J Biochem Technol (2023) 14(4): 90-99
https://doi.org/10.51847/YZLS81LfHh
ISSN: 0974-2328

Sustainable Agriculture: Growing Safflower Oilseed in Arid Climates

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Received: 29 September 2023 / Received in revised form: 26 November 2023, Accepted: 07 December 2023, Published online: 16 December 2023

Abstract

Safflower oilseed is a crop native to Egypt and India with arid climates. Global warming in the world requires an alternative approach to well-known oilseeds (sunflower, rapeseed). Many years of research have been carried out to study the culture of safflower oilseed in contrasting natural conditions: Russia, Southern Kazakhstan, and Tajikistan. The goal was to study the biological characteristics, productivity, accumulation of oil content, and the manifestation of the main disease in arid conditions and to create a variety with adaptive potential for a specific region. Based on the research results, new varieties of safflower oilseed Krasa Stupinskaya (Russia), Akmai, Nurlan, Iirkas, and Moldir-2008 (Kazakhstan), Shifo (Tajikistan) were created and recommended for sustainable farming in the above regions. In terms of the accumulation of oil and fatty acid composition in the seeds, the Krasa Stupinskaya variety from the Central region of the Russian Federation is at the level of southern varieties from Kazakhstan and Tajikistan.

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Keywords: Safflower oilseed, Drought conditions, Contrasting ecological regions, Global climate warming, Variety

Introduction

Due to the ever-increasing diversity and scale of the use of the depleted resources of the natural environment, the future of mankind depends on its ability to harmonize its relations with nature. The claim that man's discord with nature begins with agriculture is indeed justified, as evidenced by hundreds of millions of hectares of eroded, desolate, saline, and wetlands, the catastrophic destruction of forests in order to increase the area of agricultural land.

Currently, agriculture is the main user of land resources (37% of land), the world's freshwater reserves (about 80%), as well as phosphates, potassium, calcium, and other minerals. According to FAO, the annual loss of productive and pasture lands is more than 13 million and the area of irrigated lands with varying degrees of salinity has reached 110 million hectares, that is, more than 40% of their total area. In such situations, sustainable agriculture is required. To ensure food security for their people. In this regard, the purpose of our research was in the cultivation of safflower oilseeds in the growing season (dry and wet years) in the Russian Federation and the acutely arid regions of Kazakhstan and Tajikistan.

There are a small number of countries in the world where safflower is grown (Agrovestnik, 2023). Safflower was mainly grown in Kazakhstan and Russia in 2021. The share of gross safflower harvests in Kazakhstan was 35.5% (of the total collections), in Russia - 24.0%. In 2022, safflower harvests in Russia have increased significantly, **Table 1**.

Table 1. Areas, harvests, and yields of safflower by country, data for 2021

№	Country	Area, thousand hectares Collections, thousand hectares Yield. c/ha	Area, thousand hectares Collections, thousand hectares Yield, c/ha	Area, thousand hectares Collections, thousand hectares Yield, c/ha
1	Kazakhstan	367.97	223.90	6.09
2	Russia	242.31	151.38	6.25
3	USA	54.63	61.31	11.22
4	Mexico	31.10	52.55	16.90
5	India	46.47	36.00	7.75
6	China	22.75	33.55	14.75
7	Türkiye	14.45	16.20	11.21
8	Tanzania	25.16	13.83	5.50
9	Ethiopia	7.52	9.65	12.83
10	Tajikistan	4.24	6.33	14.93
11	Kyrgyzstan	7.74	6.00	7.76
12	Argentina	6.00	6.00	10.00
13	Uzbekistan	9.83	5.45	5.55
14	Iran	3.70	4.89	13.20
15	Australia	6.23	3.62	5.81
	Other countries	0.34	0.38	-
	Total	850.43	631.05	7.42

The largest importing countries and their suppliers in 2022

The largest of them in 2022 were: Turkey (62.3 thousand tons), China (60.7 thousand tons), the USA (12.2 thousand tons), Belgium (9.1 thousand tons), and Poland (5.6 thousand tons).

1. China. Imports of safflower seeds in 2022 were formed only through imports from Kazakhstan.
2. Türkiye - the main volume of purchases is carried out in Russia. Safflower seeds are also imported into the country from Kazakhstan and Egypt.
3. USA - the country makes most of its purchases of safflower seeds in Russia. According to the WTO, the United States purchased 6.1 thousand tons of safflower seeds from Russia in 2022. In addition to Russia, supplies of safflower seeds to the United States in relatively large volumes were carried out by Bulgaria, Mexico, Canada, and Argentina.
4. Belgium - the main supplier of safflower seeds is Russia, supplies also come from the Netherlands, Germany, France, and other countries.
5. Poland - the main supplier is Russia; smaller volumes of purchases are made from Kazakhstan, Belarus, and the Netherlands.
6. The Netherlands - the main volume of purchases is made in Russia. Other suppliers include Spain, Germany, and some other countries (Agrovestnik, 2023).

Materials and Methods

Long-term studies from 2005 to the present have been carried out in the Moscow, Saratov and Rostov regions (Russia), as well as in Tajikistan and Kazakhstan. The object of the study was the variety Krasa Stupinskaya (2005) created by us and the sample from the Genbank (St. Petersburg) Mahalli 260. In Kazakhstan, the object of research was the varieties Akmai, Nurlan, Iirkas and Moldir-2008, in Tajikistan the collection varieties Milutinsky 114, VIR-489, Mestnaya 498, VIR 454, VIR 483, Shifo, Mestnaya 492, Mestnaya 260, VIR 376, Mestnaya 505, VIR 487.

