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Initiation of safflower sowings in the organic farming system of Western Kazakhstan☆

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Abstract – We carried out the research in 2020–2021 in Western Kazakhstan on medium-loamy dark chestnut soils. The purpose of the research is to identify changes in physico-chemical, biological parameters of soil cover, productivity, and quality of safflower (*Carthamus tincforius* L.) under the influence of different technologies of agrarian landscape shaping, for rational management of organic agrocenoses. The field experiments showed that in the conditions of Western Kazakhstan, the use of the biologized technology of organic farming increases the yield of safflower in comparison with the traditional technology by 26.66–35.38%, with a high oil content of 30.0–39.95%. The phytoameliorative role of safflower in improving agrophysical, agrochemical, and biological parameters of dark chestnut soils is proved.

Keywords: safflower / cultivation technology / productivity / oil content of seeds / soil criteria

Résumé – Initiation des semis de carthame dans le système d'agriculture biologique du Kazakhstan occidental. Nous avons mené les recherches en 2020–2021 dans l'ouest du Kazakhstan sur des sols de châtaignier foncé moyennement argileux. Le but de la recherche était d'identifier les changements dans les paramètres physico-chimiques, biologiques de la couverture du sol, la productivité et la qualité du carthame (*Carthamus tincforius* L.) sous l'influence de différentes techniques de travail agraire, pour une gestion rationnelle des agrocénoses biologiques. Les expériences sur le terrain ont montré que dans les conditions du Kazakhstan occidental, l'utilisation de la technique biologique de l'agriculture biologique augmente le rendement du carthame par rapport à la technologie traditionnelle de 26,66–35,38 %, avec une teneur élevée en huile de 30,0–39,95 %. Le rôle phyto-améliorateur du carthame dans l'amélioration des paramètres agrophysiques, agrochimiques et biologiques des sols de châtaignier foncé est prouvé.

Mots clés : carthame / technologie de culture / productivité / teneur en huile des graines / critères de sol

Highlights

On medium-loamy dark chestnut soils of Western Kazakhstan, the biologized cultivation technology in the system of organic agriculture increases the yield of safflower (*Carthamus tincforius* L.) in comparison with the traditional technology by 26.66–35.38%, with a high oil content of seeds of 30.0–30.95%. Safflower cultivation enables the improvement of agrophysical, agrochemical, and biological parameters of dark chestnut soils.

1 Introduction

The organic market is a rapidly expanding and fast-growing market, with global retail sales reaching nearly 97 billion euros in 2018. A total of 71.5 million hectares worldwide have undergone organic management. Organic

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farmland has more than doubled in the past decade. Globally, the acreage of organic plough land amounts to over 13.3 million hectares or 19% of organic farmland and 0.9% of plough land worldwide (Willer *et al.*, 2020).

In Kazakhstan, organic products account for 0.1% of all consumed products in the country. So, out of the 62 million hectares of farmland used in the country, 26 million hectares are unfavorable in terms of erosion, salinity. More than 15 million hectares of land removed from sowing become a reservoir of disease and pest pathogens. These problems can be largely solved with the effective use of bioorganic fertilizers (Nasiyev *et al.*, 2015, 2020a, 2021).

Biologization is becoming the main direction of increasing soil fertility and obtaining guaranteed high yields of crops. It is aimed at the predominant use of biological factors to improve the economic efficiency of agricultural production. According to economists, the gross turnover in organic, environmentally safe agriculture amounts to 85–90 billion dollars a year. Biological preparations steadily increase yields by 20–25% while significantly decreasing the level of plant disease affection (Aipova *et al.*, 2019). Organic practices in agriculture are currently used in 160 countries of the world. Organic agriculture laws work in 84 countries and, moreover, in dozens of countries such bills are drafted (Development organic rural/farms in Kazakhstan, 2018). On November 27, 2015, the Law of the Republic of Kazakhstan “On production of organic products” was adopted. The Act established the legal, economic, social, and organizational bases to produce organic agriculture. This legislation is aimed at the rational use of the soil, promotion of healthy diets, and protection of the environment (The Law..., 2015). Currently, Kazakhstan is in the process of adapting the international standards of Codex Alimentarius, as well as those of IFOAM (international organization in the field of organic agriculture) and is also using the international experience as an organic agricultural producer at the local level.

Among agricultural crops, the cultivation of oil crops is important. Organic oil seeds, the demand for which is constantly growing, are an important element of organic manufacture of products that are consumed as food (products, oils) by humans and are a feed (cake) for animals. Globally, oil crops occupy 11% of the organic plough land or 1.5 million hectares (Willer *et al.*, 2020).

One of the promising oil crops is safflower, the biology of which is fully consistent with the conditions of the arid climate. By its biological characteristics, safflower has more advantages in comparison with other oil crops cultivated in Kazakhstan. Safflower plants are exceptionally drought-resistant and perfectly tolerate the lack of water, as evidenced by their yield – up to 2.5 t/ha in the conditions of the Rostov region of Russia (zone of sufficient moistening or humidity). That differs the safflower from sunflower and especially rapeseed, which constantly need water (Razumnova *et al.*, 2018). In Kazakhstan, under traditional cultivation technologies, safflower yields are 0.3–0.6 t/ha depending on weather conditions of the growing season (Usmanov, 2011). In Kazakhstan, safflower is also promising in terms of application in the system of organic farming. Safflower (*Carthamus tinctorius* L.) belongs to the family *Asteraceae* (Louaer *et al.*, 2018). It is native to Egypt and India. It is rich in vitamin E (Asmarian *et al.*, 2017; Dubey and Singh, 2019). Safflower seeds are an important alternative to oil crops because of their high oil content (27–32%), which is classified as semi-dry, its eating qualities are equal to sunflower oil, and it is rich in essential linoleic acid (55–70%) (Günç *et al.*, 2020). The technology of processing safflower seeds into oil is similar to that of sunflower and the introduction of safflower into the crop contributes to fuller use of the capacity of oil-pressing factories.

