvesting strategy (A)	0.21	0.6531
	Growing season (B)	5.59	0.0129
	A x B	2.69	0.0952
Oil content (% DM)	Harvesting strategy (A)	0.49	0.4963
	Growing season (B)	36.27	0.0001
	A x B	0.25	0.6283
Oil yield (Kg DM/ha)	Harvesting strategy (A)	3.19	0.0993
	Growing season (B)	172.94	0.0000
	A x B	8.10	0.0147

Among the main results, the harvesting strategies significantly affected only the total aboveground biomass at harvest, with higher values obtained with swathing (H2) than with conventional harvest (H1, Fig. 9).

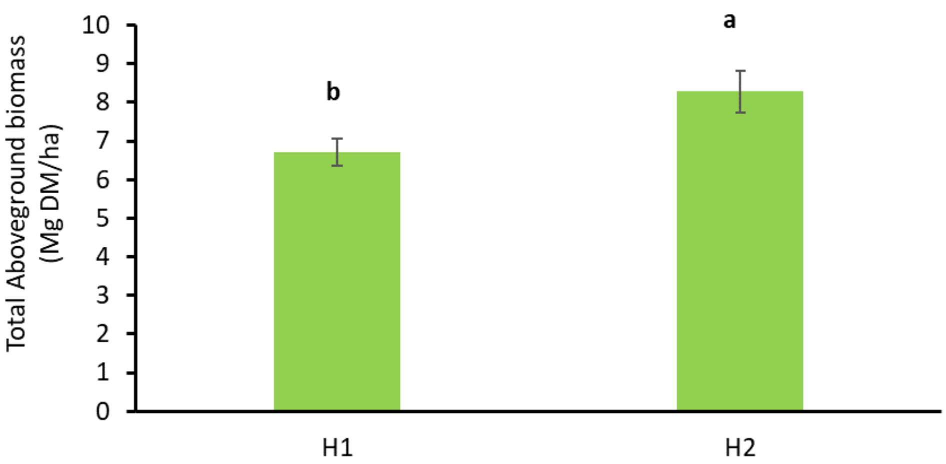

Fig. 9. Camelina total aboveground biomass in response to harvesting strategy (H1 = conventional harvest, h2= swathing). Vertical bars: standard error. Different letters correspond to significant different means (P≤0.05, LSD Test).

Otherwise, the interaction between "harvesting strategies X growing season" significantly affected total aboveground biomass, seed yield (Fig. 10), oil yield, and harvest index (data not shown), while from a seed quality perspective (1000-seed weight and seed oil content) the harvesting strategy and the interaction between "harvesting strategies X growing season" were not significant (Table 5).

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The increase of camelina productivity in response to swathing (H2) was recorded only in years when adverse meteorological conditions occurred before and during harvest, which was the case in spring 2023 when flooding occurred in Bologna and thus swathing permitted an improved harvestability of the crop. On the other hand, when some spotty rainy events occurred just after cutting, like in 2022, swathing was not the optimal technique.

