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ECONOMIC AND BIOENERGETIC EFFICIENCY OF SAFFLOWER *(Carthamus tinctorius L.)* CULTIVATION WITH DIFFERENT SOIL PREPARATION TECHNOLOGIES

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Abstract

Scientific research for increasing the productivity of new oilseed crops through the development of conservation technology of cultivation was carried out in 2015-2017 on the experimental site of LLP "Fermer 2002" in the Astrakhan district of the Akmola region, which is located in the dry steppe zone of Northern Kazakhstan with a sharp continental climate.The objects of the research were varieties of safflower *(Carthamus tinctorius L.)* of Kazakhstani breeding - Center 70, Akmai and Irkas cultivated according to the zonal (1 planed tillage of soil in 8-10 cm +2 planing tillage in 10-12 cm and loosening in 25-27 cm), Minimal I (application of herbicide + 1 planing the soil for 10-12 cm and direct sowing), Minimal II (3 planing tillage in 10-12 cm and direct sowing) and zero (herbicide application + direct sowing) soil preparation technologies. Based on the results of the research, the positive influence of Minimal 1 soil preparation technologies on the increase in the productivity of safflower varieties was revealed. Among the safflower varieties studied, the variety – Center 70 was characterized by high yield, in which this index was higher than in other varieties by 0,7-2,7 centner/ha. The safflower - Center 70 proved to be economically profitable for the years of the study on a variant with Minimal I soil preparation technology, where the profitability of the Center was 70 – 134,8%, which is higher than the profitability of other options by 3,6 – 45,6%, respectively. The bioenergetic efficiency of cultivation of safflower varieties was also higher on the Minimal I.

Keywords: oilseed crops, safflower, yield, variety, economic efficiency, bioenergetic efficiency

Introduction

In recent years vegetable oils and products based on them have become basic in the structure of the population's nutrition. They represent the most important raw material component for many types of food industry products. At present, the Government of the Republic of Kazakhstan is taking measures to expand the oilseed crops with the aim of producing sufficient raw materials for the production of vegetable oil in an amount that satisfies consumption, in the first place, of the domestic

market [1]. In order to solve these problems, the government implemented the "Agro-industrial complex development program in the Republic of Kazakhstan for 2010-2014", whose tasks included increasing the total sown area and production of oilseeds [2], and starting from 2013 the program for the development of agro-industrial complex of the Republic of Kazakhstan until 2020 (Agrobusiness 2020), which indicates that the yield of major crops, including oilseeds, is at a low level in comparison with the world yield indicators and it is said that the main constraining factors for the development of the processing sector are low quality and scarcity of raw materials [3].

In our republic, sunflower is the main oilseed crop, however, during the last decade, climate changes that tend to increase in temperature, a drier and hot summer, require an expansion of the range of oilseeds. In this regard, there is a need to select and expand the range of cultivation of more drought-resistant and thermophilic oilseeds, such as safflower, flax and mustard [4].

Diversification of crop production in a market economy implies flexibility in determining not only the contingent of cultivated crops, but also their areas in certain regions and zones. At the same time, the biological characteristics of crops, their adaptation to local conditions must be taken into account [5].

Safflower was cultivated in the beginning as a dye plant and only afterwards it was used as an oilseed plant. With the development of the industry of aniline dyes, most dyeing crops, including safflower, as raw materials for the production of colorants, have lost their economic importance. Safflower, however, retains its importance as an oil plant [6].

Whole plants, flowers, seeds, and oil are widely used for medical purposes in different countries. According to E.A. Weiss [7] in China, safflower is mainly grown for its flowers, which is used as an invigorating tea, while in Afghanistan and India tea made from safflower leaves are used to prevent infertility and miscarriage of women. In Iran, safflower oil is used in the treatment of liver and heart diseases. In Pakistan, seed decoctions are used with sugar as a laxative to wash out the urinary tract, in Bangladesh, the seeds are ground and mixed with mustard oil to reduce rheumatic pain [8,9], and in India safflower oil is used to treat ulcers and rheumatism [10].