There is an experience in the application of organic-biological fertilizers in the system of the biologized technologies of oil crops cultivation, including safflower sowings. In experiments conducted at College Farm, Rajendra Nagar, Hyderabad (India), organic-biological fertilizers ensured a high yield of safflower seeds. Nutrient uptake, gross income, and net income were recorded with soil test-based fertilizers and vermicompost (Kumar *et al.*, 2017).

In experiments carried out at the Sarayonu experimental area of Selcuk University (Dincer, Turkey), the application of organic fertilizers increased the oil content of safflower kernels (Özer and Bağcı, 2014). According to scientists, there is a promising strategy to mitigate the detrimental effects of salinity on safflower by applying antioxidants, enzymes such as glycine, betaine (GB) (Hussain *et al.*, 2016).

In Russia, as recommended by Tolmachev (2017), it is advisable to sow safflower earlier for cultivation in biological crop rotations, using biopreparations – growth regulators. In Ivanov and Tolmachev (2018) studies, the sowing of seeds treated with organic preparations Biodux (1 ml/t) in optimal early dates (temperature of 6–8 °C in the layer of 0–10 cm) resulted in safflower yield in the range of 0.6–1.0 t/ha, with an oil content of 27–30%. Treatment of safflower seeds before sowing with the biological preparation Flavobacterin contributed to a significant and stable increase in yield on the natural background of soil fertility – 0.14 t/ha or 13.6% (Razumnova *et al.*, 2019). Treatments with environmentally safe biopreparation Ribav-extra during the growing season led to a significant increase in productive stooling, which increases the yield of safflower to 4.66 c/ha (an increase of 0.77 c/ha) (Igolnikova *et all.,* 2018).

In Kazakhstan, the bio-organic preparation Avibif (1 l/ha) showed high efficiency in safflower sowings (Akhshanov, 2019). The research of Ivanchenko and Belikina (2021) under the conditions of the Federal Research Center for Agro-Ecology of the Russian Academy of Sciences revealed the effectiveness of safflower seeds treatment with a mixture of preparations – fungicide Vincit (1.5 l/t) + biostimulator Fertigrain Start (0.5 l/t). It was the most profitable variant (16.5%) with a yield of 1.2 t/ha. In fertilizer application at planting time, the chemical fertilizer 4 and 7 tons vermicompost showed a higher seed yield of safflower (*Carthamus tinctorius* L.) (Azimzadeh, 2017).

The main link of organic farming, the new direction in agriculture, is the use of agrarian landscapes of agricultural crops as phytoameliorants. Along with high drought resistance and productivity, the phytoameliorative role of safflower is of great importance. The works of many scientists have scientific evidence of the positive role of safflower in improving soil fertility when it is used as a green fertilizer (Flemmer *et al.*, 2015). Postnikov (2017) suggests growing safflower as a phytoameliorant on contaminated soils to clean them from heavy metals.

Based on the conducted studies, Marcos *et al.* (2018) note the safflower resistance to soil compaction and identify safflower as a species capable of decreasing soil density.

Soils contain natural reserves of plant nutrients, but these reserves are largely in unavailable forms to the plants, and only a minor portion is released each year through biological activity or chemical processes. This release is too slow to compensate for the removal of nutrients by agricultural production and to meet crop requirements. Therefore, fertilizers are designed to supplement the nutrients already present in the soil. The use of chemical fertilizer, organic fertilizer, or biofertilizer has its advantages and disadvantages in the context of nutrient supply, crop growth, and environmental quality. The advantages need to be integrated to make optimum use of each type of fertilizer and achieve balanced nutrient management for crop growth. Biofertilizers are the alternative sources to meet the nutrient requirement of crops. In Biofertilizers, beneficial bacteria are *Azotobacter, Azospirillium, Rhizobium, Mycorrhizae* which are very essential in crop production. Biofertilizer can also make a plant resistant to unfavorable environmental stresses (Sanjay, 2017, 2020). According to Malusà *et al.* (2016), biofertilizers can play a key role to develop an integrated nutrient management system, sustaining agricultural productivity with low environmental impact. However, there are no data on the study of the biologized technologies of safflower cultivation on the biological activity of dark chestnut soils.

The ideas of the experiment are fundamentally different from the existing analogues, as the studies conducted in different countries are focused on other quantitative characteristics of soil, climate, levels of plant productivity and profitability of agricultural production. In this regard, for the rational management of organic agrocenoses, the purpose of the research is to identify changes in physico-chemical, biological parameters of soil cover, productivity, and quality of safflower under the influence of different technologies of agrarian landscape shaping.

2 Materials and methods

2.1 Research design

We carried out the research in 2020–2021 on the fields of the "Daukara" farm in the conditions of Western Kazakhstan. According to the morphological characteristics of the pedogenic horizons of the profile and agrochemical parameters of the arable layer, the soils of the experimental plot are typical for Western Kazakhstan – they are dark chestnut medium-loamy (*Haplic Kastanozems*) soils.

The object of the research was the agrarian landscapes of safflower (*Carthamus tinctorius* L.) (Fig. 1).

Fig. 1. Safflower agrarian landscapes (orig.).

