E3S Web of Conferences **395**, 02005 (2023) https://doi.org/10.1051/e3sconf/202339502005
ETSAIC2023

Ecological plasticity of safflower varieties in contrasting natural and climatic conditions of Western Kazakhstan

V.B. Limaskaya*, *G.H.* Shektybayeva, *A.T.* Orynbayev, and *A.S.* Kasenova

Uralsk Agricultural Experimental Station LLP, Uralsk, Republic of Kazakhstan

Abstract. This research was carried out within the framework of the scientific and technical program BR10764991, "Creation of highly productive varieties and hybrids of oilseeds and cereals based on the achievements of biotechnology, genetics, physiology, and biochemistry of plants for their sustainable production in various soil and climatic zones of Kazakhstan," under the budget program 267, "Increasing the availability of knowledge and scientific research." The article presents the results of ecological variety testing of safflower in the arid conditions of Western Kazakhstan. Safflower is a drought-resistant oilseed crop that can produce a stable crop of oilseeds with an oil content of 27-38% in the conditions of the West Kazakhstan region. The main purpose of this scientific work is the systematic study of the selection material of safflower, with the identification of sources of valuable traits and properties based on ecological selection, and the creation of new competitive and patentable varieties adapted to the agroecological conditions of the region. The article presents the yield and the main elements of the structure of the yield of oilseeds of isolated safflower samples. The biological yield of safflower seeds in the nursery of ecological variety testing ranged from 6.4 to 12.0 c/ha. The article summarizes the results of ecological variety testing of safflower selection from the Kazakh Research Institute of Agriculture and Plant growing, the Research Institute of Agriculture of the South-East of the Volgograd State Agricultural Academy, the Krasnovodopadsky agricultural experimental station, and the Aktobe agricultural experimental station. These varieties were evaluated in this nursery based on their main economically valuable traits.

1 Introduction

Diversification of crop production by introducing and expanding the range of competitive drought-resistant oilseeds solves the problems of increasing profitability of production and meeting the growing demand in the vegetable oil market. Safflower is a drought-resistant crop due to its xeromorphic structure and shape of the root system, and its high concentration of cell sap, which allows it to consume soil moisture efficiently. This crop

* Corresponding author: ucxoc1914@mail.ru

© The Authors, published by EDP Sciences. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (https://creativecommons.org/licenses/by/4.0/).

has spread south of the sunflower cultivation zone and is adapted to the conditions of a sharply continental climate [1].

Safflower (Carthamus tinctorius L.) is a unique plant that was grown in Central Asia two thousand years before the Common Era. It differs from other oilseeds in drought resistance, requiring much less moisture for growth. Nevertheless, it responds well to irrigation and is demanding of heat, especially in the flowering and ripening phase. Safflower is cross-pollinated with the help of insects, with central baskets blooming first, followed by the side ones. The flowering of the baskets lasts about a month, and the growing season ranges from 90-150 days, depending on the variety and cultivation conditions. Its shoots can withstand frosts up to -3-40C. Dry years are more favorable for safflower than years with prolonged rainy weather, in which seed formation is very weak. Safflower does not make high demands on soils and grows even on slightly saline soils. These features allow it to be cultivated in difficult soil and climatic conditions. Despite all the advantages of the culture, safflower has not yet found wide distribution in rain-fed conditions and on irrigated lands.

Currently, safflower crops occupy more than 1 million hectares worldwide. In the CIS countries, breeding work on the creation of new varieties is mainly carried out in Russia. The State Scientific Institution of the Lower Volga Research Institute of Agriculture of the Russian Academy of Agricultural Sciences (Volgograd) and the Wildebeest of the Caspian Research Institute of Arid Agriculture of the Russian Academy of Agricultural Sciences (Astrakhan) [2] have used the method of multiple individual selection for arid farming conditions to create three varieties of safflower over the past 10 years: Astrakhan 744, Zavolzhsky 1, and Alexandrite.

In recent years, the Republic of Kazakhstan has implemented a strategy to saturate the market with domestically produced vegetable oil by expanding acreage and increasing oilseed productivity. The vegetable oil market in Kazakhstan is a dynamic and rapidly growing sector, making it an attractive industry for agricultural producers. Thanks to government efforts, oilseed production is increasing, and the Ministry of Agriculture plans to bring Kazakhstan to the level of leading producer-exporting countries.

Oilseed selection, particularly safflower and flax, is a new area of research in Kazakhstan. Although many varieties and hybrids of sunflower and soy have been created, their genetic potential is not yet fully utilized, making continuous crop selection necessary [3,8,10].

Since 2000, Kazakhstan has been among the top five safflower producers worldwide, and in 2010, it became the second-largest producer after India, with a harvest of 122.24 thousand tons. Safflower is also actively grown in China, Uzbekistan, Ukraine, Australia, the USA, Mexico, Argentina, Ethiopia, and Tanzania.