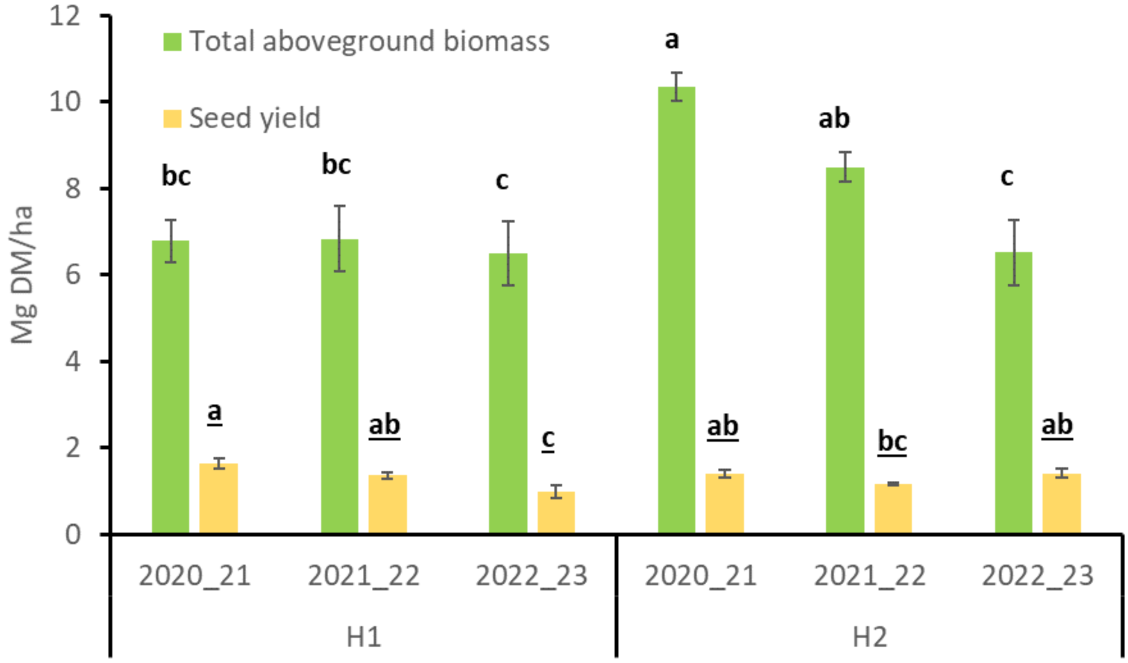

Fig. 10. Camelina aboveground biomass and seed yield in response to the interaction "harvesting strategy (H1 = conventional harvest, H2= swathing) x growing season". Vertical bars: standard error. Different letters correspond to significant different means for total aboveground biomass (P≤0.05, LSD Test). Different underlined letters correspond to significant different means for seed yield (P≤0.05, LSD Test).

Oil yield was also affected by the interaction between "harvesting strategies X growing season". However, in this case, the differences were negligible, since they were mainly driven by the difference in seed yield, since seed oil content was only significantly influenced by growing season and not by the harvesting method.
The application of the swathing technique resulted in alternate results across growing seasons, mainly in relation to the meteorological conditions occurring after cutting. Thus, while this technique did not show any limitation when applied to camelina from a technical point of view, there were no improvements or losses of the performances from the productive point of view. Some additional costs have to be taken into account both from the economic and environmental point of view, mainly related to the equipment (costs, availability in the farm, and CO_2 emissions). Thus, swathing did not improve camelina seed yield, but it allowed an anticipate harvest compared to conventional harvesting, which can be of interest in double cropping systems.

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4. Overall conclusions

Camelina confirmed to adapt well to northern Mediterranean conditions, and the shortness of its cycle allowed double cropping with soybean, after its harvest. The trials conducted within task 5.2 permitted to identify the optimal management for the crop in terms of: **sowing date** and **density**, **nitrogen fertilization,** and **harvesting method**.

So, to promote camelina productive performance while minimizing agronomic inputs, in terms of both economic and environmental costs, **the optimal combination of factors studied in UNTWIST** is as follows:

- ✓ **Delayed sowing at the end of October/beginning of November**
- ✓ **A seeding rate of 6 kg/ha**
- ✓ **N fertilization of 60 kg N/ha**
- ✓ **Conventional harvest**

The use of swathing remains an open issue so far, since if it is feasible from a technical point of view, a thorough analysis of economic and environmental costs should be carried out.

Aiming at further promoting the cultivation of camelina in northern Mediterranean environments, a "farmer-friendly" agronomic protocol has been set up and added to the present deliverable as an annex (Annex I). Since the scope of WP5 was only to investigate the effect of some agronomic factors on camelina productivity, other relevant information included in the farmer´s protocol was retrieved from UNTWIST partners´ (UNIBO & CCE) knowledge on the crop gained in previous projects and research not directly related to UNTWIST. To make this clear, a note on optimized protocol parameters derived from the UNTWIST project was added in Annex I.

