ФОТОСИНТЕТИЧНИ ПОКАЗАТЕЛИ НА ПОСЕВ ОТ САФЛОР, ОТГЛЕЖДАН В УСЛОВИЯТА НА СУХОСТЕПНАТА ЗОНА В СЕВЕРЕН КАЗАХСТАН
PHOTOSYNTHETIC ACTIVITY OF SAFFLOWER UNDER THE CONDITIONS OF THE DRY STEPPE ZONE OF NORTHERN KAZAKHSTAN

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Резюме

В статията са представени данни за фотосинтетичните показатели на посев от сафлор (*Cárthamus tinctórius*), отглеждан в условията на сухостепна зона в Северен Казахстан, в зависимост от различни срокове на сеитба, сеитбени норми и различни торови норми при минерално торене. В годините на изследване високи стойности на фотосинтетичните показатели са получени при посева, засят на 10 май с посевна норма 0,25 млн. кълняеми семена на 1 хектар. Установено е положителното влияние на внесените минерални торове при посева с ефективна активност на листния апарат на растенията, както и това че те оказват съществено влияние върху образуването на листната площ на растенията, на фотосинтетичния потенциал и добива на суха биомаса.

Abstract

The article presents data on the photosynthetic activity of safflower (*Cárthamus tinctórius*) in the dry steppe zone of Northern Kazakhstan depending on the different time of sowing, seed rate and applied mineral fertilizer. During the years of research it has been found that crops sown on May 10 with a seed rate of 0.25 million viable seeds per hectare provided higher levels of photosynthetic activity. The positive effect of the mineral fertilizer applied during sowing influenced the activity of plant leaves.

Ключевые слова: сафлор, фотосинтетическая деятельность, срок посева, норма высева, минеральные удобрения.
Key words: safflower, photosynthetic activity, time of sowing, seed rate, fertilizers.

INTRODUCTION

In recent decades Kazakhstan has seen steady expansion of planting and production of oilseeds. One of the most promising oil-bearing crops is safflower. Safflower is grown in the south (South Kazakhstan, Zhambyl region) and south- east of our republic (Almaty); now it is being cultivated in the East, the West and the North. In the market economy safflower is an economically profitable crop in South Kazakhstan (116.6 ha) and Zhambyl region (77.4 ha). In general, safflower sowing areas increased from 148 hectares in 2009 to 272 hectares in 2012, through the expansion of crop in the northern regions of the country (Kostanai (17.2 hectares) and Akmola (13.3 ha)) [1] .

Safflower can substitute sunflower as an oil plant of dry steppe regions, moreover, it is much more expensive than grains of wheat - the main crop of the country. Safflower was grown mainly in the southern regions of Kazakhstan before, but now due to its unpretentiousness and drought – resistance it is planted in the northern and western regions, gaining more and more areas [2].

The perspective direction of increasing safflower sowing is complex use of biological potential of the crop. The reason of popularity and advantages of safflower is that it is adapted to the conditions of extreme continental climate and is one of the most drought-resistant plants according to its moisture requirement [3].

Therefore, it is quite reasonable to cultivate safflower for getting oil seeds in the Northern Kazakhstan.

In this regard, comprehensive studies on the development of technology of cultivation of safflower for producing oilseeds were conducted on the experimental plot "Farmer 2002" LLP, located in Astrakhan region of Akmola area, for the first time.

One of the goals of our research was to study the photosynthetic activity of plants of safflower in the dry steppe zone of Northern Kazakhstan.

The main objectives of our study were to determine the leaf area and dry weight of the crop and calculation of net photosynthetic capacity and efficiency of safflower plant photosynthesis.

The problem of plant nutrition is the most urgent and one of the ways to solve it is the maximum and efficient utilization of solar energy by crops [4].

MATERIALS AND METHODS

The object of the research is safflower variety of Kazakhstan selection - Akmai.

In our researches the leaf area of safflower was determined in the phase of "blossom" by the formula proposed by scientists of Kazakh National Agrarian University (T.N.Nurgasenov and etc.) [5].

$$S = A \times B \times C, where:$$

S (L) - leaf area, mm^2;

A – leaf length, mm;

B - the largest leaf width, mm;

C - correction factor.

The correction factor of safflower leaves, regardless of plant location on the average is 0.707.

The photosynthetic capacity of the leaf surface is calculated by the standard technique proposed by A.A.Nichiporovich in 1961:

$$PC = L \times T, where:$$

L - leaf area, thousands m^2/ha;

T - duration of the period (days).

