

# GERMINATION AND MORPHOLOGY OF *CAMELINA SATIVA* GROWN IN THE SEMI- ARID ZONE OF NAAMA (ALGERIA)

Hafidha Boucherit<sup>1</sup>, Dahbia Izountar<sup>1</sup>, Abdelkrim Benaradj<sup>1</sup>,  
Hashas Mounira<sup>1</sup>, Belhadj Rafiqa<sup>1</sup>

<sup>1</sup> Laboratory of Sustainable Management of Natural Resources in Arid and Semi-Arid Areas, Salhi Ahmed University of Naama, P. O. B. No. 66, 45000 Naama, Algeria

Link to this article: <https://doi.org/10.11118/actaun.2025.023>

Received: 14. 9. 2025, Accepted: 2. 12. 2025

## Abstract

70% of the decline in agricultural production is caused by abiotic stress factors, such as than drought and variations in precipitation. Its factors can pose problems in terms of starting the small- seeded species in the early stages of vegetation (germination) and crop informing in plant growth. Camelina (*Camelina sativa* L. Crantz, Brassicaceae) is an important low -yield oilseed crop consumption of inputs. Camelina East considered as small- seeded species, this setting can directly influence seedling germination, growth and development. The current research East based on the study of germination and growth of sevens varieties of camelina. Germination tests have summer conducted at the laboratory level, and growth tests have summer posed on the ground according to a completely randomized block experimental design with three repetitions. The results revealed significant differences ( $p < 0.05$ ) between the different seven varieties for germination capacity, emergence, number of plants in rosette and precocity. Variety 7 is the best performing variety for the parameters studied: it has excellent germination capacity (98.66%), it produces 7 plants per 31 square centimeters, 10 rosette plants per 31 square centimeters and it is the earliest with duration of 48 days from sowing to 50% flowering.

Keywords: *Camelina sativa* L., growth, germination, varieties, Naama, Algeria

## INTRODUCTION

In the current circumstances of climate change, the increase in drought episodes and the degradation of arable land seriously affects global food security and sustainability of agricultural resources (Mirzabeav *et al.*, 2023; Fanzo *et al.*, 2025). In the face of these challenges, it is imperative to diversify agricultural crops with species that are both resilient and economically viable. Over the past decade, the production and distribution of oilseed plants and their products worldwide has expanded remarkably; oilseed crops occupy approximately 37% of the world's agricultural land. The challenge for oilseed and protein crops will therefore be to be able to supply quality products in sufficient quantity to meet the growing demand for vegetable oils (FAO,

2023; Mirzabaev *et al.*, 2023). In Algeria, oil crops for industrial purposes, especially Camelina, are still limited; they deserve special attention, due to their low environmental impact and the universal applicability of their by-products (Berzuini *et al.*; 2024; Guendouz *et al.*, 2024).

*Camelina sativa*, an oilseed plant belonging to the Brassicaceae family (Meghna *et al.*, 2018), stands out as a promising candidate due to its multiple agronomic and environmental. Grace to its high concentration of oil rich in omega-3 and omega-6 fatty acids, camelina is widely used in the food industry (Zhang and Auer, 2020). Furthermore, it contributes to the bioenergy industry through its ability to produce a very environmentally friendly biofuel (Agarwal *et al.*, 2021).



This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 (CC BY-NC-ND 4.0) International License

According to Zubr, 2003; *Camelina* has a wide adaptation and can grow in different climatic and soil conditions. This requires the search for varieties that have better adaptation while ensuring stable feed for livestock and quality oil production. Furthermore, *Camelina sativa* remains a relatively minor crop in terms of human food and its water and fertilizer requirements are low, meaning that it can be grown on light and sandy soils; it is the most drought-resistant and summer-heat resistant cruciferous crop (Bansal and Durrett, 2015). These qualities could effectively contribute to the resilience of the agricultural system in Naama and Algeria.

