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REVIEW PAPER

Camelina, an adaptable oilseed crop for the warm and dried regions of Iran

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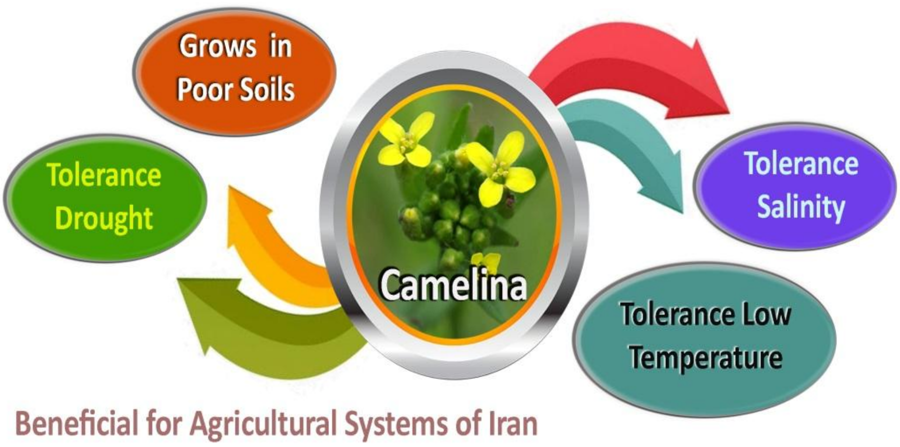
Highlights

- Camelina has a high degree of general adaptation to the climates of Iran.
- Soheil, as the first released Iranian camelina cultivar has had a good performance in the rainfed conditions of Iran.
- Camelina, Soheil cultivar, has shown relatively acceptable resistance to pests and diseases.
- Camelina can be one of the most promising oilseeds in Iran for the supply of edible oils and meals.

Graphical Abstract



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Abstract

Camelina (*Camelina sativa* L. Crantz) is an oilseed crop from the Brassicaceae family with several characteristics that made it possible to cultivate in various regions of Iran. Camelina is an allohexaploid (2n = 6x = 40) and self-pollinated crop which grows well in the marginal and poor soils and tolerant to low fertility requirement. Moreover, the hardiness of the crop makes it suitable for cropping in low input agricultural fields, such as organic systems or poor soils. Several studies reported tolerance of this crop to abiotic stress including drought, low temperature and salinity. Likewise, the tolerance of this crop to biotic stress like pests and weeds has been also reported previously. Drought, low temperature and salinity tolerance are the main characteristics of camelina. Camelina also has low susceptibility to pests and diseases. This plant has a very high resistance to common pests in oilseeds such as flea beetles. Some studies reported camelina superiority to oilseed rape in terms of biotic and abiotic stress. The unique characteristics of camelina to environmental stresses make it a potential crop for rotating with cereals, and thus, camelina may be highly beneficial for agricultural systems in warm and dried regions of Iran. In the current study, we reviewed published reports of camelina which indicate its characteristics and tolerance to biotic and abiotic stresses.

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1. Introduction

Camelina (*Camelina sativa* L. Crantz) is an oilseed plant from the Brassicaceae family which is native to the Mediterranean regions of Europe and Asia (Čalasan et al., 2019; Gugel and Falk, 2006). Camelina genus has four common species; including *C. alyssum*, *C. microcarpa*, *C. rumelica,* and *C. sativa* (Gugel and Falk, 2006). Among these species, *C. sativa* is the most cultivated species (Gugel and Falk, 2006). *C. sativa* is a diploid (2n=40) and self-pollinated crop (Parker, 2014). Camelina oil has many uses and is produced for food, pharmaceutical and industrial purposes. Use as biodiesel is one of the applications of this plant oil in the industry (Rahimi et al., 2021). Camelina grows well in marginal and poor soils (Parker, 2014) and tolerant of low fertility requirements (Royo-Esnal and Valencia-Gredilla, 2018)**.** Evidence suggests that camellia is highly resistant to environmental stresses (Budin et al., 1995). Camelina has been reported as a much more resilient crop than oilseed rape under abiotic stress (George et al., 2018; Vollmann and Eynck, 2015). It has been reported that camelina has outperformed the oilseed rape (Blackshaw et al., 2011). Previous studies also shown camelina could compete with other species of the Brassicaceae family, including *B. napus* and *B. juncea*, in terms of environmental tolerance (Gugel and Falk, 2006; Pavlista et al., 2011). Camelina was cultivated in Iran (Kermanshah Province) for the first time in the growing season 2013-2014 in two sowing dates (6th and 16th November); The highest yield and biomass was observed in first planting date (6th November) with 217.667 (Kahrizi et al., 2015). In the current review, we discussed botanical characteristics and the tolerance of camelina to the biotic and abiotic stresses.