Net photosynthesis (NP) characterizes how much dry matter is accumulated on the leaf area of 1m^2 per day. Net photosynthesis is calculated by the formula proposed by Kidd, West and Briggs:

$$NP = \frac{(B_2 - B_1)}{\frac{(L_1 + L_2)}{2} \times T}, where:$$

NP - net photosynthesis, g/m^2 /day;

B_2 - yield mass at the subsequent definition, g/m^2;

B_1 - yield mass at the previous definition, g/m^2;

L_1L_2 - leaf area in the same time frame, m^2;

T - length of time, day.

Utilization coefficient of PAR (C_{PAR}) is calculated by the formula:

$$Cpar = \frac{Y \times C \times 100}{Q_{par}}, where:$$

C_{PAR} - utilization coefficient (coefficient of efficiency) of PAR;

Y - dry biomass yield, kg/ha;

C - dry matter calorie, kcal/kg of dry matter;

Q_{PAR} – quantity of PAR over the crop growing period, kcal/ha [6].

RESULTS AND DISCUSSION

As a result of the research, we have found that the formation of leaf area of safflower in the dry steppe zone of Northern Kazakhstan is strongly influenced by weather conditions during plant growth and development.

The main limiting factor in the area of carrying out experiences is moisture. During the growing period (from May to August including) in 2012 the rainfall made up 157 mm (18.0, 30.0, 81.0, 28.0), which is less than the mean annual rainfall. The distribution of rainfall during the growing period was uneven. The main amount of rain fell at the end of July and beginning of August. During the period of greatest need for moisture (budding, blossom) - the second decade of July – there was no precipitation at all.

Quite opposite to the year 2012 the growing period in 2013 was abnormally rainy. During the growing period of safflower in 2013 the rainfall made up 278.7 mm (27.0, 11.4, 151.0, 89.3), which is higher than the mean annual rainfall by 104.7 mm.

In May, rainfall amount was at the level of mean annual rainfall. The basic amount of rain fell in the 2nd and 3rd decades of July and at the beginning of August, the amount of rainfall during this period was higher from the mean annual indicators, respectively - 100 and 48.3 mm (Fig. 1).

The mean monthly temperature in 2012 was higher than the mean annual indicators and it was 15.4 ^{0} C in May, 20.9 ^{0} C in June, 23.4 ^{0}C in July, August in 19.8 ^{0} C. The effective heat sum during the growing period in 2012 made up 2213 ^{0} C, which was within the norm. According to the value of hydrothermal coefficient the year 2012 was characterized as very droughty (HC = 0.6).

In 2013, the mean monthly temperature was the following: 12.0^0 in May, June in 18.9^{0}C, 18.3^0 C in July and 17^{0}C in August. The mean monthly temperature in May, July and August months was lower by - 0.6, 1.8, 0.9, and in June exceeded by 1.0° C. According to the value of hydrothermal coefficient

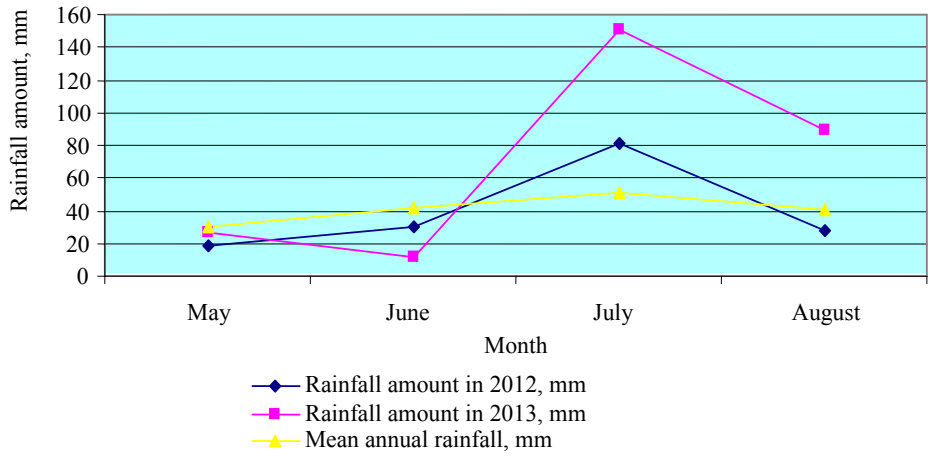

Рис. 1. *Количество осадков выпавших в вегетационный период сафлора в годы исследований, мм*
Fig. 1*. Rainfall amount of the growing period of safflower during the years of the research, mm*