Studying the germination and growth of different *Camelina sativa* varieties is important for climate change adaptation research because it allows for the selection of species more resistant to extreme conditions (heat, drought, etc.) in order to identify those more resistant to water and heat stress, thus developing more resilient crops for the future. By understanding how different varieties react to new conditions such as temperature, water, and soil conditions, it is possible to select more robust plants and develop more stable and productive crops, anticipate impacts on ecosystems, and ensure food security in the face of changing climatic conditions.

*Camelina sativa* was introduced for the first time in Algeria during the agricultural campaign (2020/2021) as part of a Partnership for Research and Innovation in the Mediterranean Area (PRIMA-4CE-MED project). *Camelina* has been the subject of several research studies semi-arid zone Setif, high-altitude of Algeria, and should be proposed as an alternative crop (Izountar *et al.*, 2025).

The objective of this work is to study the morphology and germination rate of seven different varieties of *Camelina sativa* in the Ain Sefra wilaya of Naama (southwestern of Algeria). This first study has allowed us to deepen our knowledge of the impact of environmental conditions on the behavior of camelina varieties.

## MATERIALS AND METHODS

### Study Area

The study area “Ain Sefra” is part of the wilaya of Naama. This last one, it extends over an area of 3 million hectares located on the southwestern part of the highlands and is occupied by a population estimated at 303,843 inhabitants. The rainfall regime is irregular in these steppe regions characterized by low rainfall (between 220–180 mm/year) and a fairly long dry period of 6 to 7 months, with low temperatures generally falling below  $-4^{\circ}\text{C}$ . This explains its belonging to the arid bioclimatic stage (Boucherit, 2018; Benaradj *et al.*, 2020; Boucherit *et al.*, 2024). Agriculture and pastoralism are the two main economic activities in the region. The Naama region has experienced several threats in the past, especially those linked to climatic factors (aridity, drought), desertification and sand encroachment (Benaradj *et al.*, 2021).

### Biology Material

Forage cruciferous plants (rapeseed, turnip rape, cabbage, camelina, etc.) stand out from other cover crop species due to their biomass production; highly palatable, they are also a significant source of protein.



1: Location of study area



2: The organs of *Camelina sativa* (a: Rootlet; b: leaves; c: flowers; d: fruits; e: seeds)

*Camelina* (*Camelina sativa* L. Crantz), is an oilseed species, known as cultivated camelina; it occurs as an annual herbaceous plant from the Brassicaceae or Cruciferae family (Zubr, 1997). Since the end of the 1990, *Camelina sativa* is attracting renewed interest, motivated by its unique agronomic and industrial characteristics (Putnam *et al.*, 1993; Bonjean and Goffic, 1999; Zanetti *et al.*, 2013).

*Camelina sativa* has a deep, white taproot that can penetrate deep into the soil and help break up clay clods. It is a hardy plant that can grow in undemanding soils.

### Germination of Camelina

*Camelina sativa* seeds were collected at the NIAR (National Institute of Agronomic Research) in Sétif and tested in February 2023. A germination test was carried out on seven varieties of camelina at the laboratory of the University of Naama (Tab. I).

The seeds were soaked in bleach for 5 minutes, then rinsed thoroughly with distilled water and placed in Petri dishes containing two filter paper discs, with 50 seeds per dish and 3 replicates per variety. The Petri dishes were incubated at 24 °C, with water added as needed. The daily light exposure was 12 hours for 7 days.

### The Parameters Measured

#### Germination Rate

The Germination rate (Gr) was estimated by using the following formula (Kandil *et al.*, 2012):

$$Gr (\%) = \frac{\text{Seeds germinated}}{\text{total seeds}} \times 100. \quad (1)$$

#### Speed of Germination (N)

The Speed of germination (N) was calculated using the following formula (Agrawal, 1995; Panuccio *et al.*, 2014):

$$N = \frac{N_1}{1} + \frac{N_2}{2} + \frac{N_3}{3} + \frac{N_x}{x}, \quad (2)$$

where,  $n_1 \dots n_x$  are the number of seeds germinated on day 1 to day x.

#### Germination Index (GI)

The Germination Index (GI) is an indicator that assesses both the percentage and the speed of seed germination (Panuccio *et al.*, 2014; Marvin and Gonzales, 2015).

$$GI = \sum_{i=1}^k \frac{\text{Number of germinated seed}}{\text{Count day}}, \quad (3)$$

where:  $i=1$  day one,  $k$  the last day of observation.

