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Benefits of Adding Camelina to Rainfed Crop Rotation in Iran: A Crop with High Drought Tolerance

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ABSTRACT

Oilseeds, as an important part of industrial crops, are among the products that spend billions of dollars annually to meet their needs in Iran. Conventional oilseeds such as soybean, rapeseed and sunflower, despite their many benefits, are products that require high water consumption to produce them. Therefore, the introduction of a new oilseed crop that can have an economical and satisfactory yield in drought conditions and rainfed lands, can be an effective and key solution in this regard. This is the exact situation that farmers welcome the cultivation of a new crop. Camelina oilseed has many properties and applications. From a nutrition and health point of view, its oil contains high amounts of omega-3, which helps prevent cancer and obesity. In industry, it is used as a biofuel, in the production of resins, waxes, as well as in the production of cosmetics, health and pharmaceuticals. This crop has advantages over rapeseed, including the low need for water and nutrients, adaptation to adverse environmental conditions and resistance to pests. Camelina is a crop that can adapt to cold and dry environmental conditions and is also found in warm areas. The plant can also tolerate drought stress in the early growing season. Studies show that camelina is a crop that can be economically viable in rainfed areas or during supplementary irrigation. Preliminary experiments in Iran have shown that camelina cultivation can be well developed in rainfed areas and will largely meet the country's need for oilseeds.

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1. Introduction

Agriculture is the hallmark of human history and civilization. The mission of agriculture has long been defined as the provision of food as one of the most important human needs. Thus, food security is so important that it is now defined as public goods and governments are obliged to provide it (Rahimi *et al.*, 2021). Politicians also acknowledge that agriculture plays a vital role in the development process and that political determination and resource mobilization are essential for the development of this sector. In developed countries, special attention is paid to relying on new technologies and targeted support to improve productivity and yield per unit area to provide food security. Governments in some of these countries support the farmers and production by providing targeted subsidies equal to half the value of the crops. In many developing countries, where appropriate investment has been made for sustainable development, agriculture plays a vital role in the whole process of national development (Cervantes-Godoy and Dewbre, 2010).

The agricultural sector is responsible for providing food security based on domestic production with scientific and efficient use of water, soil and other resources and protection of natural resources in the

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Islamic Republic of Iran. This sector has a high position in the national economy with about 12% of GDP (Growth degree day), 20% employment and a significant share of non-oil exports and about 80% of the country's food needs (Mousavi and Sadigh, 2015).

Optimal use of water and soil capacities in different regions will cause the proper establishment and dispersion of the country's population in these areas. Since the presence of an active population on the borders of a country can lead to comprehensive security in these areas, the development of the agricultural sector can contribute to the stability of security at the borders. Rural communities as a productive society are the main platform of agricultural activities in the country. Therefore, any change in the agricultural sector will have a reciprocal effect on these communities. As a consequence, the approach of integrated agricultural and rural development should be considered interactively. Water is a scarce and vital natural resource and a valuable and irreplaceable commodity and plays an important role in development, which is one of the most important components in producing and maintaining the balance and stability of ecosystems. The average annual precipitation of Iran is about 250 mm and approximately one-third of the global average rainfall and its evapotranspiration potential is three times the global potential, which puts the country in the group of arid and semi-arid countries. In total, the average precipitation of the country is 413 billion m^3 per year, of which 135 billion m^3 can be extracted (Shakiba *et al.*, 2009).

Based on the mentioned points, it is clear that we are going through a water shortage crisis in the region. According to the FAO forecasts, several western provinces of the country will suffer from drought by 2030, including Kermanshah province. For example, there is a possibility of reducing precipitation by up to 30% in this province. On the other hand, the agricultural sector is the largest consumer of groundwater resources (Fig. 1). Unfortunately, due to the use of improper irrigation methods and high-consumption crops, such as corn, more than 70% of water consumption is wasted in the agricultural sector and only less than 30% is used (Ghamarnia and Roshandel, 2012; Ghorbani *et al.*, 2020).

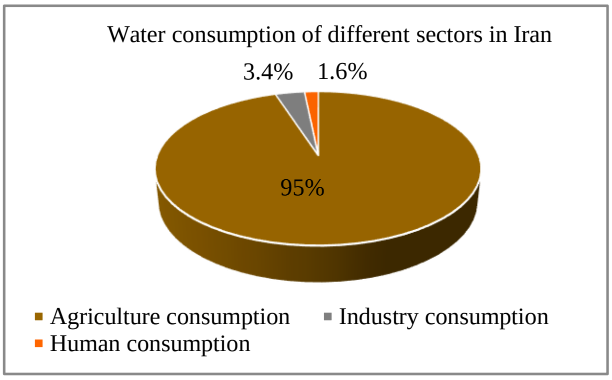

Figure 1. Water consumption of different sectors in Iran (Ghamarnia and Roshandel, 2012)