2.2 Stages of the research

According to the research program, 2 field experiments were laid out.

The scheme of the field experiment 1 is presented in Table 1.

In the research in the field experiment 1, 2 technologies of formation of agrarian landscapes were comparatively studied:

1. The traditional technology (control variant) without the use of biological preparations. In this technology, we applied nitrogen and phosphorus fertilizers in minimum doses of N_{20} P_{20} before sowing safflower. The following mineral fertilizers were used: ammonium nitrate NH_4NO_3 and double superphosphate $Ca(H_2PO_4)_2$;
2. The biologized technology using bioorganic preparations available for farmers on the market: biostimulator Biodux, biofungicide Orgamica S, and bioorganic fertilizers Organit N and Organit P. Biological preparations were applied in two doses: treatment of safflower seed material at a dose of 10 l/t and treatment of safflower plants at the stage of 3–4 true leaves by spraying the sowings. The application rate of the working solution is 300 l/ha.

The area of plots was 50 m^2, 3 replications, and the location of plots was random.

In both variants of the experiment, we applied the tillage system customary for Western Kazakhstan. The released safflower variety Akhram was used in the experiments. The seeding rate was 500 thousand viable seeds per hectare. Safflower was harvested using the solid method at the phase of the complete ripening of safflower, the yield was corrected to 10% moisture content and 100% purity. Harvesting was carried out using pin-drum harvesters at a reduced speed of 750–800 rpm.

In the field experiment 2, we studied the phytoameliorative effect of safflower. The area of plots is 50 m^2, 3 replications, location of plots is random. In this experiment, safflower was sown according to the accepted traditional technology, *i.e.*, without the use of bioorganic preparations. Safflower variety, seeding rate, sowing dates and harvesting techniques were identical to the field experiment 1.

2.3 Soil sampling

In the field experiment 2 on the study of phytoameliorative effect of safflower, indicators of dark chestnut soil were determined according to the methodology in two terms: in

Table 1. Scheme of the field experiment 1.

Variants	Traditional technology	Biologized technology*
The essence of the technology	Only mineral fertilizers are used: NH_4NO_3 (ammonium nitrate) and $Ca(H_2PO_4)_2$ (double superphosphate) at a dose of $N_{20}P_{20}$ before sowing	The biostimulator Biodux, the biofungicide Orgamica S, and bio-organic fertilizers Organit N and Organit P are used

The products are used for seed disinfection and spraying of safflower during the growing season at the stage of 3–4 true leaves.

spring before sowing and in autumn after harvesting safflower in soil layers of 0–10 cm and 10–20 cm in 3 replications (Gabdulov *et al.*, 2018).

Under laboratory conditions by analyzing soil samples using accepted modern methods, we determined the content of nitrate nitrogen and of mobile phosphorus.

2.3.1 The determination of nitrate nitrogen content in air-dry soils using calcium chloride as an extractant

Determinable soil nitrogen fractions were obtained by extraction of air-dry soil samples with calcium chloride ($SaSl_2$) solution of 0.01 mol/dm^3. Inorganic nitrogen compounds (nitrate (+nitrite) and ammonium) were determined directly in the soil extract, using automated spectrometric methods of segmented flow analysis. All operations of preparation of the extract for measurement, graduation of the spectrophotometer, and measurement of the concentration of the determined fractions were carried out in a closed flow through inside elastic silicone tubes. The flow of extract and reagent solutions was carried out with a pump forcing the solutions by rhythmic pressure of the silicone tubes. Mixing of the extractant with the reagents took place in the reaction coils with air bubbles. The colored solution entered the flow cell of the spectrophotometer, and the result of the light absorption was recorded with a chart recorder. The amount of nitrogen in the soil organic matter soluble in extracting solution with ($SaSl_2$)–0.01 mol/dm^3 was determined by the calculation method (Gabdulov *et al.*, 2018).

2.3.2 The photometric method for the determination of mobile phosphorus (the method of I. Machigin)

The method is based on the extraction of mobile phosphorus and potassium compounds from the soil with a solution of ammonium carbonate at a concentration of 10 g/dm^3 at a soil: solution ratio of 1:20 and subsequent determination of phosphorus in the form of a blue phosphorus-molybdenum complex on a photoelectric colorimeter and determination of potassium on a flame photometer (Gabdulov *et al.*, 2018).

2.3.3 The determination of the soil density in field conditions using N.A. Kachinsky drills

In the field, samples were taken from the soil horizon with a drill cylinder with a volume of about 500 cm^3. Simultaneously, to determine the moisture content, soil samples were collected in weighing bottles. In the laboratory conditions, the soil was dried at 105 °C to constant weight. Knowing the weight of the weighing bottle with dried soil and the weight of the empty bottle, we found the weight of air-dry soil. Then, by dividing the mass of dry soil by its volume (the volume of the ring), the density of the soil was established (Gabdulov *et al.*, 2018).

2.3.4 Dry soil sieving method

The assessment of the structural state of the soil was carried out by aggregate analyses using the dry sieving method. Based on the results of the aggregate analysis, the structural coefficient (Cstr) was calculated, which is understood as the ratio of the number of aggregates from 0.25 to 10.00 mm (in %) to the total content of aggregates less than 0.25 and more than 10.00 mm (in %). The bigger the Cstr, the better the soil structure. To assess the structural state of soils, we used a scale developed by Dolgov and Bakhtin (Gabdulov *et al.*, 2018).