#### Growth of *Camelina sativa*

In February, cultivation trials of the camelina species were carried out for the first time in the Naama region (Algeria), in order to test its adaptation to climatic and edaphic conditions.

The experimental design adopted is a randomized design with three replicates with a single factor studied: varieties. A substrate used was well prepared (a mixture of equal parts sand, peat and potting soil) and placed in polyethylene bags with a diameter of 20 cm. The selections of seeds were transplanted to a depth of 2 mm, at a rate of 10 seeds per bag. The different phenological stages were followed from the seed until the formation of siliques and the harvest of

I: Code of varieties tested in the experiment

Varieties	V1	V2	V3	V4	V5	V6	V7
Coded	CCE26	CCE29	CCE42	CCE43	CCE44	CCE117	Alba

the seeds where the morphological and physiological maturity was well noted.

Measured parameters: emergence; rosette plants and height of plants at maturity; Earliness

### Data Processing

The statistical processing of morphological parameters was carried out using Costat software version 6.4. The average values are calculated according to the Newman and Keuls method at the 5% probability threshold.

## RESULTS

Studying the germination and growth of *Camelina sativa* varieties is crucial for adjusting to climate change, as it aids in comprehending how temperature fluctuations, drought conditions, and other environmental factors affect its development.

### Climatic and Edaphic Aspect

Naama region is characterized by a long, hot, dry summer season and a short, cold, rainy season with increasing aridity, making the ecological conditions very unfavorable. Rainfall is variable in time and space. The soil is sandy loam in texture, with an alkaline pH of (7.9 and 8.1) and an electrical conductivity of 0.4 ms/cm.

The Naâma region is characterized by extreme temperatures, with winter lows ranging from -3.2 to 2 °C and summer highs reaching 35 to 40 °C. This significant temperature range is typical of a cold or temperate semi-arid climate, where summers are very hot and winters are long and cool. Therefore,

extreme temperatures are a characteristic of arid and semi-arid zones, along with very low rainfall and a high rate of evaporation.

The analysis of the various ombrothermal curves (Fig. 3) of the stations, allows us to observe a period of drought varies from 5 to 7 months or more (from the month from June to September) in the resorts of the northern part of the region (steppe plains). On the other hand, in the central part of Saharan Atlas (Ain Sefra), it has a fairly prolonged period of drought that varies from 10 to 11 months (from March until the end of November). Thus, a fairly short wet period; varies from 4 to 6 months for stations in the steppe space, from one month for stations in the Atlas mountainous space and zero for stations in the Saharan domain (Benaradj, 2017; Boucherit, 2018; Benaradj *et al.*, 2021)

### Analysis of Variance

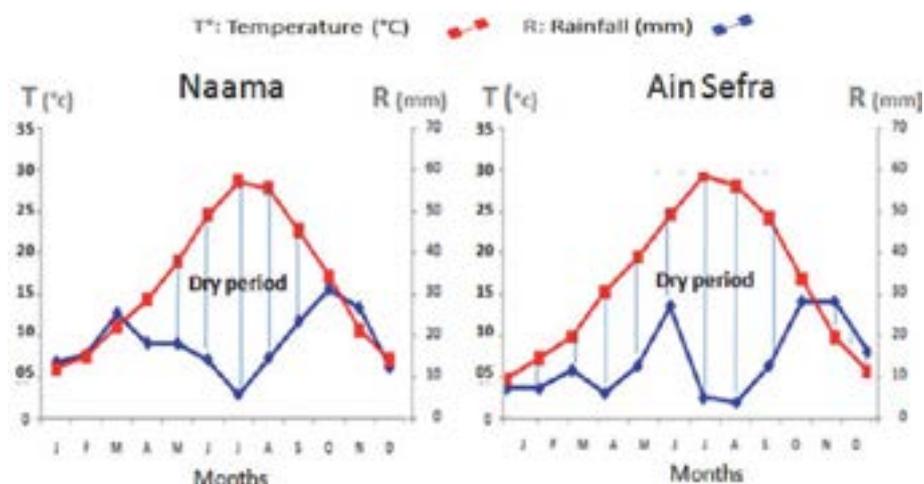
The results of the analysis of variance show significant and non-significant effects for the different parameters studied. In this regard, the analysis reveals that the speed, the germination index and the height of the plants represent non-significant differences. The number of plants emerged and the number of rosette plants present significant scores, and a very highly significant difference for the germination capacity and the precocity to flowering between the seven varieties.