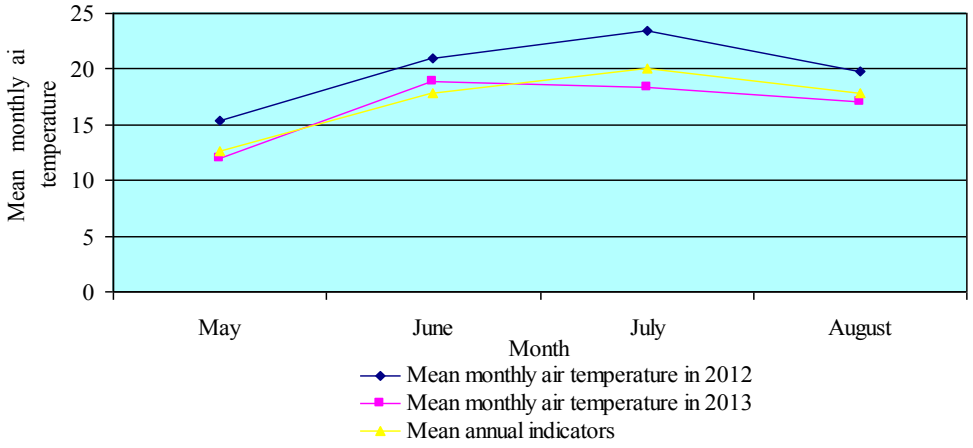

Рис. 2. *Среднемесячная температура воздуха в вегетационный период сафлора в годы исследований, ^{0}C*
Fig. 2. *The mean monthly air temperature of the growing period of safflower during the years of the research, ^{0}C*

the year 2013 is described as “well hydrated” (HC = 1.3). However, during the period from germination to flower bud formation it was at the level of 0.3 - 0.6, which corresponds to the scale of assessment as “very droughty”. In the initial period of safflower growth the temperature sum was sufficient (Fig. 2). Based on the analysis of air temperatures, we drew a conclusion that during the period of intensive growth of vegetative and reproductive parts of safflower current temperatures were unfavorable, namely plants did not have enough heat, which subsequently affected the formation and operation of safflower leaf apparatus, especially it was negatively reflected in the later crop sowing.

One of the most active parts of the plant is the leaf. The larger the area of green leaf surface of a plant, the more vigorous is accumulation of organic matter of a plant and the higher is harvest [7]. In our experiments, the leaf area during the years of the research on the average made up 9.37 -17.04 thousand m^2/ha. This index regardless of sowing date and raised seeding rate to 0.25 million viable seeds per 1 hectare is increased, and with a further increase to 0.3 million viable seeds per 1 hectare is reduced. Due to the applied mineral fertilizers the leaf area was higher by 0,17-1,13 thousand m^2/ha compared with the case when the fertilizers weren’t applied.

One of the indicators of photosynthetic activity of the crop, reflecting both the size of a leaf and duration of its activity is photosynthetic capacity (PC), which is in close correlation with yield of dry biomass [8]. In our experiments, the average value of photosynthetic capacity was 239.5 - 468.7 thousand m^2d/ha. Planting dates, May 10 and May 15, had positive impact on this indicator. Due to the applied mineral fertilizers PC was higher by 4.1 - 48.3 thousand m^2d/ha, compared with the case when the fertilizers weren't applied.

The average values of dry biomass yield was - 2019.9 - 3422.1 kg/ha. According to the variants with the seeding rate of 0.15 and 0.30 million viable seeds per 1 hectare this indicator was at the same level but with a little change. Sowing time, May 10, with the seeding rate of 0.25 million viable seeds per 1 hectare with application of mineral fertilizers and without it have formed the best values of this index - 3021,8-3422,1 kg/ha. Dry biomass yield was higher with the crops which have been fertilized (65.5 - 400.3 kg/ha).

Таблица 1. Основные показатели фотосинтетической деятельности растении сафлора, среднее за 2 года (2012-2013 г.)