1.1. Botanical characteristics at cultivars

Camelina has a straight and slightly rough stem with an alternating arrangement of simple hairy and earlobe leaves. The leaves are narrow with lengths of 2-8 cm and 2-10 mm width. The height of this plant is between 30-120 cm. Camelina includes pale yellow bisexual flowers grouped in a cluster which are placed at the top of branches. Camelina fruit is a pear-shaped pod with 5 mm in length and 10 to 25 mm in width. Fruit pod is pear-shaped contains small (one-fourth to one-half the size of canola seeds), orange to brown and rectangular shape seeds. The weight of 1000 seeds of this plant varies from 0.8 to 2 g (Figs. 1 and 2). The seeds of camelina contain 38 to 43% oil and 27 to 32% protein. Grain moisture should be reached about 11% at harvest and less than 8% during storage. During maturity, adverse weather conditions can lead to reduced grain yield (Gugel and Falk, 2006; Parker, 2014; Schuster and Friedt, 1998; Urbaniak et al., 2008).

Figure 1. Different growth stage of camelina from germination to flowering (Zahak agricultural research station of Sistan).

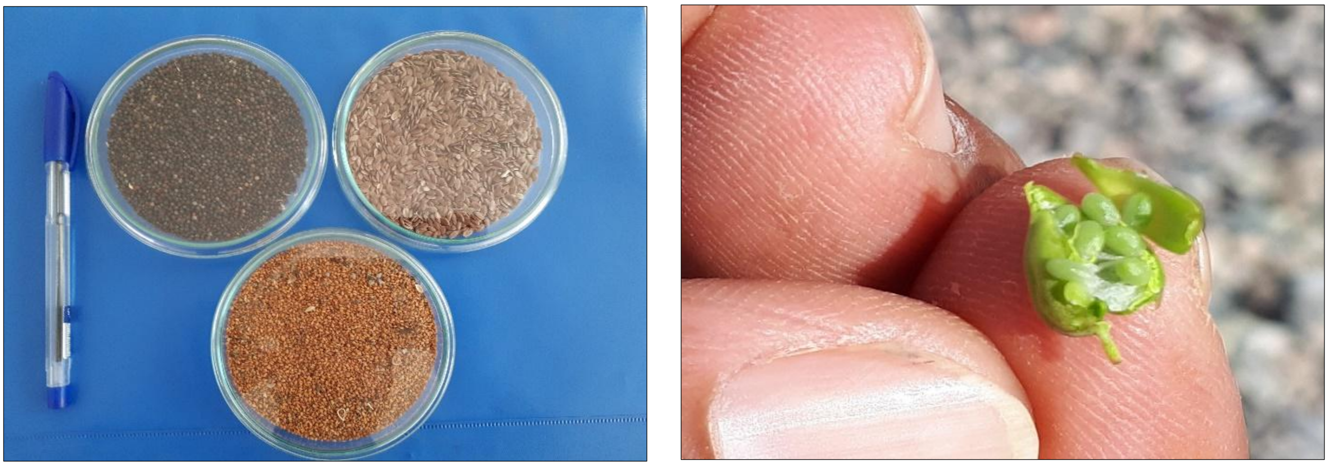

Figure 2. The left figure shows camelina seeds (bottom) in comparison to oilseed rape seeds (top left) and flax seeds (top right); the right figure shows camelina pod at pod forming stage (Zahak agricultural research station of Sistan).

Several varieties of *C. sativa* are cultivated in Europe (Celena, Celine, and Epona) and America (Blaine Creek, Suneson, Platte, SO-40, SO-50, and SO-60) (Waraich et al., 2013). Recently a new high-yielding and stable pure line of camelina variety cv. Soheil is widely cultivated in the various regions of Iran (Raziei et al., 2018). The oil of this variety has been qualified for both meal and biodiesel fuel consumption in Iran (Fallah et al., 2020; Hoseini et al., 2018; Rezaei et al., 2020). Spring genotypes not only well adapted to autumn sowing but also indicated higher yield than winter genotype in autumn sowing especially in the Mediterranean areas (Righini et al., 2019).

1.2. Camelina cultivation practices in warm and dried regions

Camelina could increase soil quality in rotation with cereals. It is recommended to cultivate camelina in late October. The suitable amount of seeds is between 4 to 6 kg per hectare. Cultivation depth should not be more than one centimeter in the soil. 20-30 cm of row-spacing is recommended for camelina cultivation. However, to decrease weed infestation, 15 cm of row-spacing could be suggested. Although Camelina needs low fertilizers, to achieve high yield, 70-100 kg of nitrogen, 30 kg of phosphate and 50 kg of potash should be considered per hectare. Additionally, three essential stages including; rosette, stem elongation and pod formation of camelina should be irrigated. By conducting these recommendations, the yield of 2.5 tons per hectare with around 40 percent of oil is achievable.

