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Adapted Oilseed Crops with the Ability to Grow Economically in Dryland Conditions in Iran

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ABSTRACT

Water is a valuable and irreplaceable natural resource 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 and environment. The average annual rainfall in Iran is one third of the global average rainfall (about 250 mm) and its evapotranspiration potential is three times the global potential. Therefore, Iran is in the group of arid and semi-arid countries. Nowadays, the vegetable oil production industry is considered a strategic industry in most countries of the world. In Iran, there are large arable lands and favorable fields for growing oilseeds. However, according to available statistics, more than 85-90% of the required oil is still supplied from abroad. Common oilseeds such as soybean, sunflower and canola, despite their many advantages, are limited in 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. Sunflower also need a lot of fertilizer and is susceptible to a variety of diseases and pests. Therefore, the need for new oil crops with more adaptation and fewer needs is strongly felt. In recent years, the planting of new oilseeds in drylands has attracted a lot of attention. The most important advantage of these crops is the high resistance to drought and spring cold. In this paper, three of these crops (safflower, camelina and dragon's head) are mentioned, which are hoped to enter the country's dryland crop rotation.

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1. Introduction

Optimal use of water and soil capacities in different regions will cause the establishment and dispersion of the country's population. Since the presence of an active population at the country borders creates comprehensive security, so the development of agriculture in these areas will help to stabilize security of borders. Rural and nomadic communities, as a productive society, are the main platform of the country's agricultural activities and any change in the agricultural sector will have a reciprocal effect on these communities. Therefore, approaches to the development of rural and nomadic communities must be considered in conjunction with agricultural development and a continuous chain in all aspects (Tesfaye and Walker, 2004).

Water is a scarce and vital natural resource and a valuable and irreplaceable commodity and plays an important role in progress and development. Also, it is one of the most important components in produce and maintain ecosystem sustainability. The average annual rainfall in Iran is one third of the global average rainfall (about 250 mm) and its evapotranspiration potential is three times the global potential. Therefore, Iran is in the group of arid and semi-arid countries. In total, the average rainfall of the country is 413 billion m^3 per year, of which 135 billion m^3 can be extracted (Mousavi, 2005). In Iran, the mountainous regions of Zagros and

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Alborz have 13 rivers with high flow. These rivers account for 53% of the total surface water resources. Other rivers in Iran flow only during floods and when agriculture does not need water. On the other hand, about 75% of the total rainfall occurs untimely and in non-agricultural seasons. Unbalanced temporal and spatial distribution of water in the country has made it necessary to control and store water to balance the temporal distribution and transfer between watersheds. The continuation and intensification of the underground aquifers water level drop and the extraction of water in the forbidden plains have also made the situation worrying and endangered the development and future of agriculture. According to expert estimates, Iran is facing with an annual negative balance of groundwater reserves of about ten billion m^3. Therefore, national management of the water crisis is essential (Khaleghi and Surian, 2019).

Regards to the severe water crisis in Iran, the government has changed its accede to the management of the country's water resources in different sectors relies on reducing water demand. on this subject, due to the high consumption of water in the agricultural sector, switching from high demanding crops, to less water-intensive ones were considered a priority for the country, and the government banned the cultivation of rice as a water conservation policy (Boazar *et al*., 2019).

Oil crops are the second largest food reserves in the world after cereals. These products have rich reserves of fatty acids. Nowadays, the vegetable oil production industry is considered a strategic industry in most countries of the world. Vegetable oils produced are mainly obtained from oilseeds such as soybean, sunflower, cottonseed, peanut and canola. 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 abroad. Common oilseeds such as soybean, sunflower and canola, despite their many advantages, are limited in 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. Sunflower also need a lot of fertilizer and is susceptible to a variety of diseases and pests. Therefore, the need for new oil crops with more adaptation and fewer needs is strongly felt (Hashemi Tabar *et al*., 2008).

In recent years, the planting of new oilseeds in drylands has attracted a lot of attention. The most important advantage of these crops is high tolerance to drought and spring cold stress. In the following, three oilseed crops that are hoped to enter the country's dryland crop rotation are introduced.