During the growth season, phenological observations and biometric evaluations were carried out in compliance with the Methodology of State testing of agricultural Cultures (Fedin, 1983).

Using three duplicates of sample plots with an accounting plot area of -10 m2, the harvest definition was carried out. The GOST 10857 «Oilseeds» was followed in order to determine the oil content of the seeds (GOST 10857-64, 1964).

Determination of oil content and the fatty acid composition of the oil were made in accordance with GOST 30623-98 «Vegetable oils and margarine. Detection method of falsification» (GOST 30623-98, 2000).

Results and Discussion

Growing Safflower Oilseed in the Acutely Dry Year of 2010 and Contrasting Humid Conditions in the Central Region of the Russian Federation

The problem of drought is acute across large areas of our country. In addition, as the results of research by major Soviet and foreign climate scientists show (Budyko, 1984). In the ensuing decades, there is a greater chance that these negative phenomena may occur. Vavilov (1967) correctly concluded that the most crucial steps in preventing drought were the selection of heat- and drought-resistant crops as well as the development of drought-resistant varieties for the nation's various ecological and geographical zones based on the extensive use of the All-Union Institute of Plant Growing's global collections of agricultural plants.

The need to carry out such work is associated with the peculiarities of the agricultural conditions of our country, characterized by the widespread and frequent recurrence of such an unfavorable phenomenon as drought (Vavilov, 1967).

The main goal was not only to study the culture of safflower oilseed under conditions of drought and high humidity but also to create a variety with adaptive potential for the development of sustainable agriculture in various regions of the Russian Federation.

Long-term studies from 2005 to the present have been carried out in the Moscow, Saratov, and Rostov regions. The object of the study was the variety Krasa Stupinskaya (2005) created by us and some samples from the Genbank (St. Petersburg).

We present the meteorological weather conditions in the year 2010, which was extremely dry for 50 years of research, and the year 2013, which was atypically overly humid.

In 2010, the vegetation conditions were not good. The vegetative season's average temperature was 6.5°C (22.9°C) higher than the long-term average of 16.4°C. In May 2010, weather conditions were favorable for the growth and development of winter wheat plants – the air temperature corresponded to the average annual value (14.2 – 14.5 °C). The last rain fell on June 18 and there was no rainfall until September 3. The air temperature in the Moscow region in June was 33ºC, in July – up to 38ºC, and in August – up to 39.7ºC (the average long-term temperature was +18.2ºC, +20.5ºC, +19.0oC in June, July, and August, respectively), the hydrothermal humidification coefficient (HHC) was 0.8. The lack of precipitation, as well as the abnormally high temperature of the air, has created a threat to the normal development and maturation of the crops.

Average daily air temperatures in the first and second ten days of May in 2013 (13.2 and 19.9 °C, respectively) exceed the long-term average by 3.5 and 8.5 °C, while the figures for the third ten days of May (+17.1 °C) are lower norms by 2 °C. In May, the highest air temperature was recorded (+3.3°C) on May 2, and the highest (30.2°C) on May 16.

In the first decade of May, 26 mm of interference fell, which is 12 mm or 46.1% above the norm. In anticipation, rains of varying waves fell daily from May 14 until the end of the month. In total, 131 mm of deviations occurred in a month, which exceeded the long-term average by 2.7 times (the norm was 49 mm).

The average daily air temperature in June (19.9°C) is 4.5°C above normal, with minimum temperatures ranging from +8.2 to +18.3°C, and maximum temperatures from +15.1 to +30.7 °C. Precipitation fell regularly as time went on, with 3 days with precipitation observed in each decade; additional monthly fluctuations (34 mm) were lower than the average summer indicators (63 mm) by 29 mm or 46%.

The first ten days of July were characterized by variable air temperatures: sounds - from +14.2 to +17.4 °C, maximum - from +24.1 to +29.5 °C. The daily average (+21.5 °C) exceeded the long-term average by 4.1 °C. In the II and III decades, a decrease in temperature was noted. Minimum air temperatures varied from + 10.5 to +15.3 °C, maximum – from +15.0 to +25.6 °C, and average daily air temperatures for the second and third decades (+17.8 °C) – at the normal level (+18 °C). The average temperature of the July month of the week is 19.0 °C, with the norm being 17.7 °C. During the month there were 21 days with precipitation. During the month, 105.5 mm fell, which is 27.5 mm or 35.2% above the norm (78 mm).

In August, the minimum air temperatures varied from +10.0 to +17.9 °C, the maximum - from +21.2 to +30.2 °C, and the average daily indicators for the month - +18.1 °C, above the summer average by 2. 1 °C. During the month there were 13 days with precipitation. During the first decade, 36.8 mm fell (+9.8 mm from the norm). In the second decade - 11 mm, and the third decade - 16.6 mm (below the norm by 13 and 6.4 mm, with the norm being 24.0 and 23.0 mm).

The growing season of bright crops was characterized by residual additives exceeding the long-term average. In the spring of 2013, precipitation exceeded the average summer norm by 2 times, and in the summer, it was 1.2 times higher than the norm. Due to the abundant snow cover and heavy rains that occurred in the spring, the soddy-podzolic soil underlying the clayey rock of the village of Mikhnevo was over-compacted and oversaturated with moisture.