1.3. Camelina tolerance to biotic and abiotic stresses

Drought tolerance is one of the main characteristics of camelina (Budin et al., 1995). This crop showed high tolerance to a mild level of drought stress (Čanak et al., 2020) while oilseed rape showed reduction under similar conditions (Channaoui et al., 2019). The superiority of camelina to brassica species in terms of drought tolerance is reported previously and it is related to the existence of high linolenic acid in this plant (Enjalbert et al., 2013). It is also reported that camelina flowered earlier than many brassica species (Enjalbert et al., 2013) which cause to escape from late-season drought condition in the warm and dried regions. Drought escape through early flowering leads to yield incensement in plants (Siddique et al., 1990). Additionally, it has been shown that spring genotypes performed better under drought stress than winter ones (Čanak et al., 2020). furthermore, roots are affected more than shoots under drought stress conditions (Čanak et al., 2020). It has been also reported that seed size is an essential trait related to drought tolerance. Such that The larger the seeds, the more drought-tolerant they are (Čanak et al., 2020).

Salinity stress reduces the speed of germination, germination percentage, germination index, shoot length, root length, vigor index, root shoot ratio and seedling fresh weight of the salt-treated camelina seeds (Yohannes et al., 2020). Several reports indicated the tolerance of camelina to different levels of salt stress. Camelina showed salt tolerance and no limitation in germination capacity, the emergence of cotyledons and the appearance of first leaves until adding 200 mM of NaCl (Khalid et al., 2015). Different varieties also showed various responses to salinity stress but generally, they reduced seed germination by adding more than 200 Mm of NaCl (Morales et al., 2017). Salt stress affects root architecture especially root elongation in plants (Potters et al., 2007). It has been also reported that roots of camelina were affected more than shoot in its length under salinity stress (Yohannes et al., 2020).

Camelina is identified as a resistant crop to low-temperature stress (Gugel and Falk, 2006). Various experiments have shown that this plant has much fewer water requirements and more resistance to low temperature than other oilseeds, especially rapeseed. High linolenic acid causes low-temperature tolerance in camelina (Enjalbert et al., 2013). Screening of 136 Camelina doubled haploid lines along with four canola cultivars (Hyola 401, Lord, Roska, and Cascade), as an experimental control, showed that most lines had a higher level of freezing tolerance (Soorni et al., 2021). It has been also reported that camelina emerged earlier than brassica species which are outstanding to low-temperature tolerance and earlier flowering (Enjalbert et al., 2013). Investigation of the upstream regions of some specific genes of *Camelina sativa* revealed the existence of some abiotic stress tolerance induction elements which might induce tolerance of this crop to abiotic stress such as low-temperature, heat stress, drought and salinity (Gishini et al., 2020). Three years adaptability test of camelina in the Sistan region showed its high adaptability to desert climates with a scorching low temperature in the winter (Fig. 3) in addition to its high adaptability to drought and salinity.

Figure 3. Camelina tolerance (Soheil cultivar) to low-temperature shock (temperature decreased suddenly to -8 °C at a night) in the Sistan region, Iran (sowing date: October 21st).

Camelina has low susceptibility to pests and diseases. This plant has a very high resistance to common pests in oilseeds such as flea beetles and bird damage (Jaafar et al., 1993) which are a challenge in oilseed rape production. It has been also shown that camelina could reduce winter weeds and recommended to use as a rotational crop to suppress winter weeds (Royo-Esnal and Valencia-Gredilla, 2018). Due to the presence of Alpha-linolenic acid (ALA), Camellia oil has protective properties on heart health, regulates inflammation and improves the function of the central nervous system. It is also rich in alpha and gamma-tocopherol (two forms of vitamin E) that protect the oil from oxidation. Therefore, it has protective effect against free radical damage and thus preventing cardiovascular attacks and cancer (Mohammadi, 2021; Sabernezhad, 2021; Hassanpour, 2021; Asgari, 2021; Roshandel et al., 2021; Rivera-Diaz et al., 2021).

2. Conclusion

Evidence of abiotic stress tolerance in Camelina justifies that this crop is suitable for poor soils especially in the warm and dried region of Iran. Three years' adaptability experiments in the Zahak Agricultural Research Station showed tolerance of this crop to abiotic stress such as low temperature, drought and salinity. Extremely limited seed shedding was observed when harvesting was delayed. Additionally, the lower sensitivity of this crop to the sowing date was observed might be due to the lower sensitivity of Camelina to environmental stress such as low temperature. It seems that the cultivation and development of the camelina crop is an essential step towards achieving the goals in the sustainable development of oil production.

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