Safflower is an excellent alternative to sunflower as an oilseed crop in arid steppe areas. While it was mainly grown in southern regions before, its drought resistance and adaptability have allowed it to expand into northern and western regions.

After sunflower, flax, ginger, and mustard, safflower occupies an important place in the world. Safflower oil is widely used in medicine and cooking, and it can also be used to make margarine. Its taste is similar to sunflower oil. Additionally, safflower oil is used for technical purposes in the production of white paints and enamels. The cake left over after oil extraction is bitter, but it can be used as feed for cattle, with 100 kg of cake providing 44 feed units of nutritional value. Safflower seeds are also good for poultry feed.

The cultivation of safflower, a relatively new and non-traditional oilseed, is relevant due to its increased characteristic of drought resistance. The seeds of safflower contain 28-38% of light yellow semi-drying oil, which is not inferior in taste to sunflower oil. Furthermore, in terms of the content of essential amino acids and vitamins, it is close to olive oil [4, 6, 7, 9]. Agroecological assessment and variety testing of domestic and foreign safflower breeds can help identify the most productive and valuable varieties in quality.

Over the past 5 years, safflower has increased its position in the structure of acreage in the West Kazakhstan region from 15.2 to 69.2 thousand hectares, with a tendency to increase in subsequent years. The biological features of the crop allow yields in arid conditions of sharply continental climates at the level of 5-8 c/ha. However, the potential of the crop is somewhat higher, and the productivity indicator can be increased by introducing the most drought-resistant and locally adapted varieties. In 2022, the sown area in the West Kazakhstan region amounted to 124 thousand hectares. Since 2006, the only safflower variety that has been zoned in the West Kazakhstan region is the Center of 70 Breeding of the Kazakh Research Institute of Agriculture and Plant growing. Unfortunately, over the years of the inclusion of the variety in the "State Register of breeding achievements recommended for use on the territory of the Republic of Kazakhstan," it has not been widely distributed in the region. Instead, a number of randomly imported varieties of non-district breeding with unstable productivity are used for sowing. Conducting ecological variety testing of the safflower collection will allow identifying adapted varieties and lines for use in the arid conditions of western Kazakhstan [5,11,12,13].

The purpose of this research is to study and isolate safflower varieties of domestic and foreign selection in ecological variety testing for adaptation and use in the arid climate of the West Kazakhstan region.

2 Material and methods of research

The research was conducted at the Ural Agricultural Experimental Station. For scientific research, the results of ecological variety testing of safflower selections from the Kazakh Research Institute of Agriculture and Plant Breeding, Research Institute of Agriculture of the South-East, the Volgograd State Agricultural Academy, Krasnovodopadsky agricultural experimental station, and “Aktobe agricultural experimental station” LLP were considered. These varieties were evaluated based on the main economically valuable characteristics.

At the “Ural Agricultural Experimental Station” LLP, 50 safflower numbers were studied from 2020 to 2022. The yield and some elements of the quality of the harvest of oilseeds from selected safflower samples for 2020-2022 are presented.

Currently, the Ural Agricultural Experimental Station is continuing its work to evaluate and identify the best safflower varieties in nurseries of ecological variety testing adapted to the arid conditions of Western Kazakhstan. Since 2006, the only safflower variety zoned in the West Kazakhstan region is the Center of 70 Breeding of the Kazakh Research Institute of Agriculture and Plant growing. Unfortunately, despite being included in the "State Register of breeding achievements recommended for use on the territory of the Republic of Kazakhstan" for several years, it has not been widely distributed in the region. Therefore, it should be replaced by new varieties that are more productive, drought-resistant, and differ in a complex of economically valuable features.

One of the areas of cooperation with research institutions in Kazakhstan and Russia is the exchange of varieties and lines for their study.

3 Results and their discussion

The safflower crop was negatively affected by the increased temperature regime during the summer months and less than normal precipitation from 2020 to 2022. In April 2020, precipitation was 17.7 mm at a norm of 22 mm, which is 4.3 mm less than the norm. In May, it was 15.2 mm at a norm of 28 mm, which is 12.8 mm less than the norm. The temperature in July was 26.1 °C at a norm of 22.9 °C. In 2021, the temperature regime increased during the summer months, with a July temperature of 25.1 °C at a norm of 22.9 °C. In August, the air temperature rose sharply to 26.0°C, with a norm of 21.1°C, and there was a rain deficit in July of 17 mm at a norm of 40 mm and in August 0 mm at a norm of 27 mm. The temperature regime during the first months of the growing season in 2022 was also unstable. In April, there was an excess of heat by 3.50°C, and in May, a shortage of 3.60°C. At the same time, precipitation fell within the normal range (22 mm) in April and in May was 38.2 mm, against the normal of 28 mm. In general, the spring was long, cool, and with cold rains.