Safflower has a laxative and choleretic action, inclusion in the diet of the safflower oil after 8 weeks will reduce the cholesterol in the blood by 9-15%. According to research of Kazakh Academy of Nutrition, safflower oil contains 76-82% polyunsaturated fatty acid, called vitamin F, which is not synthesized in the body, but comes only with food [11]. According to scientists Ahmadzadeh et al in the seeds contained 22,03-36,73% oil and 15.64-21.50% protein, from unsaturated fatty acids linoleic acid (C18: 2) was the most common, followed by oleic acid (C18:1) and linolenic acid (18:3) [12].

In our country safflower is grown on south, southeast, recently

began to be cultivated on east, west, north. Especially in recent years, safflower crops have been expanding in the northern regions. However, for this zone there is no scientifically proved and developed technology of cultivation of culture.

In this regard, for the first time we carried out complex studies on the development of safflower cultivation technology for oilseeds in the dry-steppe zone of Northern Kazakhstan.Field experiments were conducted on dark chestnut soil of LLP "Fermer 2002" located in the Astrakhan district of Akmola region.

The goal was to study some agro-practices of safflower cultivation for oilseeds to ensure high yields and good quality seed. The tasks were to define economic and bioenergetic efficiency of cultivation with different soil preparation technologies.

Materials and methods of research

In order to achieve these goals in 2015-2017 we conducted the field experiments at the experimental site LLP "Fermer 2002", located on dark chestnut soils of the Astrakhan district of Akmola region according to the generally accepted methodology.

Objects of research were safflower varieties of Kazakhstan's breeding - Akmai, Irkas and Center-70. Comparative testing of these varieties was carried out on 4 backgrounds with different soil preparation technology: zonal - control variant (1 planed tillage of soil in 8-10 cm + 2 flat-planing tillages in 10-12 cm and loosening in 25-27 cm), Minimal I (applying of herbicides + 1 flat-planing tillage to 10- 12 cm and direct seeding); Minimal II (3 flat-planing in 10-12 cm and direct seeding)and zero (herbicides application + direct sowing) (Table 1).

Table 1 – Experimental Design

Soil preparation technology	Varieties	Replicates			
		I	II	III	IV
Zonal - control	Center 70	1	13	25	37
	Akmai	2	14	26	38
	Irkas	3	15	27	39
Minimal I	Center 70	4	16	28	40
	Akmai	5	17	29	41
	Irkas	6	18	30	42
Minimal II	Center 70	7	19	31	43
	Akmai	8	20	32	44
	Irkas	9	21	33	45
Zero	Center 70	10	22	34	46
	Akmai	11	23	35	47
	Irkas	12	24	36	48

Sowing time of safflower. Sowing norm of safflower seeds– 0, 25 million viable seeds per hectare. Seed unit with seeder SZS-2,1, method of sowing for safflower wide-row. The placement of variants in the experiments is sequential in 4 replicates.

In the conditions of a market economy in agriculture, along with environmental aspects, great importance is given to the economic efficiency and profitability of conducting one or another agro-industry cultivation of agricultural crops.

The economic efficiency of new technologies is determined by their impact on the improvement of the results of agricultural production, mainly on the increase in profit through the increase of crop yields, improving the quality of products, reducing costs and reducing the cost of production. Economic evaluation of the result allows identifying and implementing effective technologies.

The economic efficiency of agricultural practices in the cultivation of safflower was determined from the technological map, compiled based on onregulatory data for the economy. In calculating the economic efficiency, the following derivatives were taken into account: the sum of all direct costs per 1 ha of sowing and the estimated cost of 1 centner of seeds; conditional net income according to the difference between the income and expenditure side; profitability of grain production, which was determined by dividing the conditionally net income by the amount of direct costs, multiplied by a coefficient 100.

$$P = \frac{I_n}{C_t} \times 100,$$

Where,

P – profitability, %

I_n – net income, tenge

C_t–total costs, tenge

$$P_g = \frac{C_t}{Y},$$

Where,

Pg - cost price of grain, tenge

Ct - Total costs, tenge

Y - grain yield, centner/hectare

The yield of safflower is determined by the method of state variety testing of agricultural crops (2002), with its reduction to standard moisture, according to the following formula:

$$X = \frac{\quad}{\quad},$$

Where

X – the final yield with reduction to standard humidity, q/ha;

Y - yield during harvest, q / ha;

B - yield humidity,%;

C_B– the standard humidity for a given crop,%.