### Germinative Faculty

The analysis of variance revealed a highly significant difference between *Camelina sativa* varieties ( $p < 0.001$ ). As shown in Fig. 2, the highest germination

II: Average monthly temperatures and precipitation for the 2023 agricultural season (Benaradj, 2023)

Month	Jan	Feb	March	April	May	Total
Temperature (°C)	5.6	7.7	14.2	17.5	18.5	
Precipitation (mm)	5.8	5.3	21.3	6.3	22.9	61.6



3: Ombrothermal diagrams of the study area

## III: Mean squares of the analysis of variance of the parameters studied

Setting	General average	Coefficient of variation	Probability
Germinative Faculty (FG)	94	2.127	0.00***
Number of plants emerged/cm <sup>2</sup> (NBPE)	4.66	27.26	0.03*
Number of plants in rosette (NBPR)	9.14	9.34	0.04*
Precocity (Pr)	55	6.25	0.000***

\* Significant difference at the 5% probability threshold  
% probability threshold

rates were recorded in V7 highest germination rates were recorded in V7 ( $98.66 \pm 1.52\%$ ) and V5 ( $97.33 \pm 1.15\%$ ) in the group a), while the lowest was observed in V1 ( $90.66 \pm 2.08\%$ , group d). Intermediate values were obtained for V2, V3 and V4 (group b-c), indicating variable germination performance among the tested genotype.

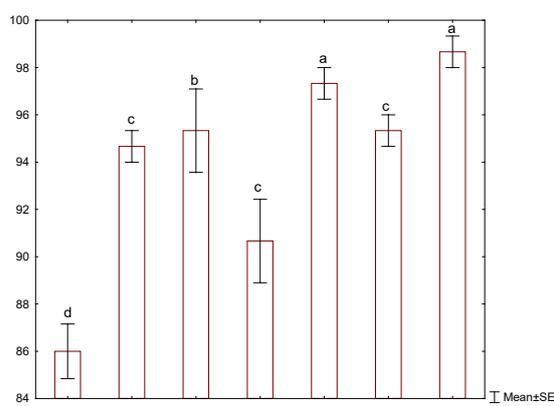
### Plant Lifting

For the parameter "number of plants emerged", the results of the analysis of variance show that there is a significant difference between the different varieties. The emergence was increased for the seventh variety to the order of

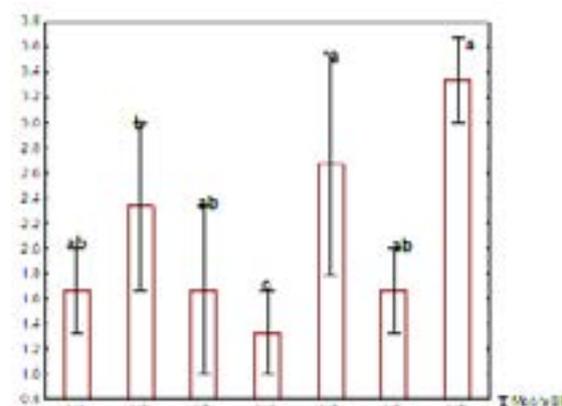
$3.33 \pm 0.21$  plants/31 cm<sup>2</sup>, group a, followed by V5 ( $2.66 \pm 0.24$  plants/31 cm<sup>2</sup>, compared to the fourth variety which showed  $1.33 \pm 0.24$  plants per 31 cm<sup>2</sup> bag (group c) (Fig. 5).