1.1. Camelina

Camelina (*Camelina sativa*) is a member of the Brassicase family. The water requirements of camelina have much less than other oilseed crops. It is also more resistant to spring cold than other oilseed crops, especially rapeseed. In addition, it is highly resistant to common pests of oilseeds such as pollen beetles. The potential of high yield production in camelina has been proven and its possibility as a suitable option in rotation with cereal 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 and was grown alone or mixed with other crops. The main growth center of camelina spread from Eastern Europe to Central Asia and was cultivated during and after the World Wars. The largest producer of this plant in the twentieth century was the Soviet Union, which in 1950 devoted about 300,000 ha of its land to camelina cultivation (Gehringer, 2010).

Camelina grains have many properties and uses. In nutrition and health, its oil contains high amounts of omega-3, which helps prevent cancer and obesity. In industry, it is used as a biofuel to produce resins, waxes, cosmetics, health and medicines. In factories, to prevent spoilage and oxidation and increase the shelf life of oil, industrial antioxidants are added, which is very dangerous for human health. However, due to the high levels of alpha-tocopherol and vitamin E in camelina oil, which are powerful antioxidants, there is no need to add industrial materials to improve shelf life (Kahrizi *et al*., 2015).

For this reason, it has been used as a good alternative to soybean oil in many countries, including Australia (Ghamkhar *et al*., 2010). Camelina is a hexaploid plant with 89,418 protein-encoding genes identified (Kagale *et al*., 2014). Due to the close genetic relationship with the Arabidopsis, as a model plant, so research findings on Arabidobsis can be used to improve the camelina plant. (Vollmann and Eynck, 2015).

Rainfed rapeseed cultivation in Iran has many limitations. In this regard, Camelina has some advantages over rapeseed, including low need for water and nutrients, adaptation to adverse environmental conditions and resistance to pests. Camelina is a plant that can adapt to cold and dry environmental conditions and is also found in warm areas. It can also tolerate water shortages as a stress in the early growing season (Francis and Warwick, 2009).

Camelina has a short growth period. This plant is high tolerant to cold stress, is compatible with existing machinery for cereals, and is also suitable for marginal areas. Camelina oil can also be used to produce biodiesel and renewable jet engine fuel. Derived biodiesel from camelina oil has similar fuel properties to soybean oil (Rode, 2002).

Camelina oil and meal have other industrial uses such as making glue, resin, coating and polishing objects. In addition, camelina oil is edible and is a good source of ALA, a precursor to omega-3 fatty acids that are effective in human health. In some Eastern European countries, camelina oil is used in traditional medicine to treat burns, ulcers, eye inflammation, as well as gastric ulcers and as a tonic medicine (Johnson and Gesch, 2013).

In some parts of Europe, camelina is known as false flax and as a weed. Although this plant was cultivated in most parts of Europe and Russia before the 1940s, it was replaced by higher-yielding crops after World War II. In Europe, the declining cultivation of camelina accelerated following the subsidies application for some oilseeds, such as rapeseed. However, in recent years, attention to omega-3-rich vegetable oils has brought camelina back into the spotlight of researchers, producers and consumers. Especially since this plant can have economic yield with minimum costs and inputs, and has shown unique agronomic properties (Gugel and Falk, 2006).

Guy et al. (2014) cultivated 18 genotypes of camelina in 18 environments in four different rainfall regimes in the United States. The highest yield was obtained in the Pullman area of Washington state at 3302 kg/ha and the lowest with 127 kg/ha in the Lind area in the same state (Kurasiak-Popowska *et al*., 2018).

Camelina is recommended as one of the serious options for cultivation in Iran's cold rainfed areas and in conditions of climate change (Rahimi *et al*., 2021; Raziei *et al*., 2018; Bakhshi *et al*., 2021). In Iran, at the beginning of the camelina development project, the DH1025 line was produced, which is now widely cultivated under the name of "Soheil" cultivar (Fig.1), and its average yield is about 1000-1300 Kg/ha without irrigation (Kahrizi *et al*., 2015).

Figure 1. Camelina (Soheil cultivar), research farm of Razi University of Kermanshah, Iran, 2018.

1.2. Safflower

Safflower (*Carthamus tinctorius* L.) is a ancient plant belonging to the Asteraceae family that has been cultivated for about 4000 years. Among the oil crops compatible with the climatic conditions, safflower in terms of favorable agronomic characteristics such as relative resistance to soil salinity and air dryness, high tolerance to winter cold stress and high-quality oil can play an important role in oil production (Weiss, 2000).