2.3.5 The method of flax linen decomposition (application method)

The intensity of fiber decomposition was evaluated by the weight loss of the flax linen. We used D.G. Zvyagintsev's scale to evaluate the biological activity of soils in terms of fiber decomposition in the autumn period (% of decomposed linen for 2 months): very weak < 10, weak 10–30, medium 30–50, strong 50–80, very strong > 80. (Zvyagintsev, 2016).

2.4 Analysis of plant samples

We determined the oil content of safflower by establishing the fat content of seeds by the extraction method. Fat content in the seeds was calculated to determine the oil content of safflower. The oil content of seeds means their crude fat content and accompanying fat-like substances transferred together with fat into the ether extract from the examined seeds. The oil content in safflower seeds was determined by the extraction method by extracting crude fat from seeds with an appropriate solvent in a Soxhlet apparatus. To determine crude fat content in safflower seeds, about 40 g of seeds were isolated, weighed to the nearest 0.01 g, and sieved through two sieves with hole diameters of 3 and 0.5 mm in the upper and lower sieves, respectively. The seeds, freed from the above-mentioned impurities, were transferred into a porcelain cup and dried at 100–105 °C for 1 h. Subsequently, extraction was carried out. The duration of sunflower seed extraction was 22–24 h. The end of extraction was determined by the absence of fat in the extraction-completed sample. At the end of

Table 2. Average monthly air temperature and precipitation during the growing season of safflower in 2020–2021.

Years	Months May	June	July	August
Average monthly temperature, °C				
2020	16.4	20.7	26.2	19.9
2021	21.5	24.5	25.3	26.1
Long-time average annual data for 10 years	15.6	20.4	22.4	20.6
Precipitation, mm				
2020	7.6	56.1	5.8	17.1
2021	19.3	68.8	15.6	1.0
Long-time annual average data for 10 years	27.0	31.0	41.0	25.0

extraction, the ether was stripped and the oil was dried in a desiccator at 100–105 °C until weight constancy (Gabdulov *et al.*, 2018).

2.5 Statistical analyses

The data obtained were subjected to a single-factor analysis of variance using a computer program. In the experiment 2, the mean results of agrophysical and agrochemical indicators of dark chestnut soil in the layer of 0–20 cm were subjected to a single-factor analysis of variance. We conducted statistical processing of soil biological activity data by a single-factor analysis of variance of mean data of initial and final linen weights for 2 months of exposure.

2.6 Weather conditions

During the years of research, the weather conditions of the growing season, along with the cultivation technology, had a great influence on the growth and development, and ultimately, on the yield and quality of safflower. 2020 and 2021 were dry years for safflower growth and development, especially July and August. Of these two years, 2020 was drier: during the period of active growth and yield development, especially during the July average monthly temperature of 26.2 °C, precipitation was extremely insufficient – 5.8 mm or 35.2 mm less of the annual average level (Tab. 2).

2021 was the most favorable at the beginning of crop development due to sufficient precipitation (19.3 mm) and high air temperature (21.5 °C). However, weather conditions of 2021 were not quite favorable for safflower growth and development due to high temperatures in June (24.5 °C) and July (25.3 °C). In 2021, the atmospheric precipitation in June (68.8 mm) and July (15.6 mm) contributed to the shaping of more productive agrarian landscapes of safflower in the research area compared to 2020. Safflower, as a drought-resistant crop, was able to overcome the effects of drought during the ripening phase in August and maintained the yield parameters developed in the earlier months (June, July).

3 Results and discussion

The characteristics of safflower growth and development depending on the cultivation technology. Despite the weather conditions in the years of research, biological preparations and bioorganic fertilizers had a positive effect on safflower growth and development. Due to the positive conditions of precipitation and temperature, they increased the field germination of safflower. In the years of research, the field germination of safflower in the variant of the biologized technology varied from 92.8–93.0% at the density of 46.40–46.50 plants per m^2, while in the control, *i.e.*, safflower cultivation by traditional technology, it was lower by 1.00–1.30% at the density of 45.75–46.00 plants per m^2.

The data on the plant density before harvesting showed better preservation of safflower during the growing season when bioorganic preparations and fertilizers were used. In the case of the control, 38.0–38.55 plants per m^2 were standing by the time of harvesting (preservation of 83.04–84.04%), in the case when biological preparation Biodux, biofungicide Orgamica S and biofertilizers Organit N, Organit P were used for safflower cultivation (biologized technology), the parameter was 40.78–40.85 plants per m^2 (preservation of 87.70–88.04%).

The results of phenological observations. In the years of research, the duration of the interstage periods of the safflower vegetation depended on both weather conditions and the cultivation technology. Under the conditions of 2020, the duration of the growing season in the control was 107 days; when we used the biologized technology, the processes of plant development were faster, and the total duration of the growing season was 104 days, *i.e.*, 3 days shorter compared with the traditional technology.

Weather conditions in 2021 contributed to the rapid development of safflower plants. The lasting high temperature during the ripening phase in July–August had an impact on the growing season of safflower decreasing it by 6–7 days compared with 2020. At the same time, in the variant of the biologized technology, the duration of growth and development was 98 days, which is shorter by 2 days compared with the control (100 days).

On average, for the years of research (2020–2021), the duration of the growing season of safflower was 104 days when using the traditional technology. When using biologized technology, *i.e.*, seed treatment and treatment of plants at the stage of 3–4 true leaves with Biodux biopreparation, biofungicide Orgamica S, and bioorganic fertilizers Organit N, Organit P, the growth and development of safflower from seedling to harvesting took 101 days.