Due to waterlogging of the land from the end of April - the beginning of May, difficulties arose in preparing the land for spring fieldwork. Safflower sowing was carried out at a relatively late date, May 10-13. Shoots were noted on the fifth or sixth day. On May 14, a period of heavy rains began, which lasted until the end of the month. An excessive amount of interference, combined with a favorable temperature regime in July-August, disrupted the seed-filling process. The safflower crop produced a low yield of poor quality. The total temperature above +5 °C in 2013 was - 2264.8 °C and the growing season in 2013 was characterized by wet weather - HHC (hydrothermal coefficient) = 1.6. Agrometeorological conditions in 2013 can be characterized as factorial for all crops.

Biological Characteristics of the Oilseed Safflower Variety Krasa Stupinskaya in Contrasting Soil and Climatic Conditions

A comparative analysis was conducted to determine how the growth zone affects the vegetation period and the primary economically valuable indicators of safflower grown in four regions: Central Tajikistan, the Volga Federal District (Saratov region), the Southern Federal District (Rostov region), and the Central Federal District (Moscow region). The annual herbaceous plant Krasa Stupinskaya has a well-developed tap root system that reaches a depth of 10–20 cm in the southern parts and 1.5–2 m in Central Tajikistan (Temirbekova *et al*., 2016).

The stem is glabrous, erect, branchy, height is about 83-90 cm. Leaves are sessile, lanceolate, oval, or elliptical lancets, on the edges with small teeth, ending with small spines. The inflorescences are many baskets, 1.5-3.5 cm in diameter. The number of baskets on the plant is from 5-7 to 20-50 pieces. The flowers are tubular, with five separate corollas yellow or orange. Fruit - achene, brilliant, reminiscent of sunflower achenes**.** Its hard shell, which is difficult to split, is 40-50 % of the seed weight. The seeds do not crumble and can germinate at a temperature of 1-2 ° C, but they are better and more friendly when the soil warms up to 5-6 ° C and more at a depth of 10 cm.

Every year, the following regions spend their seeding budgets: Mikhnevo (7.05.11.05.05), Saratov (7.05.05), Rostov (26.04.04), Central Tajikistan (20.12–25.12), and 10.03–15.03 (spring planting). The seedlings appeared in three to eight days and have always been friendly. The time span between the onset of budding and flowering ranged between 18 and 23 days. About 29–35 days passed during flowering. Harvest ingathering was carried out in

Mikhnevo – 23.08, in the Rostov region – 12.08, in the Saratov region – 16. 08, In Central Tajikistan – 7.04-10.04 (at the winter sowing) and 28 June - 2 July (during the spring sowing).

In the Moscow region, it took 96 days from germination to maturity in 2013, compared to 112 days in the Rostov region, 93–95 days in the Saratov region, 89–103 days in the Saratov region, and 110 days in Central Tajikistan. The time of safflower vegetation was about the same in every place.

The calculation of basic safflower harvest indicators gave the following results: the number of plants per 1 m2 (p/m2) was in Mikhnevo – 26 p/m2, in the Rostov region – 30 p/m2 (planted for seeds), in the Saratov region – 62 p/m2 (planted for feeding purposes). Plant height ranged from 63 - 80 cm in all regions. The mass of 1000 seeds was as follows: in Mikhnevo in 2010 – 50.0 g; 2013 – 30.3 g; in the Saratov region in 2013 – 30.9 g, 2010 – 48.1 g; in the Rostov region in 2010 – 42.3 g, in 2013 – 53.4 g. In the Moscow region productivity of safflower Krasa Stupinskaya was 2013 0.4 t/ha, in 2010 – 0.8 t/ha; in the Saratov region: 2013 - 0.9 t/ha, 2010 – 2.0 t/ha; in the Rostov region - 1.25 t/ha in 2010 and 0.6 t/ha in 2013.

Krasa Stupinskaya is recommended as green manure, phytosanitary, fodder, ornamental, promising oilseed crop, and also for use in medicine. Safflower performs best as a green manure on soddy-podzolic soils.

The Phytosanitary Role of Safflower

After two years of safflower growth, contamination from spring barley cereal can be reduced by up to 24 pieces/m2 or 62% (2008-2009), spelled -11 pieces/m2 or 89% (2013-2014), from safflower cultivation for green manure. The average number of lupines in barley and spelled crops after mustard, white, and blue was 17–20 pcs/m2, or 20.2%.

Safflower as a Fodder Crop

At 100 kg of safflower green mass with a moisture content near 76.06% found 22.75 k.e. At 100 kg of silage with a moisture content of 82.78% - respectively, 15 k.e. and 1.3 kg of digestible protein. The 100 kg of safflower oil cake contained 75.5 k.e.

Safflower as an Oilseed

These days, seeds with higher oil content are becoming a valuable asset to our agricultural output; for example, the land can be used as a breeding ground for changes in oil quality.

It has been demonstrated that every variation and even the population's shape is made up of a greater or lesser number of biotypes that vary in a variety of ways, including the amount of fatty acid oil present (Ermakov & Popova, 1972).

Understanding the genotypic diversity of the fatty acid composition in a range of farmed species and their wild relatives is the basis for selecting the quality of oil for technical and food usage.

The study of differentiation within species for chemical indicators of quality grades was highly valued by Vavilov (1967), emphasized the necessity of identifying genetic differences that can be observed in the study of different varieties in different geographical locations under the same conditions.