### Number of Rosette Plants

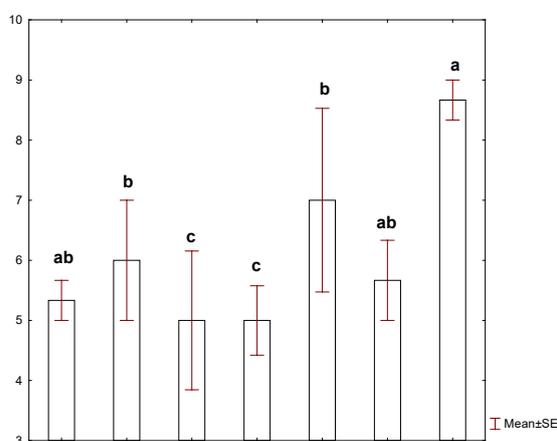
The rosette stage is an important varietal criterion, which could provide information on the potential of varieties. The results of the analysis of variance indicate a significant difference between the different varieties tested. We note that varieties 3 and 4 produced low rosette plants of around  $8 \pm 0.25$  plants/cm<sup>2</sup> (group c), compared to the Alba variety (V7) which produced 10 plants/cm<sup>2</sup> (group a).



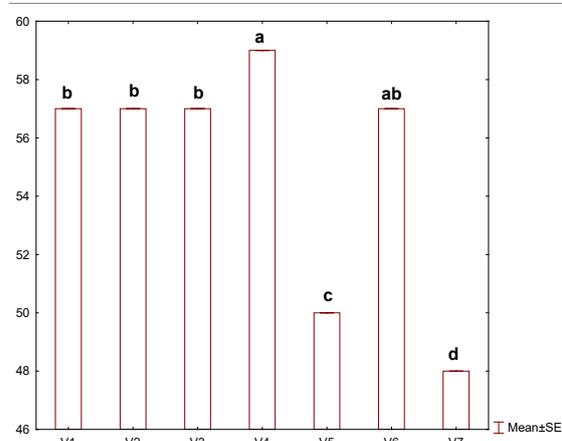
4: Germination rate



5: Average emergence



6: Number of plants in rosette



7: Earliness of varieties per day

### Precocity (Number of Days to Flowering)

The analysis of variance for the parameter “earliness to flowering” shows a very highly significant difference between the varieties. The Fig. 5 shows that V4 is the latest variety with 59 days (April 27, 2023), from sowing to flowering. On the other hand, the Alba variety is the earliest (V7) whose flowering lasted 48 days (Note on April 16, 2023); this seems to be due to the genetic diversity of the plant material used. Intermediate values were recorded for V1, V2 and V3 (group b), while V5 belonged to group c and V7 to group d, indicating clear genetic variability among the tested genotypes.

### DISCUSSION

Monitoring the germination behavior of camelina seeds helps us to better understand a geographical and edaphic area suitable for germination and establishment of the species. The germination capacity obtained in our experiment varies from 90.66% to 98.66%, this is probably due to the genotype effect. This result was consistent with previous research conducted by Batrina *et al.* (2017), which presents high values for germination capacity at 97% and 98%. The emergence of plants is correlated by the sowing density, the quality of the seeds and the climatic influences after sowing (Malki *et al.*, 2002). The significant difference for this parameter can inform the low temperatures recorded at the seed germination stage: March 3, 2023 at -3.2 °C (Tab. II). The variability of response of different varieties with respect to the number of rosette plants can be attributed to their intrinsic characteristics which are summarized in the variability in their genetic behavior or their adaptation to the pedoclimatic

conditions of the study region (Zanetti *et al.*, 2017; Izountar *et al.*, 2025).

According to Francis and Warwick (2009), the plant grows most effectively in the grasslands or steppes found in areas with a cold, semi-arid climate.

Lily *et al.* (2021), and Zanetti *et al.* (2017) found a large variation in flowering time depending on the genotype at 85 and 125 days after sowing. In our experience, the dates to reach 50% flowering (earliness) are late (48 to 59 days after sowing). Environmental (thermal stress and water stress) and genotype factors can influence the flowering time. Early flowering is essential for local adaptation as well as to maximize camelina yield (Lily *et al.*, 2021). Flowering is strongly influenced by temperature and genotype Angelini *et al.* (2020). Flowering starts 4 to 6 weeks after germination, with a flowering period of about 2 weeks depending on climatic conditions (Akk and Ilumäe, 2005).