Safflower cultivation has a long history in Iran and due to having suitable ecological conditions, Iran is one of the most important areas for production of this crop. Safflower before being introduced as an oilseed, it was cultivated for the use of florets (Pourdad, 2006).

However, due to susceptibility to pests, diseases, weeds, late maturity, unavailability of suitable cultivars and sufficient information on safflower cultivation, its cultivation had decreased in recent years. Recently, by removing production barriers and introducing new cultivars (high yield, high oil, spinless, cold-resistant, less susceptible to pests and diseases), it is possible to develop safflower cultivation in rainfed areas. Economically, safflower cultivation has sufficient potential to replace common crops in rainfed areas such as wheat, barley, lentil, chickpea and can be rotated with these crops (Fig. 2) (Hagigati-Maleki *et al*., 2014).

Safflower is adapted to areas with low winter and spring rainfall and dry weather during the flowering, grain filling and grain ripening periods. It is also considered as a drought-resistant crop due to having the strong and long roots with the ability to absorb water from deep parts of soil (Yau, 2006). Safflower is also tolerant to salinity stress and is adapted to a wide range of soil conditions in rainfed areas of Iran (Koochakzadeh *et al*., 2018).

Figure 2. Safflower (Faraman cultivar), Dryland Agricultural Research Institute (DARI), Sararood Branch, Kermanshah, Iran.

This plant is long-day in nature, but many of its improved cultivars are neutral to the day length. Safflower can be planted at altitudes below 1000 to 2300 m above sea level, but at higher altitudes its yield and oil content decrease (Hagigati Maleki *et al*., 2014).

The oil content of safflower grains varies between 30 and 36% depending on the environmental conditions of the region. Safflower oil is one of the most valuable vegetable oils due to its more than 90% unsaturated fatty acids and high content of linoleic acid (omega-6), oleic acid and high antioxidant activity (Velasco and Fernandez-Martinez, 2001), and because of this reason, it has recently been priced separately from industrial oil.

In developed countries where more research is being done on health and diet, the demand for oils similar to safflower oil (which have the highest ratio of unsaturated to saturated fatty acids) is increasing. In this respect, safflower oil is similar to olive oil and in addition to having high amounts of linoleic acid and oleic acid, it is also less expensive (Pourdad, 2006).

Safflower oil has many uses in the food, cosmetics and pharmaceutical industries (Khalid *et al*., 2017). Flower of spinless safflower cultivars can be harvested manually. These flowers have medicinal and industrial uses and are bought from farmers at a reasonable price. Therefore, in addition to selling grains to extract oil, selling flowers can be an income source for farmers. Cartamine pigment of flower is used as food coloring (ice cream, jelly, soup), additives in beverages and cosmetics products (Machewad *et al*., 2012; Yue *et al*., 2013).

1.3. Dragon's head

Dragon's head (*Lallemantia iberica*) from the Lamiaceae family is a old origin plant that has various uses. Dragon's head is considered as a multi-purpose plant due to its food, medicinal, forage and industrial properties (Jones and Valamoti, 2005). All its parts (leaves and grains) are used economically and can play an important role in sustainable agriculture in arid and semi-arid regions of Iran and the rotation of rainfed crops (Samimifar *et al*., 2019).

The origin of dragon's head is the Caucasus. It has been cultivated in Iran since ancient times for oil production. Iran is one of the main centers of dragon's head genetic diversity and its cultivation has a long history. Also due to the adaptation, it has gained in these areas over time, it contains desirable genes such as drought and salinity tolerance and resistance to pests and diseases in this country. The presence of such hereditary reserves (germplasm) makes it possible to increase the quantity and quality of this plant through breeding, because for breeders, the presence of genetic diversity is the basis for selecting superior lines (Shahbazi- Doorbash *et al*., 2012).

Efforts have been made to cultivate this plant and produce grains in Germany, Austria and Canada, but have failed due to the humid climate of these areas (Shahbazi- Doorbash *et al*., 2012). In humid climates, the occurrence of rainfall at the time of crop ripening causes grain mucilage seepage, adhesion of grains to each other and quality loss. While in arid and semi-arid regions, the ripening season is accompanied by warm and dry weather, and this weakness in wet areas has become a strong point in arid and semi-arid areas (Shafagh-Kolvanagh and Dast-Borhan, 2017).