We conducted a comparative analysis of the oil content determination in the safflower seeds (Krasa Stupinskaya) for three years, obtained from the Rostov region. The mass fraction of fat in the seeds was 19.02% in excessively wet 2013, while the fat content in seeds was 23.7% in severely dry 2010. In the Moscow region, in the excessively humid year of 2013, the oil content was 6.4%, and in the extremely dry year of 2010 - 31.2%.

We noted that the accumulation of oil content depends not only on the amount of precipitation but also on the temperature factor. Moderate amounts of precipitation and temperatures above 18 °C (flowering and filling phases) have a positive effect on the formation of oil content.

In 2013, when 335.8 mm of precipitation fell during the growing season (the norm was 264 mm) and the temperature was 18.4°C, the mass fraction of fat was only 6.4%. In 2010, an acutely dry year, with an increased air temperature of 18.8 °C (average temperature of 15.1 °C) and a reduced amount of precipitation of 154.4 mm during the growing season, the accumulation of the mass fraction of fat was 31.2%.

In terms of linoleic acid concentration, which the human body cannot produce, this variety (Krasa Stupinskaya) is comparable to the southern variation Mahalli 260, **Table 2**. It outperformed other kinds in terms of oleic acid concentration (16.89%), which is crucial for maintaining the freshness of the oil over an extended period of time. Krasa Stupinskaya was distinguished by its increased concentration of saturated fatty acids, especially palmitic acid. Krasa Stupinskaya yields about 240 kg of oil per hectare (at 250–300 thousand plants per hectare) and 0.8 t of seed per hectare. At a plant density of 160 thousand plants per hectare and crop seeds of 1.7 t/ha, the oil yield in Central Tajikistan was close to 940 kg per hectare.

Table 2. Fatty acid composition of safflower oil in 2013

Fatty acids	**Mass fraction of fatty acids, % to the total content of fatty acids**			
	Mahalli 260 (Tajikistan), 2013	**Krasa Stupinskaya, 2010**	**Krasa Stupinskaya, 2013**	**Norms in accordance with GOST 30623-98**
$C_{14:0}$ (myristic)	0.1	0.1	0.1	< 1.0
$C_{16:0}$ (palmitic)	7.6	9.94	7.7	2.0-10.0
$C_{16:1}$ (palmitoleic)	0.2	0.55	0.1	< 0.5
$C_{18:0}$ (stearic)	2.6	2.48	2.0	1.0-10.0
$C_{18:1}$(oleic)	13.2	16.89	13.6	7.0-42.0
$C_{18:2}$ (linoleic)	75.6	65.88	75.7	55.0-81.0
$C_{18:3}$ (linolenic)	0.2	-	0.1	< 1.0
$C_{20:0}$ (arachidic)	0.3	-	0.4	< 0.5
$C_{20:1}$ (gondoinovaya)	0.2	-	0.3	< 0.5

The productivity increase and safflower product quality depend on farming practices of cultivation. It is necessary to adhere to the morphological features of crops and varieties, keeping the complex soil-climatic conditions of the region, a specific agricultural production, and a hydrothermal regime during the growing season. What matters are technical equipment, financial condition, and agronomic management frames.

Therefore, the potential yield and economic effect of the new culture introduction will largely depend on the use of cultivation technology adapted to local conditions, taking into account all these factors. All agricultural practices that are recommended for the cultivation of crops should be carried out at one time because the omission or wrong application of one of the elements will affect the yield and quality of seeds.

Place in Crop Rotation and Tillage

The best safflower precursors are crops. Safflower is not demanding to soil. It grows well even on poor (on qualitative structure) sod-podzolic soils of the Moscow region. Culture is particularly demanding of the heat in the phase of flowering and ripening. Seedlings can withstand frosts to 3-5 ° C.

The fat content in seeds of safflower depends on temperature. Under optimum standards rainfall during the growing season (average 255.4 mm, normal 264 mm) and moderate temperatures - at a rate of 18,2 15,1 ° C, oil content in seeds is up to 30.5%, in the dry 2010 - 31.2 % (on dry substance).

High humidity like in 2013 (not typical), reduces the yield and oil content in seeds and also enzyme-mycotic exhaustion to develop in an abundance of empty seeds.

The Results of the Survey in 2010, an Acutely Droughty Year with Late Harvesting

The list of the most common diseases of safflower is quite extensive. Among the harmful bacterial diseases is bacterial spotting of leaves and stems, caused by the bacteria *Pseudomonas syringae*. Phytoplasmas (mycoplasma-like organisms - MLO organisms) can cause growth and phyllodes of safflower inflorescences.

Among fungal diseases, the most common are *Alternaria* leaf spot, caused by a specific species *Alternaria carthami* (Rodigin) Chowdhury, as well as other leaf spots caused by anamorphic fungi, incl. cercospora - *Cercospora* sp., septoria - *Septoria* sp., ascochyta - *Ascochyta carthami* M. Chochr., phyllosticta - *Phyllosticta carthami* Tropova, ramularia - *Ramularia carthami* Zapr. Safflower plants can be affected by sclerotial rot caused by the fungi *Macrophomina phaseolina* Ashby. downy mildew - *Bremia lactucae* Regel, powdery mildew - *Oidium carthami* Jacz., and several species of rust pathogens from the genera *Puccinia* and *Aecidium*. Of the pathogens with a wide phylogenetic specialization, the causative agents of carbonaceous hard botrytis rot - *Botrytis cinerea* Pers and white rot - *Scleritinia sclerotiorum* Fuck.; Plant wilting can be caused by soil-dwelling fungi *Fusarium oxysporum* Schl. and *Verticillium dahlia* Kleb; The causative agents of late blight root and stem rot are oomycetes of the genus *Phytophthora*, most often *P. cactorum* (Lebert & Cohn) J. Schröt.; In the early stages of ontogenesis, root rot of seedlings is caused by *Pythium* spp (Khokhryakov *et al*., 2003).