The study of germination aims to select more resistant varieties and their adaptation mechanisms, with faster germination or greater tolerance to high temperatures and drought for future crops, thus ensuring better yields. It also aims to understand physiological adaptation through the study of seedling and adult plant growth, revealing how different varieties manage long-term climatic stresses (drought, extreme temperatures: cold and heat). Finally, it seeks to optimize crops by better understanding the growth characteristics of each variety. It is possible to adapt agricultural practices (for example, crop cycles, irrigation techniques) to maximize productivity in changing climatic conditions (Benaradj, 2000; Benaradj, 2009; Benaradj *et al.*, 2012; Pepin, 2020; Hadad and Haddouche, 2022; Debaeke *et al.*, 2025; Lamara, 2025).

### CONCLUSION

Camelina (*Camelina sativa* L.) is known as a species of the future, a crop oilseed has attractive agronomic and socio-economic advantages. Yield assessment for oilseed crops is limited by agro-ecological conditions. This study showed the effect of different factors on the adaptation of camelina to the pedoclimatic conditions of the Naama region. A sandy loam soil and alkaline pH; irregular rainfall combined with prevailing dry winds led to the observation of remarkable morphological diversity with respect to the growth of seven varieties. The observed genotypic variability underlines the potential of *Camelina sativa* to thrive in arid and semi-arid environments, which is essential to support food security in regions vulnerable to the effects of climate change. The significant differences in germination capacity, number of plant emergence, number of rosette plants and earliness, it is recommended that farmers pay special attention to the integration of this crop into agricultural systems as it could not only improve crop resilience but also offer practical solutions to the challenges posed by climate change.

The large-scale implementation of *Camelina sativa* could have significant socio-economic consequences. By reducing dependence on crops that require a large quantity of water and chemicals, the growth of camelina cultivation could promote more sustainable and environmentally friendly agriculture. Furthermore, *C. sativa* could have a crucial impact on agricultural and socio-economic development by providing economic opportunities to farmers and contributing to food security locally and nationally. This study on *Camelina sativa* establishes the scientific basis necessary to create more robust varieties through selection or genetic improvement, thereby strengthening the resilience of agriculture to climate change.

### Acknowledgements

We would like to thank Dr Abderrahmane Hannachi researcher at the National Institute of Agronomic Research-Sétif. We also appreciate the precious help of the farmer Mohamed who participated in the various works (sowing, irrigation, processing and harvesting).

### Conflict of Interest

The authors declares no conflict of interest, financial or otherwise.