Meteorological conditions will be taken into account according to the meteorological station of the Zhaltyr settlement of the Astrakhan region of the Akmola region [13].

To judge the advisability of introducing technology into the production as a whole from the energy standpoint, it is necessary to establish a quantitative assessment of their energy efficiency. For this reason, energy efficiency coefficients were used that prove how many times the energy contained in the crop is more then energy invested in the basic working capital goods and in living labor. We estimated the bioenergetic evaluation of safflower cultivation on the basis of a methodological recommendation compiled by the scientists of the All-Union Scientific Research Institute of Animal Health (now the Scientific Research Center of A.I. Barayev Institute) I.A. Vasko, G.M. Lisenovich, T.A. Rau, M.E.Yantsen [14].

According to the technological map, compiled without the use of fertilizers and with the introduction of mineral fertilizers , which indicates all types of agricultural work carried out by us in the experiments, we found the aggregate energy of the cost of production with the help of energy equivalents. Calculated the total energy for fuel and lubricants (fuel) and labor resources, as well as aggregate energy for seeds and mineral fertilizer was calculated.

For estimating the energy accumulated in a business hour of the crop, we used the formula:

$$V = Af \times \lambda_1 f \times Lf$$

Where:

V – the energy content in the economically valuable part of the crop of agricultural crops, mJ/ha;

Af - economically valuable part of the crop of agricultural crops, kg/ha ;

λ_1 f – is the ratio of the unit of production received to dry matter;

Lf – the total energy content in 1 kg of dry matter, mJ.

The energy efficiency coefficient of safflower cultivation was defined as the ratio of the energy content of the safflower yield (mJ/ha) to the total energy consumption for safflower production (mJ/ha).

Research results

According to Agrochemical soil survey data held in 2014 on the farm LLP "Fermer 2002" Astrakhan district of Akmola region obsession with humus 4%, N – 36,8 mg/kg, P_2O – 19,4 mg/kg, K_2O - 509 mg / kg, pH – 8,52. The territory of the economy is located in the transition zone from dark chestnut soils to southern chernozems.

Over the years of research, the distribution of precipitation during the growing season of crops was uneven. In 2015, the main amount of precipitation fell in May and July, which contributed to the emergence of amicable and timely shoots, the formation of a good vegetative mass of plants, but in July the average daily air temperature was

slightly below the average long-term indicators, which adversely affected the formation and maturation seeds. In 2016, the main amount of precipitation occurred in June and July months, in the remaining months the amount of precipitation was at the level of the average long-term indicators, the temperature regime was also at the normal level (Fig. 1, 2).