Among viral diseases, the most common are *Alfalfa mosaic virus*, *Cucumber mosaic virus*, *Lettuce* mosaic *virus*, *Turnip mosaic virus*.

Based on the results of visual diagnostics of the variety samples, it was revealed that the seeds had no external signs of damage. On the leaves, 40.5% of the lesion was found in the form of black-gray and white-gray fungal plaque on necrotic areas of round or irregular shape. On inflorescences, similar external signs of damage were common at the level of 50%.

The results of assessing the infestation of aboveground organs of safflower plants using the wet chamber method are presented in **Table 3**. Fungal infestation was assessed by the presence of plaque-mycelium structures and sporulation. Only on inflorescences were fungal and bacterial microorganisms found in almost equal proportions. On the seeds and inflorescences, bacteria dominated in prevalence, determined by the presence of bacterial exudate in the form of droplets of mucus or liquid.

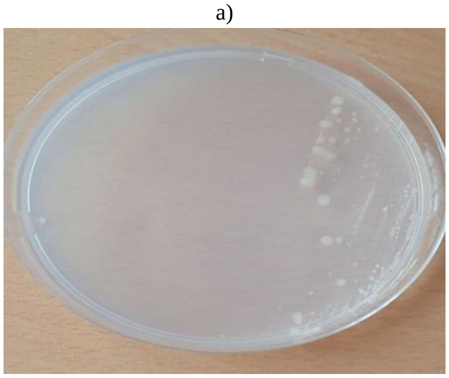
Table 3. Average infestation of above-ground organs of safflower plants, identified by the wet chamber method

Test samples	Contamination, %		
	bacteria	fungi	total
Leaves	25,0±1,5	12,0±2,1	40,5±1,2
Seeds	60,0±1,7	40,7±2,0	50,0±2,4
Inflorescences	20,5±2,0	20,5±1,5	60,4±1,7

Subsequently, the plaque and exudate structures were transferred under sterile conditions to a nutrient medium, where pure cultures of microorganisms were obtained. Based on the appearance of the colonies and the color of the exudate, bacterial pathogens, presumably *Pseudomonas* syringae, were dominant, **Figure 1**. According to microscopy results, the main component of the fungal microbiota, both on seeds and on leaves and inflorescences, were fungi of the genus *Alternaria*; zygomycetes, presumably of the genus *Rhizopus*, were less common, **Figure 2**. At the same time, there were no differences in the presence of microorganisms on the surface and inside the seeds, except for damage by *Rhizopus*, which was isolated only from the surface. The high overall contamination of seeds - 50% - may have been associated with the increased moisture content of the examined seeds.

When assessing the frequency of occurrence of fungal and bacterial species on the nutrient medium (based on CFU), it was found that bacterial pathogens predominated, presumably *Pseudomonas syringae* (P=60%), fungi of the genus *Alternaria* (P=35%) and *Rhizopus* (P=35%) were less common. P=5%).

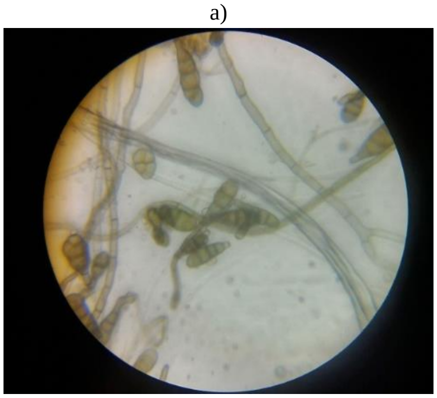
a)



b)

Figure 1. a mixture of colonies of microorganisms isolated from the surface of safflower seeds (a), colonies (reseeding with streaks) of bacteria (Pseudomonas sp.) on a CHA (b)

a)



b)

Figure 2. Sporangia and mycelium of Rhizopus sp. (a); conidia and mycelium of Alternaria sp (b) from safflower seeds (x400)

According to the results of the phytosanitary examination, it was revealed that on the seeds of safflower oleaginous varieties, with a total seed infection of 50%, bacterial pathogens, presumably *Pseudomonas syringae* (P=60%) dominate; Fungi of the genus *Alternaria* (P=35%) and *Rhizopus* (P=5%) were less common.

For more precise identification, the use of molecular research methods is additionally required.

Conclusions. As a result of many years of research on the safflower crop in the Central region of the Russian Federation, the influence of arid and humid climate conditions on yield and accumulation of oil content, as well as disease damage, has been established.

The genotype of the safflower crop showed its advantages in arid conditions. Consequently, with an annual increase in air temperature, i.e. With climate change, for sustainable agriculture in the Central region, we can recommend the Krasa Stupinskaya safflower variety we created for cultivation in agricultural production.

Cultivation of Safflower Oilseed in the Southern Arid Climate of Kazakhstan

Kazakhstan is among the top producers of wheat in the world, and a lot of farmers there also grow crops like safflower and flax that can withstand drought. This is made possible by the great profitability of producing these crops, which allows one to diversify risks associated with farming traditional crops.