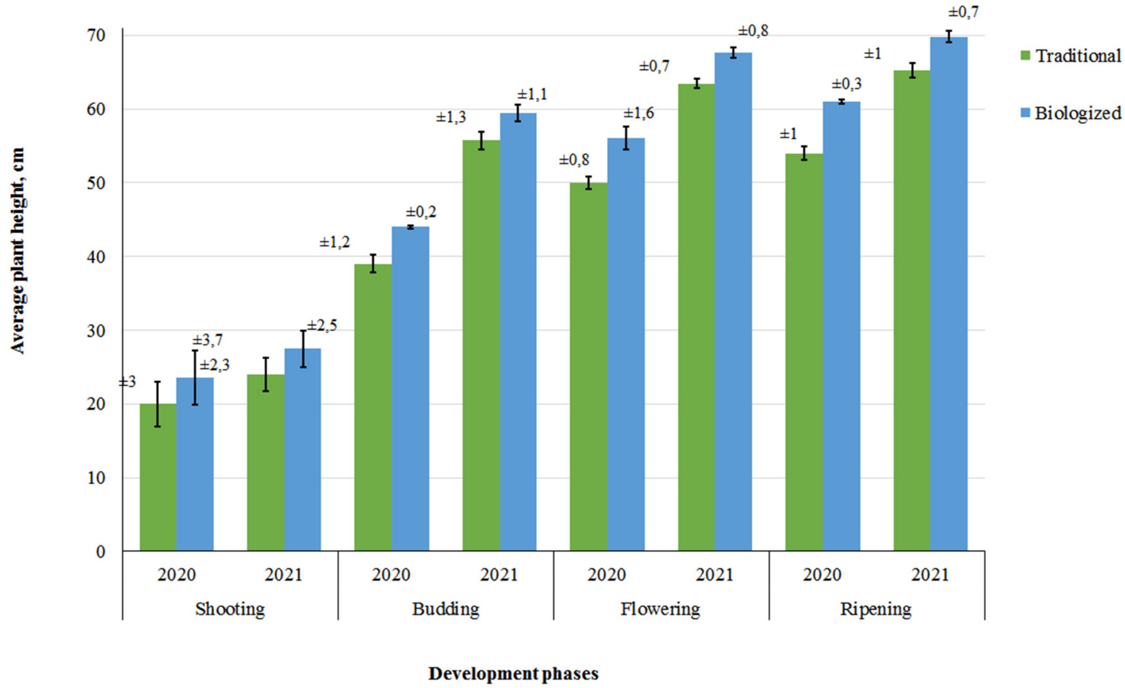

Fig. 2. Growth dynamics of safflower depending on cultivation technology in 2020–2021 (in cm).

In general, compared to traditional technology, the use of biologized technology contributed to shortening the duration of the growing season of safflower by 3 days. The shortening of the growing season of safflower using the biologized technology by 2–3 days compared with the traditional technology is important in terms of management of the harvesting. Moreover, the decrease in the duration of the growing season and uniformity of safflower maturing is important for timely and quality harvesting work.

Growth dynamics of safflower plants. One of the parameters characterizing the state of agrocenosis is the height of plants. Observations of the dynamics of safflower linear growth showed that the plant height depended on weather conditions of the growing season and the cultivation technology. The analysis showed that at the beginning of vegetation safflower has a low growth rate. At the same time, we noted the most intensive growth of plants in height in the period from shooting to the beginning of flowering. Then the growth rate decreased and by the beginning of maturing, the plants in the studied variants had the highest height.

Beginning from the shooting phase of safflower, we noted the difference in plant growth between the variants of the experiment. Thus, the height of plants at the shooting phase of safflower in the control variant was 20.0 cm in 2020 and 23.50 cm in 2021, and in the variant with the biologized technology – 24.00 and 27.45 cm, respectively, with the difference between the variants of 3.95–4.00 cm.

Under the conditions of 2020, the height of safflower plants at the budding phase by the variants of the experiment ranged from 39 to 44 cm, by the flowering phase – from 50.0 to 56.0 cm. In 2021, depending on the cultivation technology, the height of crop plants at the budding phase varied from 55.70 to 59.42 cm, and at the flowering phase – from 63.45 to 67.65 cm. At the same time, in 2020–2021, the combined use of biopreparation Biodux, biofungicide Orgamica S, and bioorganic fertilizers Organit N, Organit P ensured the maximum growth of safflower plants compared with the control.

By the ripening phase, safflower plants in the variant of the biologized technology reached 61.0 cm in 2020 and 69.8 cm in 2021, which is 7.0 and 4.6 higher than in the control variant. According to the results of the analysis, there was an excess of values of the average height of safflower plants in the variant of biologized technology in comparison with the control, *i.e.*, traditional technology. The average height of the plants was significantly higher when using the biologized technology. At the budding phase of safflower, there were differences between the variants of the experiment in terms of the average height of plants: in 2020 – by 5 cm, in 2021, the difference was 3.72 cm. The most significant differences were observed in the vegetation phases of safflower: at flowering, in 2020, the plants were higher by 6 cm, in 2021 – by 4.2 cm, at ripening, in 2021, the plants were higher by 7 cm, in 2021 – by 4.6 cm.