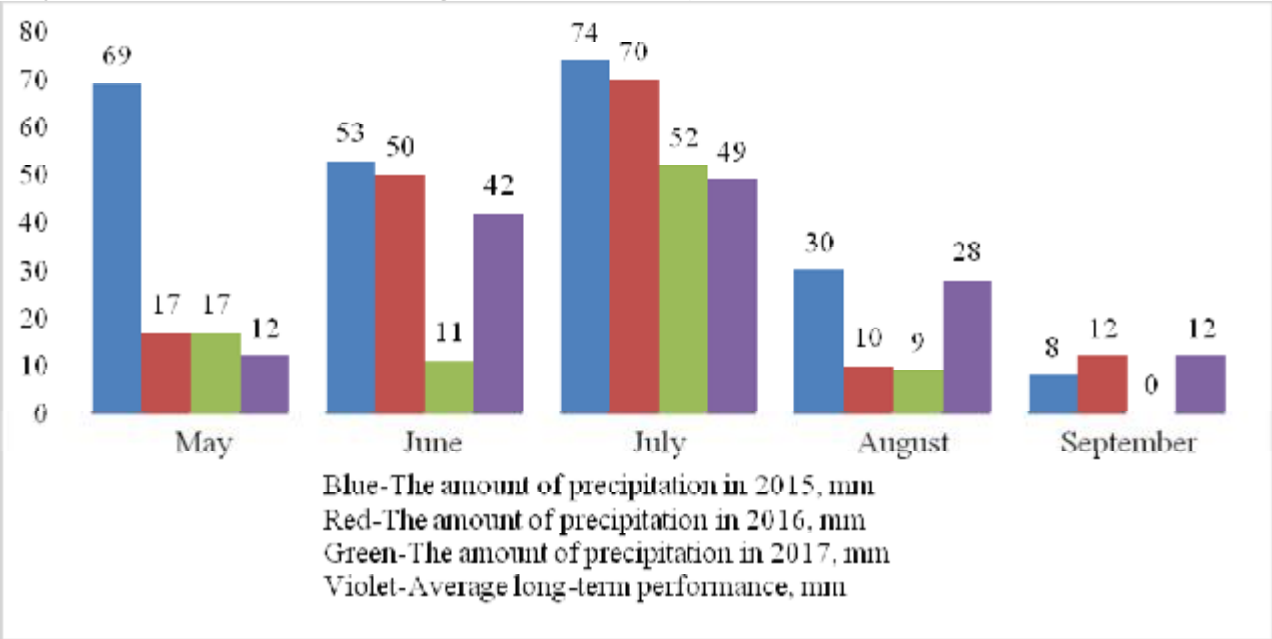

Figure 2 – The amount of precipitation during the growing season of oilseeds in the years of the study, mm.

During the sowing season for oilseeds, the II-III decade of May in 2017 weather conditions were favorable, precipitation fell by 5 mm, more indicators of mean and average temperature was higher, rates on long-term average were +3.5 ^{0} C. However, in June month of precipitation fell just 11 mm, which is below the average annual 33 mm, particularly hot proved II and III decades, and the average air temperature during this period was higher than the norm for many years + 2.5^{0}C. And June was rainy, especially much precipitation was in I and II decade.