In the south of Kazakhstan, due to a decrease in precipitation during the growing season, there is a need to select drought-resistant crops, one of which is safflower. Also, a biological feature of safflower is the ability to grow on saline salt marshlands and produce crops in extremely dry years, when other grain crops die. In addition, the cost of safflower production is much lower and the costs are economically justified compared to sunflower. Safflower also showed resistance to pests and diseases compared to sunflower in the south of the country.

Safflower is mostly grown in Kazakhstan for its seeds, which are then processed into edible vegetable oil and used for breeding and seed production.

The production of plant food products is carried out using environmentally friendly cultivation technology.

Kazakhstan led the world in safflower seed production in 2018, accounting for 34% of the total with 627,653 tonnes produced worldwide. Other significant producers were the United States and India, 26% of world production combined.

In Kazakhstan, safflower selection is carried out at the Kazakh Research Institute of Agriculture and Plant Growing (KazNIIZiR), the Krasnovodopadskaya Agricultural Experimental Breeding Station (SHOSS), and the Aktobe Agricultural Experimental Station (ASC). These scientific institutions have created many safflower cultivars which have good productive and economic qualities. Drought-resistant varieties. Huskiness – 38-45%. Oil content 36-38%. The yield, depending on the rainfed zone, averages 7-12 c/ha.

The introduction of a new safflower cultivar into production will correspond to the main direction of diversification of the crop-growing industry in the region - expanding the range of drought-resistant oilseed crops.

Safflower is not a commodity crop, and the price is based on an analysis of production and consumption in the world. The most important price parameter is the quality of edible safflower oil. Of course, the price depends on many factors, in particular on the balance of supply and demand. But over the past 4-5 years, safflower supplies to China have been the most profitable.

Safflower is adapted to the conditions of a sharply continental climate and, due to its demands on moisture, is one of the most drought-resistant plants.

Safflower seeds germinate at soil temperatures at a seeding depth of 1-2ºC, and seedlings tolerate frosts down to – 6-8ºC. The growing season in the conditions of the South and South-East of Kazakhstan is 110-120 days.

In addition, safflower is a honey plant. As a honey plant, safflower is very unstable but is a good pollen bearer. In the South Kazakhstan region, where its crops cover 80-105 thousand hectares, it produces nectar in rare years and usually for no more than 5-10 days. At this time, the control hive gains weight from 0.5 to 2.5 kg per day. It has been noticed that at the slightest change in weather or wind, the function of the honey plant is interrupted. Beekeepers use safflower crops only in combination with other honey plants so that in extreme cases the bees can stock up on pollen.

Safflower honey is usually light in color, with a characteristic yellowish tint, without any particular aroma.

The yield of safflower seeds in the unsecured rainfed areas of the southern regions was 8-10 hectares, and in the semi-secured rainfed conditions of the South-East of Kazakhstan - 12-14 c/ha.

Place in Crop Rotation: Leguminous crops, perennial grasses, and clean fallows are some excellent predecessors during cultivating safflower for seeds.

When safflower is cultivated for oil and feed purposes, the predecessors for safflower can be grains, as well as other crops.

Safflower in crop rotations is cultivated as a trailing crop to clear weeds and is a good precursor for spring crops.

Soil Cultivation: The biological characteristics of safflower determined a number of agrotechnical methods for its cultivation. Preparing the soil for safflower sowing begins in the fall. The soil is plowed to a depth of 20-22 cm on heavy soils, and on light soils to a depth of 10-12 cm with flat-cutting subsoilers.

In dry autumn conditions, as a rule, the soil is dry, so the plowed land is left unfenced for the winter. Tilling dry soil with harrows in the fall leads to its spraying, which causes severe wind erosion.

In early spring, it is necessary to monitor the readiness of the soil, and as it dries, harrow with needle harrows in an active position with a low angle of attack.

Sowing Time: The influence of sowing timing on the yield of cultivated crops is well known. Particularly important is the choice of time for sowing safflower in unsupplied rainfed areas, where in the spring there is a rapid increase in positive temperatures, causing increased evaporation of soil moisture.

The optimal time for sowing safflower in the rainfed conditions of the Turkestan region is before the first half of March (March 15). In Almaty and Zhambyl regions, the optimal sowing time is considered to be early April (before April 5), the period one week after the start of spring field work, i.e. after early spring harrowing in order to seal off moisture and carry out pre-sowing cultivation with harrowing and rolling. Later sowing dates, as well as excessively early sowing, lead to a decrease in safflower yield.

Sowing Methods: Safflower is sown with a vegetable seeder SON-4.2 with a row spacing of 45 cm. If there are no special seeders on the farm, safflower is sown with ordinary seeders SZ-3.6; SZP-3.6; SZT-3.6 with setting the specified row spacing.

The continuous or row (15 cm) method is used when cultivating safflower for green fodder or silage.

Seeding Rates: The optimal seeding rate when sowing with a row spacing of 60 cm is 160,000 seeds or 7.5-8.0 kg per 1 ha.

When sowing in a row method, the seeding rate increases 3-4 times - 0.5-0.7 million seeds or 25.5-32.5 kg per 1 ha.