In Figure 2, the bar graph columns are supplemented with error bars calculated as the ± standard deviation of the sample. The value of the standard deviation placed next to the error bar shows how far the values in the presented sample may differ from the average value in the given sample. The analysis shows a higher dispersion of values of the average value at the shooting phase of plant development in 2020 and 2021. At the following phases of plant development, the standard deviation of the average values is lower: at the budding phase with the traditional technology in 2020 and 2021, it ranges from 1.2 to 1.3 cm, respectively, and with the biologized technology in 2020 and 2021 – from 0.2 to 1.1 cm, respectively; at the flowering phase with the traditional technology in 2020 and 2021, the height during the flowering phase ranged from 0.8 to 0.7 cm, respectively, and from 1.6 to 0.8 cm with the biologized technology in 2020 and 2021, respectively; during

Table 3. Structure of safflower productivity elements depending on the cultivation technology in Western Kazakhstan in 2020–2021.

Parameter	Number of productive heads, pcs/plant		Head diameter, cm		Number of seeds, pcs/plant		Thousand-seed weight, g	
Year/Technology	2020	2021	2020	2021	2020	2021	2020	2021
Traditional (control)	15.0	16.0	2.18	2.22	24.40	24.90	42.70	42.30
Biologized	17.0	19.0	2.41	2.49	25.50	26.35	43.15	42.85
LSD_{05}*	1.7	1.9	0.12	0.15	0.56	0.65	0.23	0.33

* LSD_{05} is the least significant difference for 5% significance level.

the ripening phase in 2020 and 2021, it was 1.0 cm with the traditional technology, and from 0.3 to 0.7 cm with the biologized technology in 2020 and 2021, respectively. The lower value of the standard deviation indicates that the value of plant height is clustered around the average value.

In comparison with traditional technology, the use of biologized technology gave a significant increase in plant height. The most favorable agrarian landscape of safflower with tall plants was formed with the use of biologized technology, *i.e.*, seed treatment and treatment of plants at the stage of 3–4 true leaves of safflower with Biodux biopreparation, biofungicide Orgamica S, and bioorganic fertilizers Organit N, Organit P. Differences in plant height are observed for each phase of development, but in our opinion, the most significant differences in plant growth are observed for Budding, Flowering, Ripening phases. The figure shows that the error bars of these three phases do not overlap. The standard deviations from the average values are much lower (almost by 2–3 times).

Influence of cultivation technology on the development of productivity elements and oil content of safflower. Agricultural crops have noticeable characteristics in the development of elements of sowings productivity when they are grown in different soil and climatic conditions. However, as a rule, the elements of technology in these conditions significantly affect the productivity of any crop. Improperly chosen technology parameters can lead to the development of low productivity of safflower sowings, which, consequently, will affect the yield of oilseeds (Roche *et al.*, 2019; Salvatore *et al.*, 2019; Iztaev *et al.*, 2020). The conducted research revealed that the best parameters of the elements of yield structure and safflower productivity are established in the application of the biologized cultivation technology.

The combined use of the biopreparation Biodux, biofungicide Orgamica S and bioorganic fertilizers Organit N, Organit P (seed treatment, treatment during the growing season) ensured the highest number of productive heads in safflower plants compared to the control variant – up to 17.0 pieces per plant in 2020 and up to 19.0 pieces per plant in 2021. With an average head diameter of 2.41–2.49 cm, the number of seeds per head was higher by 1.10–1.45 pieces in the biologized technology variant compared with the control. Application of biological preparations also contributed to increasing the thousand-seed weight from 43.15 g in 2020 to 42.85 g in 2021 (Tab. 3).

It should be noted that under the conditions of 2020 and 2021 the parameters of the elements of productivity structure of the control variant were lower compared with the biologized technology variant. At the same time, the best parameters developed in the conditions of 2021, except for thousand-seed weight. Under the conditions of 2021, as a result of high air temperature during the ripening phase (July, August), we observed a decrease in safflower thousand-seed weight by 0.45–0.55 g compared with 2020.

The data in Table 3 show the positive effect of seed treatment and treatment of plants at the stage of 3–4 true leaves with Biodux biopreparation, biofungicide Orgamica S, and bioorganic fertilizers Organit N, Organit P on elements of safflower yield structure. On average for 2020–2021, in comparison with traditional technology, the use of biologized technology on safflower sowings resulted in the formation of a greater number of productive heads, by 16.13%, or by 2.5 pieces per 1 plant. The use of biologized technology increased the diameter of heads of safflower plants by 0.25 cm, or 11.36%, compared to the variant of traditional technology. In comparison with biologized technology, the traditional technology decreased the number of seeds per 1 plant of safflower by 1.28 pieces, or 5.19 %.

The research results also showed the effectiveness of the biologized technology by the indicator of the thousand-seed weight of safflower. This indicator has the most advantageous position with the use of biologized technology during cultivation. The average thousand-seed weight of safflower seeds for 2 years after seed treatment and treatment of plants at the stage of 3–4 true leaves with Biodux biopreparation, biofungicide Orgamica S, and bioorganic fertilizers Organit N, Organit P was 43.0 g, which is more by 0.5 g, or 1.18%, compared to the traditional technology. Statistical analysis confirms dependence of indicators of structure elements of safflower yield on the technology of crop cultivation.

The oil content (fat content) of safflower seeds, as research showed, varies under the influence of environmental conditions during the growing season and elements of the cultivation technology, which confirms the findings of other scientists (Norov, 2014; Arslan and Bayraktar, 2016; Ummahan, 2017; Sayilir *et al.*, 2019; Kumari *et al.*, 2021; Joshi *et al.*, 2021). Under the traditional technology, the fat content of seeds decreased both in 2020 (28.80%) and in 2021 (29.50%). The comparative studies revealed an increase in the oil content of safflower seeds under the biologized technology up to 30.00% in 2020 and up to 31.00% in 2021. The increase in the oil content of safflower seeds in both variants in 2021 can be explained by high temperature conditions during the ripening phase in July and August. The influence of semi-arid

Table 4. Parameters of productivity and quality of safflower depending on the cultivation technology in the system of organic farming in Western Kazakhstan in 2020–2021.