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5. References

Gesch & Cermak, 2011. DOI: 10.2134/ agronj2010.0485.
Zanetti et al. 2017. DOI: 10.1016/j.indcrop.2017.06.022
Righini et al. 2019. DOI: 10.1016/j.indcrop.2019.05.009

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Annex 1: *Camelina sativa* protocol for introduction as an autunm crop for double cropping in Italy

CAMELINA SATIVA PROTOCOL FOR INTRODUCTION AS AN AUTUMN CROP FOR DOUBLE CROPPING IN ITALY

INTRODUCTION

Camelina can be introduced in farmer rotations as an autumn intermediate crop preceding summer main crop such as sorghum, soybean or sunflower in Italian regions where double cropping is feasible. The present protocol, optimized within the UNTWIST project through three years of field experiments in northern Italy, addresses the introduction of camelina as an autumn intermediate crop for double cropping.

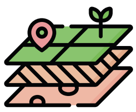
FACTS

- **Common names:** Camelina, Leindotter, Gold of Pleasure, False Flax.
- **Scientific name:** *Camelina sativa* (L.) Crantz Family: Brassicaceae or Cruciferae.
- **Drought-resistant oil crop** with a yield potential of 2.5 t/ha.
- **Plant height:** 60 to 120 cm.
- **Pollinator friendly species.**
- **1000-seed weight:** 0.8 - 1.6 g.

ADVANTAGES

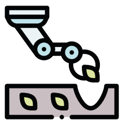
- **Conventional machinery for winter cereals.**
- **Easy implementation & low-input crop.**
- **Drought & frost tolerant.**
- **Catch crop.**
- **Pest & disease tolerant.**
- **Pivoting root** - soil structure improver.
- **Fit for autumn, winter and early spring sowing.**
- **Suitable summer crops** after camelina harvest: soybean, sunflower.

AGRONOMIC PROTOCOL KEY POINTS



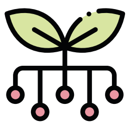
PLOTS

Avoid easily waterlogged soils, with crust formation and pH less than 5.5 and greater than 8.5.



SOWING

Shallow sowing (≈ 1 cm) in rows (13-17 cm distance) on a plot without weeds or straw.



NUTRIENTS

Guarantee minimum nitrogen availability including soil N (100 kg N/ha).

HERBICIDES

Resistant to many grass-killer but susceptible to dicot herbicides.

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CAMELINA SATIVA PROTOCOL

FOR INTRODUCTION AS AN AUTUMN CROP FOR DOUBLE CROPPING IN ITALY

SOWING

- Sowing date: Autumn (last two weeks of October - first two weeks of November).
- Sowing rate: 5-6 kg/ha.
- Row sowing: 13-17 cm between rows.
- Sowing depth: Superficially ≈ 1 cm. Ensure a good seed-soil contact.
- Roll before sowing, if needed.
- Fertilization: Guarantee minimum nitrogen availability (100 kg N/ha).

WEEDS

Check soil N availability before sowing. Apply N fertilizer at rosette stage to reach in total max 100 kg N/ha. Excessive fertilization decreases seed oil content and causes lodging problems. With a proper crop establishment, camelina competes well with weeds (allelopathic effect). Check the herbicides registered for narrowleaf control in your country.

HARVEST

Between end of May until mid June, when the siliques have turned from lemon yelow to brown, seeds should be light brown. Do not wait until basal part of the plant is dry, it will be too late. Combine setting: i) Raise the cutting bar to the height of the first fruits (10-15 cm from the soil) and lower rpm; ii) Set the combine for small seed harvest; iii) Reduce to minimun the vertilation in the sieve and straw separation system.

POST-HARVEST

Maximum moisture for storage: 8 %.
If an excess of moisture is detected in the harvested grain (symptom: heating), pre-cleaning and eventually drying is recommended.

*Sowing date, sowing rate and strategy as well as nitrogen fertilization rate was optimized in 3-year field trials within the **UNTWIST project**. The other parts of the protocol are based on previous experience with the crop and other projects and research work.*

STAGES IN CAMELINA PRODUCTION

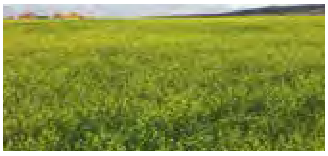
SOWING

COTYLEDONS

ROSETTE

ELONGATION

BLOOM



FRUIT FILLING

MATURATION

HARVEST

Photographs provided by Camelina Company.

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UNCOVER AND PROMOTE TOLERANCE TO TEMPERATURE AND WATER STRESS IN CAMELINA SATIVA

UNTWIST PARTNERS

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