In almost all areas of the region, farmers prefer to sow zoned cultivars of safflower: “Akmai”, “Nurlan”, “Iirkas” and “Moldir-2008”. They have proven their worth more than once, withstanding droughts, 50ºC heat, and dry winds. Judging by the first cuttings, the safflower yield in 2021 was not bad, on average 9-10 centners per hectare. This is approximately 0.5 centners per hectare more than the yield of the previous 2020 year. Safflower harvesting in the region traditionally ends in early September (September 5).

The eastern and central regions of the South Kazakhstan (now Turkestan) region have been growing safflower from 1996 to the present time. This is a common agricultural crop, often found in the southern regions of Kazakhstan. In the structure of areas cultivated on rainfed lands in the Tulkubas, Kazygurt, Baidibek, Ordabasin, Sairam, Keles, and Tolebi regions, safflower occupies about 35%. The average yield in 2021 was 10 c/ha.

Farms in the region use seeds bred by the Krasnovodopadskaya Agricultural Experimental Breeding Station.

In the southern regions of Kazakhstan, there is a tendency to reduce the amount of precipitation during the growing season for this oilseed crop, hence the lack of moisture, so there is a need to select drought-resistant crops, one of which is safflower. Also, a biological feature of safflower is the ability to grow on saline lands and produce crops in extremely dry years when other grain crops die.

In 2014 an oil plant for processing safflower seeds was launched. Raw materials are mainly sold to China since there is a stable demand for these products in that country. At the same time, part of the safflower is processed into oil, which is sold both for export and on the domestic market of the country.

The prospects for safflower in Southern Kazakhstan are high. Firstly, this is a highly profitable production, even with a yield of 3 c/ha it gives a profit, **Table 4**. Secondly, innovative areas of safflower use in the world in the form of flower petals in medicine are being developed, especially in the treatment of cardiovascular diseases. Therefore, there will always be a demand for this crop.

Table 4. Safflower yield in the Turkestan (South Kazakhstan) region

	2016	2017	2018	2019	2020
ha	70 546	109 287	92 827	88 055	80 732
Tons	59 258,64	93 986,82	81 687,76	72 205,10	75 080,76
c/ha	8,4	8,6	8,8	8,2	9,3

"Akhram" - a new cultivar for conditions of hot dry winds. It is a promising and adapted safflower cultivar for Western and Northwestern Kazakhstan. It was created by KazNIIZiR (Almaty region).

The plants have a compact shape, the number of productive baskets on one plant is 10-16 pieces, and the height of the plants is 45-65 cm. The leaves are entire and sessile, and the lower ones are oblong-oval without thorns. The flowers are orange-red, and the achenes are yellowish-white.

The weight of 1000 seeds is 44.0-45.2 grams, which exceeds the standard by 10-15%. Seed oil content is 37-38%, which is 13.8% higher than the Akmai standard cultivar.

The average yield in the conditions of the Aktobe region is 9.5-10.5 c/ha, which is 30% higher than the zoned cultivars.

The following productivity structure element accounts for the high oilseed yield when compared to the "Akmai" standard cultivar: on a single plant, there are two or more times as many productive baskets with large seeds than the standard.

Cultivation of a newly adapted safflower cultivar "Akhram" for oilseeds is profitable. The oil yield per hectare is 286 kg, which is 90 kg higher than that of the Akmay standard.

The introduction of this cultivar into production will contribute to the sustainable development of agriculture in the acutely arid regions of Kazakhstan.

Conclusions. The southern region of Kazakhstan is acutely arid. Many years of research have shown the successful cultivation of safflower oilseed in the fields. Scientists have created varieties "Akmai", "Nurlan", "Iirkas" and "Moldir-2008" that form a yield of 7 to 12 c/ha and an oil content of 36-38% even at 50ºC heat. Currently, a new variety, Akhram, has been created for the Central regions with an arid climate. The average yield is 9.5-10.5 c/ha, seed oil content is 37-38%. The varieties are recommended for the sustainable development of agriculture in the region.

Key Findings from Research of Safflower Cultivation in Tajikistan

The search for innovative agricultural technologies is one of the most important problems of agricultural production. This is especially important in the arid climate of Tajikistan.

With the help of new, highly productive, drought-resistant crops that can tolerate the climatic conditions of rain-fed areas, the yield of fodder and oilseed crops in zones should be increased using cutting-edge technologies. These requirements are met by safflower, which, due to its biological characteristics, can produce quite high yields of green mass with good feed qualities in conditions of dry-farming lands. It is also a universal culture that may be grown on seeds to produce oil (Norov, 2005).

Safflower is currently grown throughout the republic as an oilseed crop. Up to 37% of the edible oil is found in its seeds. The absolute fat content in the purified seeds reaches 60%. It is quite similar to hemp and poppy seed oils chemically, refers to semi-drying oil, and the iodine number is 126-151. Safflower oil serves a variety of technical functions, including the creation of drying oils, the production of soap, the creation of linoleum, the preparation of margarine, and other uses in the paint and flooring industries.

The waste of oil production - oilcake and meal – is an excellent feed for animals.

Productivity of Different Safflower Cultivars

More than 10 safflower varieties have been studied and the most productive of them for producing green mass have been identified. The goal was to investigate and pinpoint the plant cultivars that, under the bogara conditions of Tajikistan, produce the most seeds with a high oil content.

It is well known that the number of baskets on each plant, the number of seeds inside each basket, and the weight of 1000 seeds are the three most significant components of the structure of the safflower grain harvest.