Dragon's head is competitive with weeds, high resistance to pests and diseases, low food expectation, short growing period, ecological resilience to diverse climates, tolerant of drought and salinity, with the ability to grow in late autumn and winter, fall and spring are dry with the least care. The challenge of water shortage in Iran and the unique capabilities of the dragon's head in ecological adaptation to this climate, shows the importance of extensive research in various dimensions on this crop (Fig. 3). Dragon's head can grow in different soils, however light soil with good drainage is better for it and does not tolerate heavy clay soils. Suitable soil acidity for the growth of this plant is a neutral range, but it can grow in a range from slightly acidic to slightly alkaline. The dragon's head capsules that the grains are placed inside them, are closed in dry air, which prevents the grains from falling out of the capsules (Shafagh-Kolvanagh and Dast-Borhan, 2017).

Figure 3. Dragon's head (Sara cultivar), Dryland Agricultural Research Institute (DARI), Sararood Branch, Kermanshah, Iran.

The effective substances of dragon's head grains are mainly oil and mucilage. However, this crop is mainly cultivated for oil extraction from seeds (seeds contain 30% oil). The iodine index of this oil is between 163 and 203 and it has antioxidant properties (Shafagh-Kolvanagh and Dast-Borhan, 2017). The oil is composed of 68% linolenic acid, 10.8% linoleic acid, 10.3% oleic acid, 6.5% palmitic acid and 1.8% stearic acid (Overeem *et al*., 1999). The high content of linolenic acid (omega-3) in dragon's head oil has led to its widespread use for various purposes (Ion *et al*., 2011). In terms of linolenic acid content, dragon's head oil is similar to Linum oil and can be considered as a competitor of Linum oil in nutrition and industry (Zlatanov *et al*., 2012).

In addition to food, dragon's head oil is used in the color and polished oil industry and like Linum oil in tanning, soap making, oil paint production, linoleum production and as a lubricant, wood protection against decay, sofa wax, printing ink (Amanzadeh *et al*., 2011), lighting, polishing oil, oil Grease and medicinal uses are used (Shahbazi- Doorbash *et al*., 2012).

Other uses of dragon's head include production of mucilage from seeds, production of essential oil from the vegetative body of the plant, use of meal after oiling as food for humans and livestock, use of leaves and green branches of the plant before flowering as a fresh vegetable (Shafagh-Kolvanagh and Dast-Borhan, 2017).

Comparison of oil content, yield (Table 1) and fatty acid profile (Table 2) of candidate rainfed oilseed crops in Iran are illustrated below.

Table 1. Comparison of oil content and yield of rainfed oilseed crops

	Camelina	Safflower	Dragon's head
Grain oil content (%)	35-45	30-36	35-40
Grain yield (t/ha)	0.9-2.24	0.5-1.2	0.7-1
Oil yield (lit/ha)	106-907	100-400	150-350

Table 2. Fatty acid content of rainfed oilseeds crops (%)

	linolenic acid (18:3)	linoleic acid (18:2)	oleic acid (18:1)	palmitic acid (16:0)	stearic acid (18:0)
Camelina	31.7	21.4	14.9	7.5	4.0
Safflower	0.248	74.81	11.95	8.98	2.46
Dragon's head	68.0	10.8	10.3	6.5	1.8

2. Conclusions

Iran is facing a shortage of water resources and is severely dependent on imports of oilseeds. More than 90% of this country's oil needs are supplied from abroad. Common oilseeds such as soybeans, sunflowers, and canola despite their many advantages, have their limitations on various aspects of cultivation and climatic conditions. Therefore, it seems that the need for new oil products with more compatibility and fewer needs is strongly felt. Cereals (wheat and barley) and legumes (especially chickpeas in temperate and warm regions) are the most important crops grown in rainfed lands of Iran and unfortunately no other crop for cultivation in these lands has been introduced so far. Due to Camelina, Safflower and dragon's head yield and price, they can enter rainfed crop rotation and in addition to the stability of production in these lands, they can also increase farmers' incomes. These new oil crops that can be grown rainfed have attracted a lot of attention in recent years, and their most important advantage is their high resistance to drought and spring cold stress.

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