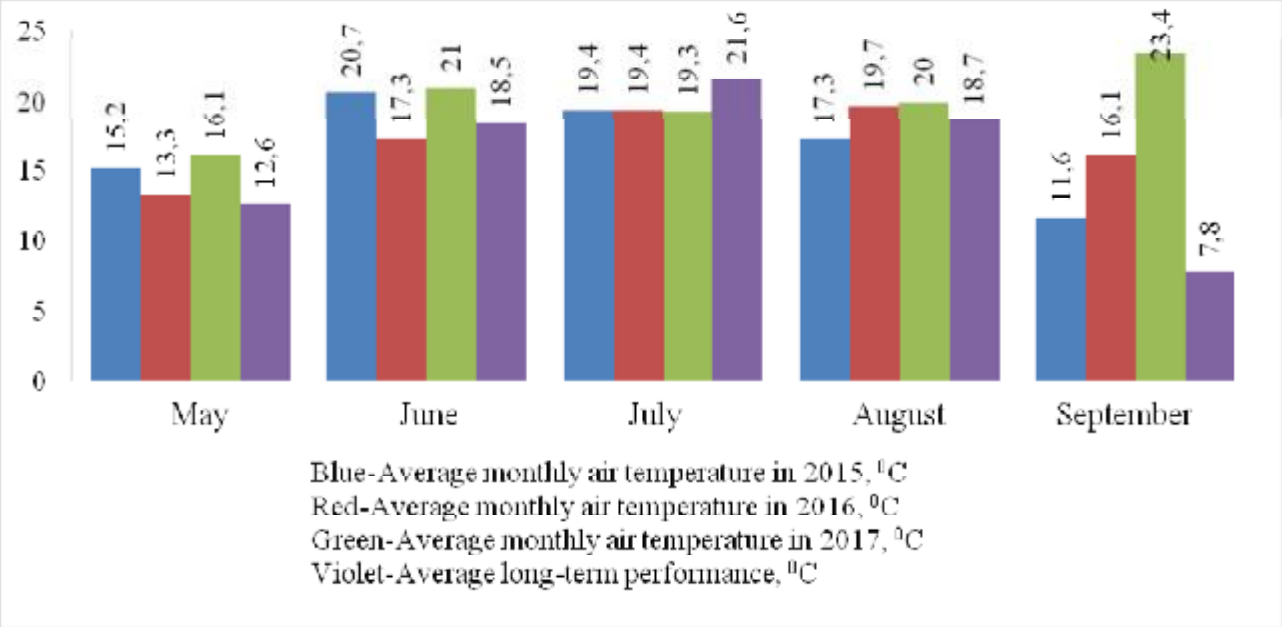

Figure 3 – Average monthly air temperature during the growing season of oilseeds in the years of research, °C

During all the years of research, August and September months were dry and warm, and that contributed to the timely maturation of seeds of safflower, especially in 2017.

In the experiment, with all soil preparation technology among varieties of safflower, the highest yield of seeds was noted for the cultivar Center 70, its productivity was 12,7 centners per hectare for zonal soil preparation technology, with a Minimal I of 1 to 14,0 centners per hectare, with a Minimal II – 13,2 centner/ha and at zero – 12,2 centner/ha, which is higher than the yield of Irkas and Akmai varieties by 0,9 centner/ha with zonal technology; by 0,7-0,8 c/ha - with a Minimal of I; on 1,1 centner/ha - with a Minimal of II and with zero technology - by 0,8-0,9 centner/ha, respectively (Table 2).

Table 2 – Yield of varieties of safflower with different soil technologies (2015-2017)

Soil preparation technology	Varieties	Yield, c/ha	Deviation from control
Zonal - control	Center 70	12,7	-
	Akmai	11,8	-
	Irkas	12,0	-
Minimal I	Center 70	14,0	+1,3
	Akmai	13,2	+1,4
	Irkas	13,3	+1,3
Minimal II	Center 70	13,2	+0,5
	Akmai	12,4	+0,6
	Irkas	12,4	+0,4
	Center 70	12,2	-0,5

Zero	Akmai	11,3	-0,5
	Irkas	11,4	-0,6

In our studies total costs of cultivation varieties of safflower with Zonal technology was 20478,6 tg. This indicator on other technologies of soil preparation decreased and amounted 19617,9 tg in the Minimal I, in the Minimal II – 19077,7 tg and in zero technologies – 19435,3 tg. The highest net income was obtained in the variant with soil preparation technology Minimal I and was 63196,9 tenge. Significantly lower it was on the option with Zonal and Zero technology. At the same time, the profitability of grain production in versions with Minimal I and Minimal II technology turned out to be much higher than on the variant with Zonal technology and was 134,8; 131,2%. among the safflower varieties studied - Center 70 showed high profitability – 134,8 (Table 3).

Table 3 - Indicators of economic efficiency of cultivation of varieties of safflower depending on soil preparation technologies

Soil preparation technology	Variety	Yield, centner / ha	Total costs, tenge	Income, tenge	Costs Price, tenge	Profitability, %
Zonal - control	Center 70	12,7	20478,6	22541,5	1612,5	110,1
	Akmai	11,8	20478,6	19301,5	1735,5	94,3
	Irkas	12,0	20478,6	19841,5	1706,6	96,9
Minimal I	Center 70	14,0	19617,9	26447,1	1401,3	134,8
	Akmai	13,2	19617,9	25142,1	1486,2	128,2
	Irkas	13,3	19617,9	25292,1	1475,0	128,9
Minimal II	Center 70	13,2	19077,7	25022,4	1445,3	131,2
	Akmai	12,4	19077,7	23462,4	1538,5	122,9
	Irkas	12,4	19077,7	23057,4	1538,5	120,8
Zero	Center 70	12,2	19435,3	19804,7	1593,1	101,9
	Akmai	11,3	19435,3	17344,7	1719,9	89,2
	Irkas	11,4	19435,3	17599,7	1704,9	90,6

To fully meet the population's demand for food, not only additional material and energy costs are required , but also measures to save them, as well as a fundamental revision of the principles of agriculture, the design and use of agricultural machinery. This is especially important now, when the entire national economy of the country is oriented towards a market economy.