According to meteorological conditions, continuous air drought in June and July led to the loss of moisture in the soil. Precipitation in June was 8.0 mm at a norm of 33.0 mm. Thus, the formation of the vegetative mass of plants took place under extreme conditions of atmospheric and soil drought.

In July, the situation changed little. The average daily temperature was 23.20°C, while the norm was 22.90°C. Precipitation was only 15 mm at a norm of 40 mm. Starting from the third decade of July and throughout August, there was a lack of precipitation. The average daily temperature in August was 24.20°C, while the norm was 21.10°C. The deviation of the average daily temperature in July was +0.3 degrees, and in August, it was +3.1 degrees. The lack of precipitation in July was -25 mm, and in August, it was -25.9 mm. Precipitation in September was 30.9 mm, with a monthly norm of 29 mm (see Table 1).

Table 1. Meteorological indicators of the safflower growing season for 2020-2022 (according to the weather station in Uralsk, https://rp5.ru/)

Month	Temperature, °C			Precipitation, mm		
	fact.	norm	variation	fact.	norm	variation
2020						
april	7.9	8.1	-0.2	17.7	22	-4.3
may	17.0	16.0	+1.0	15.2	28	-12.8
june	20.7	20.9	-0.2	56.6	33	+23.6
july	26.1	22.9	+3.2	5.4	40	-34.6
august	20.5	21.1	-0.6	16.9	27	-10.1
september	8.8	14.5	-5.7	38.8	29	+9.8
2021						
april	9.8	8.1	+1.7	29	22	+7
may	21.5	16.0	+5.5	20	28	-8
june	24.5	20.9	+3.6	69	33	+36
july	25.1	22.9	+2.2	17	40	-23
august	26.0	21.1	+4.9	0	27	-27
september	13.4	14.5	-1.1	33	29	+4
2022						
april	11.6	8.1	+3.5	22	22	0
may	12.4	16	-3.6	38.2	28	+10.2
june	20.9	20.9	0	8.0	33	-25.0
july	23.2	22.9	+0.3	15.0	40.0	-25.0
august	24.2	21.1	+3.1	1.1	27.0	-25.9
september	15.5	14.5	+1.0	30.9	29.0	+1.9

The soils at the experimental site are dark chestnut heavy loamy. The arable horizon contains 2.74% humus. The availability of mobile forms of phosphorus is average, at 13.7–

16.3 mg/kg of soil. The content of alkaline hydrolyzable nitrogen is very low, at 25 mg/kg, while exchangeable potassium is high, at 466 mg/kg of soil.

The experiment was conducted using the predecessor of black steam in the selection and seed crop rotation. Pre-sowing tillage consisted of surface treatment with a cultivator for the main and pre-sowing treatments, followed by rolling with ring-spur rollers.

Depending on the weather conditions of the year, sowing was carried out in the first decade of May using a self-propelled seeder "Wintersteiger–TS". The seeding rate was 0.5 million germinating seeds per hectare. The area of the plot in the nursery was 21 m2. Standard grade Center 70, according to the experiment scheme, was located in five rooms.

The aridity of the climate during the growing season of safflower somewhat reduced the periods of passage of the main phases of development, especially during grain pouring. Prolonged drought, high daytime temperatures, and frequent dry winds led to poor-quality pollination and accelerated seed maturation.

The height of the standard plants averaged 60.2 cm. The tallest varieties were Alkyzyl, PRR-853, K-3, and M-114.

The productivity of varieties and cultivars is the main and most important criterion characterizing their breeding value and further economic use. Under the prevailing climatic conditions for three years, the average yield was in the range of 8.5–13.0 c/ha, with an average value of the Center standard of 70 at 9.5 c/ha. Of the 50 varieties, 16 provided a reliable increase from 0.8–3.5 c/ha, while 23 were at the standard level. One of the elements influencing the formation of the crop is the mass of 1000 grains. This indicator is closely dependent on external conditions and is prone to significant changes over the years. For three years, the average value of this indicator was 44.0 g for the best cultivars, with a standard indicator of 38.1 g. The characteristics of the crop structure are presented in Table 2.

Table 2. Yield (c/ha) and the main elements of the structure of the yield of oilseeds of selected safflower samples for 2020-2022.