### REFERENCES

- AKK, E., ILUMÄE, E. 2005. Possibilities of growing *Camelina sativa* in ecological cultivation. *Estonian Res Institute Agric.* 1, 28–33.
- AGRAWAL, RL. 1995. *Seed technology*. New Delhi: Oxford and IBH publishing company Pvt. Ltd., pp. 580–582.
- AGARWAL, A., PRAKASH, O., BALA, M. 2021. Effect of irrigation schedule on growth and seed yield of camelina (*Camelina sativa* L.) in Tarai region of central Himalaya. *Oil Crop Science.* 6(1), 8–11. <https://doi.org/10.1016/j.ocsci.2021.01.004>
- ANGELINI, L. G., ABOU CHEHADE, L., FOSCHI, L. *et al.* 2020. Performance and potentiality of camelina (*Camelina sativa* L. Crantz) genotypes in response to sowing date under Mediterranean environment. *Agronomy.* 10, 1–21. <https://doi.org/10.3390/agronomy10121929>
- BANSAL, S., DURRETT TIMOTHY, P. 2015. *Camelina sativa*: An ideal platform for the metabolic engineering and field production of industrial lipids. *Biochemistry.* 120, 9–16. <https://doi.org/10.1016/j.biochi.2015.06.009>
- BĂTRÎNA, S., IMBREA, F., IMBREA I. M. *et al.* 2017. Comparative study of germination in an assortment of *Camelina sativa* varieties. *Research Journal of Agricultural Science.* 49(4), 409–411.
- BENARADJ, A. 2000. *Contribution à l'étude de la germination et multiplication in vitro de l'Arganier Argania spinosa (L.) Skeels*. Mémoire d'Ingénieur d'Etat en Agronomie, Université de Mostaganem.
- BENARADJ, A. 2009. *Mise en défens et remontée biologique des parcours steppiques dans la région de Naâma: dissémination et multiplication de quelques espèces steppiennes*. Mémoire de Magister en Eco-biologie. Université Mustapha Stambouli de Mascara, Algérie.
- BENARADJ, A., MANSOUR, A., BOUCHERIT, H., MEDERBAL, K. 2012. Effect of temperature on seed germination of some Steppe species. *Research Journal of Pharmaceutical Biological and Chemical Sciences.* 3(4), 1060–1070.
- BENARADJ, A., BOUCHERIT, H., MERZOUGUI, T. 2020. Water Resources, State of Play, and Development Prospects in the Steppe Region of Naama (western Algeria). In: *Water Resources in Algeria, Part II. The Handbook of Environmental Chemistry. Vol 98 AG.* Springer Nature Switzerland, pp. 253–283. <https://doi.org/10.1007/978-3-030-57887-9>
- BENARADJ, A., BOUCHERIT, H., BOUDERBALA, A. *et al.* 2021. Biophysical Effects of Evapotranspiration on Steppe Areas: A Case Study in Naâma Region (Algeria). In: *Climate Change in Asia and Africa - Examining the Biophysical and Social Consequences, and Society's Responses*. IntechOpen. <https://doi.org/10.5772/intechopen.97614>
- BENARADJ, A. 2023. *Écologie et statut phénologique des oiseaux d'eau des zones humides de la wilaya de Naama ouest de l'Algérie*. Thèse de Doctorat en Biologie animale. Université Badji Mokhtar Annaba, Algeria
- BERZUINI, S., ZANETTI, F., ALBERGHINI, B. *et al.* 2024. Assessing the productivity potential of *Camelina* in the Mediterranean basin: results from multi-year and multi-location trials in Europe and Africa. *Industrial Crops and products.* 219, 1–10. <https://doi.org/10.1016/j.indcrop.2024.119080>
- BOUCHERIT, H. 2018. *Étude ethnobotanique et floristique de la steppe à Hammada scoparia (Pomel) dans la région de Naama (Algérie occidentale)*. PhD Thesis, Université Abou Bakr Belkaid Tlemcen, Algeria.
- BOUCHERIT, H., BENARADJ, A., BOUDERBALA, A. 2021. Conservatory Management of Natural Resources in the Naâma Region (Southwest Algeria). *Water Conservation Science and Engineering.* 6(1): 249–262. <https://doi.org/10.1007/s41101-021-00118-9>
- BOUCHERIT H., A. BENARADJ, S. BOUARFA, *et al.* 2024. Ecological characterization of steppe formations in the Naama region (western Algeria). In: *Scrub Vegetation as Dynamic States of Forests - Methodologies for Learning and Research*. Intech Open, <https://doi.org/10.5772/intechopen.115130>
- DEBAEKE, P., DURAND, J. L., OLLAT, N. 2025. Les leviers d'adaptation au changement climatique en production végétale. In: *Agriculture et changement climatique: Impacts, adaptation et atténuation*. Éditions Quæ, pp. 261–281. <https://doi.org/10.35690/978-2-7592-4012-8>