Parameter	Productivity, t/ha		Oil yield, t/ha		Fat content, %	
Year/Technology	2020	2021	2020	2021	2020	2021
Traditional (control)	0.60	0.65	0.17	0.19	28.8	29.5
Biologized	0.76	0.88	0.23	0.27	30.0	31.0
LSD_{05}*	0.12	0.16	0.03	0.05	0.45	0.66

* LSD_{05} is the least significant difference for 5% significance level.

conditions characterized by low precipitation and high temperatures on oil content is also confirmed by scientists studying different safflower varieties in a semi-arid area in Tiaret (West of Algeria) (Zemour *et al.*, 2021).

In 2020, the highest oil yield of 0.23 t/ha was obtained with the combined use of the biopreparation Biodux, biofungicide Orgamica S, and bioorganic fertilizers Organit N, Organit P. Under the traditional technology, along with the biological productivity, we observed oil yield decrease by 0.06 t/ha or 35.29%. In 2021, in the variant with the traditional technology oil yield was 0.19 t/ha, and the use of the biologized technology increased oil yield to 0.27 t/ha or 0.08 t/ha (42.10%) The results of statistical analysis showed a high probability of dependence of productivity, oil yield, and oil content on the cultivation technology (Tab. 4).

The research showed the highest yield of oilseeds of 0.76 t/ha (2020) and 0.88 t/ha (2021) when the biopreparation Biodux, biofungicide Orgamica S, and bioorganic fertilizers Organit N, Organit P were used together; under the traditional technology, the biological yield of safflower was decreased to 0.16 t/ha or 26.66% in 2020 and to 0.23 t/ha or 35.38% in 2021. On average, during the years of research, the application of the biologized technology provided a yield of 0.82 t/ha of oil seeds, which is advantageous for farmers in the arid climate of Western Kazakhstan.

On average over the research years (2020–2021) in the organic farming system of Western Kazakhstan the highest productivity of safflower is established when using biologized technology. Thus, with seed treatment and treatment of plants at the stage of 3–4 true leaves with Biodux biopreparation, biofungicide Orgamica S, and bioorganic fertilizers Organit N, Organit P, safflower yield was 0.82 t/ha, which is higher by 0.19 t/ha, or 30.16%, compared to traditional technology.

The use of biologized technology was also effective in terms of safflower oil yield. In 2020–2021, this variant of cultivation technology yielded 0.25 t/ha of oil, which in comparison with traditional technology is higher by 0.07 t/ha, or 38.89%. Along with yield, biologized technology also contributed to an increase in the fat content of safflower seeds. If at traditional technology the fat content of safflower seeds was 29.15%, the use of biologized technology increased the fat content of seeds to 30.15%.

The results of statistical analysis showed reliable differences between the studied variants of safflower cultivation technologies in yield, oil yield, and oil content of seeds at a 95% significance level.

Seed huskness is a quality parameter that must be reduced (Norov, 2014). The lowest seed huskness parameter was observed with the use of the biologized technology – 32.3% (2020) and 33.0% (2021). During the research, the huskness increased up to 33.6% (2020) and 34.1% (2021) with traditional cultivation technology. On average for the years of research (2020–2021), the higher huskness of safflower seeds (33.85%) was established in the variant of traditional technology. When using biologized technology, the huskness of safflower seeds was 32.65%, which is less by 1.20%, in comparison with traditional technology.

The study of phytoameliorative role of safflower in the conditions of dark chestnut soils of Western Kazakhstan. The modern agriculture of Kazakhstan is currently in a situation where it is necessary to solve the problems of soil fertility restoration, associated with a severe reduction in the fields occupied by forage grasses, green manure crops, decrease in the use of organic fertilizers, non-observance of crop rotation systems (Nasiyev and Yeleshev, 2014; Nasiyev *et al.*, 2020a). Therefore, to maintain or restore agricultural soils in terms of fertility factors, it is necessary to develop agronomic practices using new and traditional green manure crops. Green manure management has been studied by many scientists, and the main studies were conducted with cruciferous and leguminous crops. As a rule, the authors note a generally positive trend in increasing the content of nitrogen, mobile phosphorous, and potassium in the arable layer (Nasiyev, 2013; Flemmer *et al.*, 2015; Osipova, 2016; Sanjay, 2020; Nurmukhametov, 2020).

During the research, we sow safflower on April 27, 2020, and May 4, 2021, to evaluate its phytoameliorative role in the conditions of Western Kazakhstan. By the flowering phase, the height of safflower plants in 2020 was 45 cm, and 64 cm in 2021. Mass flowering of safflower began on July 16 in 2020, and on July 13 in 2021. In 2020, safflower plants at the flowering phase developed a green mass of 117.7 c/ha, in 2021 – 135.60 c/ha. Safflower green manure was incorporated into the soil at the flowering phase using disc harrows at a depth of 18–20 cm (Fig. 3).

As the data of agrochemical analysis showed, on average for 2020–2021, by the time of plowing, the safflower green mass contained 1.76% of nitrogen and 3.30% of phosphorus in dry matter. Most soils naturally contain insufficient amounts of nitrogen, phosphorous, and potassium available to plants, as well as other nutrients. In addition, each year, a significant amount of these elements is disposed of from the soil with the harvest. In addition, most of them are still lost by removal; evaporation of becoming fixed in the soil, turning into forms inaccessible to plants. The reserves of these elements can only be replenished artificially by applying fertilizers, including green manure (Nasiyev *et al.*, 2020b).