Oilseeds are of special importance among crops and are the second largest food reserves in the world after cereals. These products have rich reserves of fatty acids. The vegetable oils are mainly obtained from oilseeds such as Soybean, Sunflower, Cottonseed, Peanut and Canola. Nowadays, the vegetable oil industry is one of the strategic industries in most countries of the world. In Iran, there are large arable lands and favorable fields for growing oilseeds. Unfortunately, according to available statistics, more than 90% of the country's oil needs are still supplied from imports (Kahrizi *et al.*, 2015; Ahmadian Kooshkghazi *et al.*, 2021; Piravi-vanak *et al.*, 2021).

However, common oilseeds such as Soybean, Sunflower, and Rapeseed despite their many advantages, have their limitations on various aspects of cultivation and climatic conditions. For example, Soybean is an ideal crop in the North American Corn belt and is not well adapted to other regions. Soybean and Sunflower also need a lot of fertilizer and are susceptible to a variety of diseases and pests. Therefore, it seems that the need for new low-input oil crops with more compatibility is strongly felt (Ghamarnia *et al.*, 2020; Zarei *et al.*, 2021; Mirmoeini *et al.*, 2021; Kooshkghazi *et al.*, 2021).

Camelina (*Camelina sativa*) is a member of the Brassicaceae family and has been reported to have much lower water requirements and more resistance to spring frosts than other oilseed plants. This plant also has a high resistance to common pests in oilseeds such as pollen beetles. The potential for high yield production in camelina has been proven and its possibility of being a suitable option in rotation with cereals has been reported (McVay, 2008).

Camelina is native to Europe and South Asia and its cultivation dates back to 4,000 years ago. In ancient Rome and Greece, the cultivation of this plant was developed as an oil crop as pure or mixed with other crops. The main growth center of this plant spread from Eastern Europe to Central Asia during and after World War II. The largest producer of camelina was the Soviet Union in the twentieth century, which in 1950 cultivated about 300,000 hectares (Gehringer, 2010).

Camelina has some advantages over rapeseed, including the low need for water and nutrients, adaptation to adverse environmental conditions and pest resistance. Camelina can adapt to cold and dry environmental conditions and is also found in warm areas. This plant can also tolerate drought as a stress in the early growing season (Francis and Warwick, 2009).

2. Camelina cultivation

Preliminary experiments on camelina in 1958-60 have shown this crop has high potential in the northern parts of the United States and southern Canada as a new oilseed with significant benefits such as cold tolerance and early maturity (Murphy, 2016; Soorni *et al*., 2021).

Over the past two decades, camelina has been cultivated in other parts of the world such as European countries (Akk and Ilumäe, 2005) and more recently in Iran (Fig. 2) (Kahrizi *et al*., 2015). 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).

Figure 2. The first cultivation of camelina in Iran (2012-2013)

Cultivation of this crop in rotation with wheat and other cereals increases soil quality (Chen *et al*., 2015). Camelina needs low water and nitrogen to grow, in general, the fertilizer requirements of this plant are low. Therefore, it can be successfully cultivated in low and marginal areas (Putnam *et al*., 1993; Zarei *et al*., 2021).

Adaptation to different environments and soil types in the context of climate change is one of the most important advantages of camelina cultivation (Murphy, 2016).

Although camelina is sensitive to herbicides, it is considered a crop with unique characteristics for the northern climates. Therefore, this crop is well adapted to high cold tolerance (Plessers *et al*., 1962).

Camelina seeds contain 35-40% oil; approximately 90% of this oil is unsaturated fatty acids and 10% is saturated fatty acids. Camelina contains many unsaturated fatty acids with versatile potential. The most important of these are oleic (Omega-9), linoleic (Omega-6), linolenic (Omega-3), eicosenoic and erucic acid (Table 1). Camelina oil is accepted as a vegetable oil source with cholesterol-lowering properties in human nutrition due to its high (29-32%) Omega-3 content (Kurt and Göre, 2020; Fallah *et al*., 2020).

Growth degree day (GDD) for seedling emergence, flowering and physiological maturity of spring cultivars has been reported to be 34, 417 and 998 ℃, respectively, indicating the low heat requirement and early maturity of this crop (Sintim *et al*., 2016).

In another study, the average base temperature for five of the most important camelina cultivars in Montana was reported to be -0.7 ℃ and had a daily growth rate of 1150 ℃ (Allen *et al*., 2014). Camelina is a sensitive plant to photoperiod, but so far no report has been published in this regard (Turley, 2014). Russo (2013) claimed that some camelina cultivars, unlike spring cultivars, need vernalization. However, there is very limited information on this subject.