The Shifo cultivar has the highest indicators and produces an average of 27.0 baskets, each containing 33.2 of the largest seeds, on a single plant. 1000 seeds mass was 32.7 grams in total. The highest seed productivity was also the highest -26.3g per plant. The biological crop of seeds has a yield of 31.6 c/ha.

The number of baskets per plant, which in these cultivars is 24.5; 25.2; and 25.7 pcs, is also very interesting. Each basket contains 30.4; 31.6; and 32.0 seeds, weighing 25.0; 23.7; and 25.2g, respectively.

Table 5 shows that throughout the years of research, the Shifo cultivar produced the highest seed yield. The average yield of seeds from one hectare of this cultivar's crops in three years was 24.3 c/ha. The seed yield of the VIR-464 was slightly lower (23.2 c/ha).

Table 5. Safflower seed yield, c/ha

Cultivars	Years			Average	Deviation from the standard
	2018	2019	2020		
Milutinsky 114 (standart)	16,7	20,7	17,8	18,4	-
VIR-489	20,6	26,2	22,2	23,0	+4,6

Mestnaya 498	16,8	20,9	18,1	18,6	+0,2
VIR 454	21,9	25,9	21,8	23,2	+ 4,8
VIR 483	25,7	21,0	18,5	18,4	± 0
Shifo	22,4	27,5	23,0	24,3	+ 5,9
Mestnaya 492	16,1	20,2	17,1	17,8	- 0,6
Mestnaya 260	20,5	24,2	21,3	22,0	+3,6
VIR 376	14,9	19,3	16,2	16,8	-1,6
Mestnaya 505	19,6	23,4	20,9	21,3	+2,9
VIR 487	18,0	22,7	20,5	20,4	+2,0

Therefore, it was found that the Shifo cultivar of safflower is promising for cultivation in conditions of rainfall-rich bogara of Tajikistan based on the results of three-year tests of various safflower varieties.

This cultivar was created using the individual selection method from the VIR catalog number 494's source material. Its plants stand out due to their height; in rain-fed bogara, stem lengths can reach 145–150 cm.

The leaves are large, completely extreme, almost sessile, oblong-lanceolate, and arranged in the following order.

The number of first-order branches is large, ranging from 14 to 18 and each ends in a basket. On the branches of the first order, 4-5 branches of the second order frequently form and carry seed baskets as well. On one plant, 20–30 baskets are formed. The tubular, five-part, orange or yellow flower has five distinct petals. In the basket, between 30 and 65 seeds are formed. 1000 of their pieces weigh 34–40 g each. The white, glossy shells that make up the seeds' weight range from 34 to 39 percent. The core tightly fills the shell. The fat content in the dry kernel is 55-60%. The oil content of the whole achene ranges from 30-34%. The variety belongs to the medium-ripe group. With spring sowing, the duration of the growing season is 100-120 days, with winter (December) sowing 170-180 days.

In the arid climate region of Tajikistan, several safflower varieties were evaluated for yield and oil content. The Shifo variety was isolated with a maximum yield of 24.3 c/ha (average for three years of research) and, oil content of 55-60% (in dry kernel). The variety belongs to the mid-ripening group with a growing season of 100-120 days.

Following the ideas of Vavilov, scientists attract study and introduce into production crops previously unknown to our agricultural science and practice (Gorbatenko, 2007; Temirbekova, 2018). Therefore, the problem of the introduction of new crops is becoming increasingly relevant due to the fact that Russia is supplied with vegetable oils and preparations of biologically active substances through imports. In recent years, the import of edible vegetable oil in the country amounted to 35-38%; a further increase in the production of vegetable oil by expanding the area of cultivation of the main oilseed crop: sunflower is impossible due to dangerous quarantine objects (Shevchenko & Zubkov, 2011). Therefore, there is a need to cultivate non-traditional crops that can adequately respond to changing weather conditions. The most promising oilseed crop is safflower. The areas under cultivation of safflower are small and concentrated in the acutely arid regions of the Russian Federation (Shevchenko & Zubkov, 2011; Medeubaev, 2014; Kshnikatkina *et al*., 2019). Therefore, the promotion of safflower to the northern regions of Russia is of scientific and practical interest (Adamen & Proshina, 2016). No one has yet studied the productivity and accumulation of oil in seeds in the Central region (Temirbekova *et al*., 2020).

Conclusion

The development of stable, sustainable agriculture during severely dry years in the Russian Federation, Kazakhstan, and Tajikistan has highlighted the benefits of the safflower oilseed crop, which is native to Egypt and India. The biological characteristics, productivity, accumulation of oil content, and disease development in safflower plants were studied. Oilseed safflower varieties with adaptive potential have been created, combining a stable yield and sufficient oil content. In the context of impending climate warming, the varieties will ensure food security in the above-mentioned countries.

Acknowledgments: None

Conflict of interest: None

Financial support: The study was carried out as a part of the State Assignment for the All-Russian Research Institute of Phytopathology (theme no. 0598-2019-0005, Official Registration Number EGISU R&D–AAAA-A19-1191212901090); and as a part of the Governmental Task for the Federal Horti-cultural Center for Breeding, Agrotechnology and Nursery to preserve, enlarge and study the genetic collections of agricultural plants and establish the repositories of the horticultural and small-fruit crops that are free from hazardous viruses (theme no, 0432-2021-0003). This study was also supported by the Kazan Federal University Strategic Academic Leadership Program (PRIORITY-2030). This paper has been supported by the RUDN University Strategic Academic Leadership Program.

Ethics statement: None

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