Breed	Productivity, c/ha by years				% to the standart	plant height, sm	number of baskets per plant, unit	basket diameter sm	number of grains in one basket, unit	weight of 1000 grains, grams
	2020	2021	2022	Average						
Center 70, standard	9.6	10.8	8.1	9.5	100.0	60.2	7.6	2.9	24.3	38.1
C-31-PC 228	12.3	16.1	10.6	13.0	136.8	60.7	9.8	3.2	29.8	41.6
C-39-PRRS 837	11.8	17.2	9.4	12.8	134.7	64.7	9.0	2.9	28.9	42.0
K-23	11.0	16.8	10.3	12.7	133.7	67.2	8.8	3.1	30.8	42.8
Alkyzyl	11.2	17.0	9.6	12.6	132.6	71.2	9.1	3.0	32.2	43.8
KP-40-18c 109	10.7	16.4	10.4	12.5	131.6	65.2	8.5	2.9	30.0	42.7
K-3	10.4	17.6	9.2	12.4	130.5	69.7	9.3	3.3	28.9	39.2
Ershovsky 4	11.0	16.2	9.4	12.2	128.4	64.2	8.6	3.0	26.8	43.1
PC 184	10.3	16.0	9.7	12.0	126.3	65.0	8.8	3.2	26.3	44.0
M-114	10.2	15.8	10.0	12.0	126.3	68.1	9.0	3.3	31.2	41.8
PRR-853	11.0	15.2	9.2	11.8	124.2	69.7	8.6	2.9	29.8	40.0
Ат -103	10.8	15.5	9.1	11.8	124.2	62.2	8.8	3.1	30.0	42.8
PC-171	10.4	13.8	10.3	11.5	121.1	61.7	8.1	2.9	27.8	39.7
K-392	11.0	12.1	10.8	11.3	118.9	70.0	8.5	3.1	27.3	41.5
86-85K	11.4	12.0	9.6	11.0	115.8	67.2	8.9	3.3	30.0	42.8
PC-150	10.2	11.6	9.7	10.5	110.5	64.2	8.1	3.0	31.8	42.4
K503	10.1	11.2	9.6	10.3	108.4	65.0	8.5	3.2	31.3	43.9
LSD_{05}				**0.8**	**11.2**	**6.2**	**0.7**	**0.28**	**2.8**	**4**

Elevated temperature conditions during crop formation reduce the oil content in the seeds. The oil content of seeds in the standard was 35.8%, and in the studied varieties, this indicator was close to the standard level and varied from 35% to 38%.

4 Conclusions

Based on the ecological variety testing of safflower in the arid conditions of Western Kazakhstan, a number of samples were identified with economically valuable characteristics and high oil content of seeds. These samples will serve as a valuable source material for practical breeding. Currently, work is ongoing at the Ural Agricultural Experimental Station to evaluate and identify the best samples of safflower in nurseries of ecological variety testing that are adapted to the arid conditions of Western Kazakhstan.

References

1. A.M. Kuleshov, Scientific and agronomic journal, 2-32 (2019)
2. A.M. Kuleshov, Bulletin of the Nizhnevolzhsky NIISH, **1**, 38-40 (2012)
3. E.Z. Mateev, A.A. Usmanov, S.V. Shakhov, D.B. Shalginbaev, K.K. Bukharbaeva, Bulletin of the Almaty Technological University, **3**, 81-88 (2019)
4. E.Z. Mateev, A.A. Usmanov, S.V. Shakhov, D.B. Shalginbaev, K.K. Bukharbaeva, Bulletin of the Almaty Technological University, **3**, 81-88 (2019)
5. K.Zh. Zhambakin, M.Kh. Shamekova, D.V. Volkov, A.K. Zatybekov, Prospects for growing safflower in Kazakhstan (2014) https: //www.ecologic.ru.research/net/publicationn/284270702/
6. T.Y. Prakhova, V.A. Prakhov, V.N. Brazhnikov, O.F. Brazhnikova, "Niva Povolzhya", **3 (52)**, 30-37 (2019)
7. E.A. Kalashnikova, R.N. Kirakosyan, S.K. Temirbekova, O.O. Beloshapkina, M.M. Tareeva, D.A. Postnikov, Bulletin of Russian Agricultural Science, **2**, 44-48 (2019)
8. E.Z. Mateev, A.A. Usmanov, S.V. Shakhov, D.B. Shalginbaev, K.K. Bukharbaeva, Bulletin of the Almaty Technological University, **3**, 81-88 (2019)
9. N.A. Zaitseva, A.F. Tumanyan, A.P. Seliverstova, I.I. Klimova, E.V. Yachmeneva, A.S. Dyakov, Theoretical and applied problems of the agro-industrial complex, **4 (42)**, 30-34 (2019)
10. A.M. Kuleshov, Scientific and Agronomic Journal, **3 (106)**, 29-32 (2019)
11. M.S. Norov, Oil crops, 3 (179), 60-63 (2019)
12. N.V. Safina, T.V. Kilyanova, Beekeeping, **8**, 24-26 (2019)
13. S.V. Shakhov, E.Z. Mateev, A.V. Vetrov, D.A. Zotov, Scientific Review. Pedagogical Sciences, **3-4**, 108-111 (2019)