To evaluate the phytoameliorative effect of safflower on dark chestnut soil, we took soil samples and analyzed them by

Fig. 3. Incorporation of safflower green mass into the soil (orig.).

Table 5. Phytomeliorative effect of safflower on the content of nitrate nitrogen and mobile phosphorus of dark chestnut soils, average for 2020–2021.

Soil layer, cm	Nitrate nitrogen, mg/100 g of soil (LSD_{05}* = 0.18)			Mobile phosphorus, mg/100 g of soil (LSD_{05}* = 0.04)		
	Spring	Autumn	Difference	Spring	Autumn	Difference
0–10	4.89	5.10	+ 0.21	1.20	1.26	+ 0.06
10–20	5.23	5.59	+ 0.36	1.12	1.17	+ 0.05
0–20	5.06	5.35	+ 0.29	1.16	1.22	+ 0.06

* LSD_{05} is the least significant difference for 5% significance level (according to the average indicators of the layer 0–20 cm).

autumn. As the data of agrochemical analysis showed, safflower contributed to an increase in the content of mineral nutrients in the soil. Thus, by autumn, we observed an increase in the content of nitrate nitrogen and mobile phosphorus on the plot plowed with safflower compared with the springtime before sowing. On average for 2020–2021, by autumn there was an increase in nitrate nitrogen content from 5.06 to 5.35 mg/100 g of soil or by 5.95% in the soil layer of 0–20 cm under the influence of phytoameliorative effect of safflower. There is a similar tendency in the content of mobile phosphorus. During spring-autumn, in the soil layer of 0–20 cm, the content of mobile phosphorus increased from 1.16 to 1.22 mg/100 g or by 5.17% (Tab. 5).

Soil density, its water-air properties, temperature, and nutrient regimes, microrelief, vegetation cover dynamics, quality of soil micro- and macro population of soil change under the influence of cultivated crops in arable land. Planting of phytoameliorants has a positive effect on agrophysical parameters of soils. The findings of other authors (Flemmer *et al.*, 2015; Osipova, 2016; Marcos *et al.* 2018) are confirmed in the research. While the average density in the spring was 1.30 g/cm^3 in the root-inhabited soil layer of 0–20 cm, by autumn there was a downward tendency for layers of 0–10 and 10–20 cm. During the vegetation period, there was soil loosening by 0.010 g/cm^3 in the layer of 0–20 cm.

The analysis of dynamics of structural-aggregate composition of dark chestnut soils reveals some improvement of soil structure under the influence of phytoameliorative effect of safflower and expressed tendency to restoration that we noted during the observation period. Thus, in the autumn period after safflower, the average content of agronomically valuable aggregates in the layer of 0–20 cm was 64.45% (increasing by 0.77%) with the structure coefficient of 1.73. According to the accepted standards, the soil has good structure and texture (Tab. 6).

The influence of safflower on the biological activity of dark chestnut soils is important in evaluating the phytoameliorative role.

Studies on determining the microbiological activity of dark chestnut soil showed that in the variant with the safflower use, there was a high rate of decomposition of flax linen, and 2 months after it was laid, the total weight of the linen on average for 2 years was lower by 53.72 % compared with the control, which corresponds to the biological evaluation of soil activity as “strong” (Tab. 7).

Thus, in the field crop rotations of organic farming in Western Kazakhstan, it is advisable to introduce safflower, as a green manure crop, which has a positive effect on the agrophysical, agrochemical, and biological parameters of dark chestnut soils after plowing.

Table 6. Phytomeliorative effect of safflower on the agrophysical parameters of dark chestnut soils, average for 2020–2021.

Soil layer, cm	Density, g/cm^3 (LSD_{05}* =0.01)			Content of agronomically valuable aggregates of soil, % (LSD_{05}* = 0.76)		
	Spring	Autumn	Difference	Spring	Autumn	Difference
0–10	1.30	1.29	- 0.010	62.13	62.95	+ 0.82
10–20	1.29	1.28	- 0.010	65.22	65.95	+ 0.73
0–20	1.30	1.29	- 0.010	63.68	64.45	+ 0.77

* LSD_{05} is the least significant difference for 5% significance level (according to the average indicators of the layer 0–20 cm).

Table 7. The effect of safflower green manuring on the biological activity of dark chestnut soils, average for 2020–2021.

Replications (clean linen)	Linen weight, g (2 months exposure)		Difference from control, due to microbiological decomposition, g	In % to control	Biological activity of soil compared with control (D.G. Zvyagintsev scale)
	Initial	Final			
Control (clean linen)	5.35	5.35	–	100	–
1	5.25	2.35	2.90	55.24	Strong
2	5.35	2.57	2.78	51.96	Strong
3	5.25	2.48	2.77	52.76	Strong
4	5.05	2.28	2.77	54.85	Strong
Average	5.23	2.42	2.81	53.72	Strong
LSD_{05}*	–	0.98	–	–	–

* LSD_{05} is the least significant difference for 5% significance level (according to the average indicators).

4 Conclusion

The biologized technologies of safflower cultivation in agrarian landscapes of organic agriculture with the use of bioorganic preparations and fertilizers lead to increased biometric parameters, productivity, and oil content. At the same time, studies have shown a significant phytoameliorative role of safflower in the system of organic agriculture, which is confirmed by the data of standard methods for evaluation of the physico-chemical and biological parameters of dark chestnut soils under safflower agrarian landscapes in Western Kazakhstan.

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