In agriculture, there are large reserves of energy saving both in terms of technology, and through the use of energy-saving means of mechanization and organizational and technical measures. For example, in plant growing, the transition to minimal tillage provides fuel economy by 25-30%, in addition, the use of effective agricultural methods of crop cultivation can be attributed to possible technological directions of energy saving in crop production.

Table 4 - Indicators of bioenergetic efficiency of cultivation of varieties of safflower depending on soil preparation technologies

Soil preparation technologies	Variety	Yield, centner/ha	Content of total energy in grain , mJ/ ha	Expended total energy, mJ / ha	Coefficient of energy efficiency
Zonal-control	Center 70	127 0	22643,6	4045,2	5,6
	Akmai	118 0	21038,9	4045,2	5,2
	Irkas	120 0	21395,5	4045,2	5,3
Minimal I	Center 70	140 0	24961,4	3776,6	6,6
	Akmai	132 0	23535,1	3776,6	6,2
	Irkas	133 0	23713,4	3776,6	6,2
Minimal II	Center 70	135 0	24069,9	3883,7	6,2
	Akmai	124 0	22108,7	3883,7	5,7
	Irkas	124 0	22108,7	3883,7	5,7
Zero	Center 70	122 0	21752,1	3844,7	5,6
	Akmai	113 0	20147,4	3844,7	5,2
	Irkas	114 0	20325,7	3844,7	5,3

Based on calculations made by us, it was revealed that the most efficient from the energy point of view, the embodiments sowing safflower varieties with soil preparation technology Minimal I. In this version, the energy efficiency coefficient was 6,2 to 6,6.

Energy efficiency coefficients of safflower varieties in the control variant were lower in comparison with the options Minimal I and Minimal II, however, were on the same wel with the Zero soil preparation technology option (Table 4).

Conclusion

As a result of the studies conducted in the conditions of the dry steppe zone of Northern Kazakhstan, it was revealed that the most effective soil preparation technology for safflower cultivation is Minimal I. Among the varieties of safflower that have been studied, the Center 70 grade was found to be economically advantageous for the years of Minimal I soil preparation technology. In this variant, the lowest

cost index of production of oilseeds (1401,3 tenge), the level of profitability (134,8%), and the maximum net income (26447,1 tenge) were obtained.

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Түйін

Мақалада Солтүстік Қазақстанның күңгірт қара-қоңыр топырақты құрғақшылықты аймағында мақсары *(Carthamus tinctorius L.)* сорттарының

өнімділігіне әр түрлі топырақ дайындау технологияларының әсерін зерттеу бойынша үш жылдық (2015-2017 жж) нәтижелер келтірілген, сондай-ақ, дақылды өсірудің экономикалық және биоэнергетикалық тиімділігі көрсетілген. Зерттеу жылдарында қалыптасқан ауа райы жағдайларына жасалынған сараптамаға сәйкес, мақсары сорттарының өсіп-дамуы кезеңінде ылғалмен қамтамасыз ету деңгейі бойынша 2015 және 2016 жылдар оңтайлы болып табылды, ал 2017 жылқолайсыздау, яғни, ылғал тапшылығы байқалып, гидротермиялық коэффициент көрсеткіші бойынша «құрғақ» деп бағаланды. Зерттеу жылдарында тамыз және қыркүйек айлары жылы әрі құрғақ болып, мақсары сорттарының тұқымының қалыптасуы мен пісуі кезеңдерінің қарқынды жүруіне ықпал етті, ол тұрақты тұқым өнімін алуды және зерттелген нұсқалардың экономикалық тиімділігін қамтамасыз етті. Зерттеу нәтижелері бойынша мақсары сорттарының өнімділігінің жоғарылауына Минималды I топырақ дайындау технологиясының оң әсері анықталды. Сыналған сорттардың ішінен жоғары өнімділікті Центр 70 сорты көрсетті, басқа сорттармен салыстырғанда өнімділік - 0,7-2,7 ц/га артты. Зерттеу жылдарында экономикалық тұрғыдан тиімді сорт Минималды I топырақ дайындау технологиясы қолданылған нұсқада өсірілген Центр 70 сорты болып табылды, аталмыш сорттың рентабельділік деңгейі - 134,8% - ды құрады, ол басқа зерттеу нұсқаларында өсірілген сорттар рентабельділік деңгейінен -3,6 - 45,6% - ға жоғары болды. Мақсары сорттарын өсірудің биоэнергетикалық тиімділігі Минималды I топырақ дайындау технологиясы қолданылған нұсқада қалыптасты, энергетикалық тиімділік коэффициенті - 6,2 - 6,6 құрады.