The optimal density of camelina has been reported 220-250 plants per m^2. The recommended spacing between planting rows is 12 to 20 cm and the planting depth should not exceed 1 cm. This plant has a high tolerance to heat and drought and high resistance to shattering and some common diseases in the Brassicaceae family including black leg (*Leptosphaeria maculans*). So far no insects have been found to cause economic damage to camelina. Camelina seeds can germinate at 1 °C and plants which reaching the rosette period can be resistant to frost up to -10°C. This property facilitates cold tolerance and sowing in autumn and early spring. Studies in Saskatchewan, Canada, have shown that camelina's yield is comparable to other *Brassicaceae* species. Some studies have also shown that the yield of Camelina is negatively affected by waterlogging conditions. Severe early flooding conditions will result in the loss of 27 to 32% of plants at harvest time (Gugel and Falk, 2006).

Table 1. The fatty acid profile (%) of cold-pressed camelina seed oil (Ergönül and Özbek, 2020)

Fatty acid	Yang et al. (2016)	Wu et al. (2011)	Berti et al. (2016)	Raczyk et al. (2016)
Miristic acid	0.1	0.2	–	–
Palmitic acid	5.5	5.1	5.7	6.1
Palmitoleic acid	0.1	0.3	–	0.1
Stearic acid	2.4	2.4	2.4	2.6
Oleic acid	14.4	17.6	15.7	16.1
Linoleic acid	19.1	18.7	18.5	18.5
Linolenic acid	33.5	28.6	32.8	35.8
Arachidic acid	1.5	1.8	1.7	1.3
Gadoleic acid	15.0	11.9	15.1	14.0
Eicosadienoic acid	2.2	1.9	1.8	1.8
Arachidonic acid	1.4	–	–	1.4
Behenic acid	0.3	0.8	0.4	–
Erucic acid	3.1	4.2	3.5	2.3
Clupanodinic acid	0.2	0.4	0.5	–
Docosatrienoic acid	0.4	–	–	–
Lignoseric acid	0.2	–	–	–
Nervonic acid	0.6	–	0.7	–

Dobre and Jurcone (2011) reported that in addition to being compatible with little or no-tillage systems, camelina can grow even in light and sandy soils with low nutritional value as well as it is highly drought-tolerant, resistant to pests and diseases.

A study of camelina genotypes in different drought levels reported that its photosynthetic mechanism is resistant to water scarcity and tolerates limited availability of water (Ahmed *et al.*, 2017).

Guy et al. (2014) cultivated 18 camelina genotypes in 18 environments in four different rainfed areas in the United States. The highest yield was obtained in the Pullman area of Washington state by 3302 kg/ ha and the lowest by 127 kg/ha in the Lind area of the same state.

Kurasiak-Popowska et al. (2018) compared the yield of Polish and Ukrainian camelina genotypes. In this experiment, Polish spring cultivars had higher yields than Ukrainian cultivars. The average yield of five mutant lines was estimated at more than 2000 Kg/ha.

Seed size was reported to play a role in the camelina's response to drought in a study comparing six winter and six spring genotypes with different seed sizes at increasing osmotic stress levels. Large seed spring biotypes had the highest germination percentage and were less affected by osmotic stress. Among the winter biotypes, those with small seeds performed best and were more affected by osmotic stress than spring biotypes (Čanak *et al.*, 2020).

As a result of the research comparing the seed yield of rapeseed and camelina in Russia, it was determined that the seed yield of camelina was 1.47 t / ha and the seed yield of rapeseed was 1.14 t /ha (Sagirova *et al.*, 2020). This result proves that the camelina is strong enough to compete with other oilseeds.

The most important differences between camelina and other oilseed crops are as follows:

- Less water requirement so that the camelina conditions of Kermanshah can be cultivated in rainfed areas and has a higher yield than the global average.
- It has more allelopathic properties than other oil crops, making it more successful in competing with weeds.
- The omega-3 content of camelina is much higher than other oilseeds and about the same as flaxseed oil.
- Due to suitable height, the harvest of camelina is completely possible by common harvesting machines.
- Since the camelina spends its growth period very quickly and its harvest time in some climatic conditions of the country is the middle of May, it is possible to cultivate a second crop after harvest (Ghamarnia *et al.*, 2020)

3. Conclusion

Considering the unique characteristics of camelina and Iran's high dependence on edible oil supply, it seems that the development of the cultivation of this crop in drought and climate change conditions can be a big step towards food security in the country. This goal undoubtedly requires extensive research to study the sustainability and adaptation and agro-ecological characteristics of this crop.

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