- FANZO, J., CARDUCCI, B., LOUIS-JEAN, J. *et al.* 2025. Climate Change, Extreme Weather Events, Food Security and Nutrition: Evolving Relationships and Critical Challenges. *Annual Review of Nutrition*. 45(1), 335–360.
- FAO, 2023. *The State of Food Security and Nutrition in the World 2023*. Food and Agriculture Organisation of the United Nation.
- FRANCIS, A., WARWICK, S. I. 2009. The biology of Canadian weeds. 142. *Camelina alyssum* (Mill.) Thell.; *C. microcarpa* Andr. ex DC.; *C. sativa* (L.) Crantz. *Can. J. Plant Sci.* 89(4): 791–810.
- GUENDOUZ, A., HANNACHI, A., BENIDIR, M. *et al.* 2022. Agro-biochemical characterisation of *Camelina sativa* (L.) Crantz: A review. *Agricultural Reviews*. 43(3), 278–287.
- HADAD, A., HADDOUCHE, Y., 2022. *Etude du comportement de quelques variétés de Camelina sativa à l'étage climatique semi-aride (El Hammadia-Bordj Bou Arreridj)*. Mémoire de Master en Sciences Agronomiques, Université Mohamed El Bachir El Ibrahimi de Bordj Bou Arreridj, Algérie.
- IZOUNTAR, D., BOUCHERIT, H., BENNIOU, R. *et al.* 2025. Evaluation and adaptation of camelina (*Camelina sativa*) Crantz L in semi-arid Algeria. *Pakistan Journal of Agricultural Research*. 38(1), 77–84. <https://dx.doi.org/10.17582/journal.pjar/2025/38.1.77.84>
- LAMARA, A. 2025. *Contribution à l'étude de la sélection de l'adaptation de quelques géotypes de blé tendre (Triticum aestivum L.) dans les conditions agro-climatiques semi-aride de la région de Sétif*. Thèse de doctorat en Sciences Agronomique. Université de Université Ferhat Abbas Sétif 1, Algérie
- LILY, Z. L., FAHLGREN, N., KUTCHAN, T. *et al.* 2021. Discovering candidate genes related to flowering time in the spring panel of *Camelina sativa*. *Industrial Crops and Products*. 173, 114104.
- MALIK, M. R., TANG, J., SHARMA, N. *et al.* 2018. *Camelina sativa*, an oilseed at the nexus between model system and commercial crop. *Plant Cell Rep.* 37, 1367–1381 <https://doi.org/10.1007/s00299-018-2308-3>
- MARVIN, L., GONZALES R. 2015. *Germination response of eggplant (Solanum melongena L.) seeds to different vinegar concentration as seed priming agents*. *Int. J. Sci. Res. Publ.* 5, 770–773.
- MIRZABAEV, A., BEZNER KERR, R., HASEGAWA, T. 2023. Severe change risks to food security and nutrition. *Climate Risk Management*. 39, 1–10. <https://doi.org/10.1016/j.crm.2022.100473>
- PEPIN, P. 2020. *L'adaptation aux changements climatiques en agriculture: Identification des pratiques et des technologies permettant d'augmenter la résilience des productions végétales du Québec*. Maîtrise en Environnement, Université de Sherbrooke.
- PUTNAM, D. H., BUDIN, J. T., FIELD, L. A. *et al.* 1993. Camelina: a promising low-input oilseed. In: JANICK, J., WHIPKEY, A. (Eds.) *New crops*. New York, USA: Wiley, pp. 314–322.
- ZANETTI, F., MONTI, A., BERTI, M. T. 2013. Challenges and opportunities for new industrial oilseed crops in EU-27: A review. *Industrial Crops and Products*. 50, 580–595.
- ZANETTI, F., ALBERGHINI, B., MARJANOVI, J. A. *et al.* 2017. Agronomic performance and seed quality attributes of camelina (*Camelina sativa* L. Crantz) in Multi- Environment Trials Across Europe and Canada. *Industrial Crops and Products*. 107, 602–608.
- ZHANG, C., AUER, C. 2020. Industrial Crops & Products Hybridization between *Camelina sativa* L. Crantz and common Brassica weeds. *Industrial Crops & Products*. 147, 1–11. <https://doi.org/10.1016/j.indcrop.2020.112240>
- ZUBR, J. 1997. Oil-seed crop: *Camelina sativa*. *Ind. Crops Prod.* 6(2), 113–119.
- ZUBR, J. 2003. Dietary Fatty Acids and Amino Acids of *Camelina sativa* Seed. *Nutrition and Food Science*. 26, 451–462.

Contact information

Abdelkrim Benaradj: benaradj@cuniv-naama.dz (corresponding author)