Резюме

В статье приведены данные трехлетних исследований, проведенных на темно-каштановых почвах сухостепной зоны Северного Казахстана по изучению влияния разных технологий подготовки почвы на продуктивность сортов сафлора *(Carthamus tinctorius L.)*, а также даны расчеты экономической и биоэнергетической эффективности возделывания культуры. Анализ погодных условий, сложившийся в годы исследования показал, что по уровню обеспеченности влагой за вегетационный период растений благоприятными считаются 2015 и 2016 годы, менее благоприятным оказался 2017 год с уровнем гидротермического коэффициента - 0,4, что характеризуется как «сухой». За все годы исследования август и сентябрь месяцы выдались сухими и теплыми, что способствовало ускоренному прохождению периода формирование - созревание семян, что способствовало получению стабильного урожая и обеспечила экономическую эффективность изучаемых вариантов. По результатам исследований выявлено положительное влияние Минимальной I технологии подготовки почвы на повышение продуктивности сортов сафлора. Из испытанных сортов сафлора высокой урожайностью характеризовался сорт - Центр 70, у которого этот показатель был выше, чем у других сортов на 0,7-2,7 ц/га. Экономичеси выгодным за годы исследований оказался сорт сафлора - Центр 70 на варианте с

Минимальной I технологией подготовки почвы, где рентабельность составила- 134,8%, что выше рентабельности других сортов по всем вариантам опыта на 3,6 - 45,6%. Биоэнергетическая эффективность возделывания сортов сафлора также была выше на варианте Минимальная I, где коэффициент энергетической эффективности составил – 6,2 - 6,6.

Summary

The article presents data of three-year studies conducted on dark chestnut soils of the dry steppe zone of Northern Kazakhstan on the study of the influence of different soil preparation technologies on the productivity of safflower varieties *(Carthamus tinctorius L.)*, and the calculation of the economic and bioenergetic efficiency of cultivation. An analysis of the weather conditions during the study showed that in 2015 and 2016 are favorable for the level of water supply during the vegetative period of plants, 2017 was less favorable, with a hydrothermal coefficient of 0.4, which is characterized as "dry". During all the years of the study, the months of August and September were dry and warm, which facilitated the accelerated passage of the period of formation and maturation of seeds, which contributed to a stable yield and ensured the economic effectiveness of the variants studied. Based on the results of the research, the positive influence of Minimal I technology of soil preparation on the increase in the productivity of safflower varieties was revealed. Of the varieties of safflower that were tested, the grade-Center 70 was characterized by high yield, in which this index was higher than in other varieties by 0,7-2,7 centner/ha. Economically advantageous for the years of research was the safflower - Center 70 variant with a variant of Minimal I soil preparation technology, where profitability was 134.8%, which is higher than the profitability of other varieties for all variants of the experiment by 3,6 – 45,6%. The bioenergetic efficiency of cultivation of varieties of safflower was also higher in the Minimal I variant, where the energy efficiency coefficient was 6,2 – 6,6.