Table 1. Key indicators of photosynthetic activity of safflower, mean indicators for 2 years (2012-2013)

Time of sowing	Seeding rate, million viable seeds per ha	Leaf area (S), thousand m^2/ha	Photosynthetic capacity (PC), thousand square meters per day and ha (m^2/d/ha)	Net photosynthesis (NP) g/m^2/day	Yield of dry biomass, kg/ha	Utilization coefficient of PAR, %	Coefficient of correlation (r) between photosynthetic potential and dry biomass in the process of increasing seeding rate
Fertilized ground (P_{20})							
May 5th	0,15	13,39	350,3	2,29	2463,7	0,4	0,90±0,30
	0,2	15,17	396,6	2,22	2752,9	0,5	
	0,25	15,63	406,5	2,12	2872,2	0,5	
	0,3	11,54	300,9	1,91	2465,7	0,4	
May 10th	0,15	14,66	385,9	2,39	2798,8	0,5	0,93±0,25
	0,2	16,60	457,9	2,37	3354,6	0,6	
	0,25	17,04	468,7	2,31	3422,1	0,6	
	0,3	12,52	344,7	1,94	2861,9	0,5	
May 15th	0,15	13,54	381,1	2,23	2556,1	0,4	0,89±0,32
	0,2	15,86	446,4	2,14	3049,9	0,5	
	0,25	16,20	454,8	2,12	3077,3	0,5	
	0,3	11,68	328,1	1,94	2621,9	0,5	
May 20th	0,15	11,35	317,2	2,06	2359,1	0,4	0,86±0,36
	0,2	12,52	350,8	1,89	2639,4	0,5	
	0,25	12,41	342,3	1,88	2626,6	0,5	
	0,3	10,31	286,4	1,77	2385,8	0,5	
Nonfertilized ground (P_0)							
May 5th	0,15	12,26	320,9	2,23	2345,2	0,4	0,92±0,27
	0,2	14,31	374,3	2,11	2605,9	0,4	
	0,25	14,58	379,9	1,96	2625,4	0,5	
	0,3	11,37	296,8	1,77	2400,2	0,4	
May 10th	0,15	14,45	396,4	2,29	2689,8	0,5	0,91±0,29
	0,2	16,10	441,5	2,19	2993,5	0,5	
	0,25	16,15	443,3	2,12	3021,8	0,5	
	0,3	12,18	334,4	1,84	2643,2	0,5	
May 15th	0,15	12,62	368,3	2,14	2411,0	0,4	0,86±0,36
	0,2	14,81	432,0	1,98	2728,8	0,5	
	0,25	15,23	443,7	1,85	2734,1	0,5	
	0,3	11,01	320,5	1,73	2487,3	0,4	
May 20th	0,15	10,97	280,8	1,86	2054,9	0,4	0,90±0,30
	0,2	11,82	302,5	1,85	2276,4	0,5	
	0,25	12,03	312,6	1,70	2293,1	0,4	
	0,3	9,37	239,5	1,64	2019,9	0,4	

The direct correlation between photosynthetic capacity and yield of dry biomass with increasing seeding rate is defined. According to the rate scale system (G.F. Lakin) [9] the most strong correlation was observed on the fertilized ground with the sowing time May 10th (0,93 ± 0,25), and on the nonfertilized with the sowing time May 5th (0,92 ± 0,27).

An important indicator of photosynthetic activity of crops is net photosynthesis (NP), which characterizes the average activity of a plant leaf on the accumulation of dry biomass. This indicator during the early dates of sowing (May 5-10) was higher compared to the late dates (May15-20). Net photosynthesis varied slightly on the fertilized ground and on the nonfertilized ground, so on the ground with mineral fertilizers it was up to 0.04 - 0.27 g/m^2 /d. The value of net photosynthesis (NP) decreased with increasing seeding rate from 2.39 to 1.64 g/m^2 /d (Table 1).

According to A.A. Nichiporovich (1961), in practice, utilization coefficient of PAR is only about 0.5-1% for crops, as the whole systems, but theoretically and practically coefficients can be 5.4% or more. In our experiments, utilization coefficient of PAR of safflower was 0.4-0.6%. The best utilization coefficient of PAR was on May 10th sowing with seeding rates of 0.20 and 0.25 million viable seeds per 1 hectare. On the ground with mineral fertilizers for different time of sowing the value of this index was up 1% compared to nonfertilized ground (Table 1).

CONCLUSION

1. Low rainfall (2012), as well as, insufficient accumulated temperatures (2013) during the “budding - blossom” period had negative impact on the formation and activity of a leaf.

2. Plants sown on May 10th, regardless of fertilization showed most photosynthetic activity.

3. Net photosynthesis of sowing with seeding rate of 0.15 million viable seeds per 1 ha was higher, but according to the other indicators of sowing photosynthetic activity was best with seeding rate of 0.25 million viable seeds per 1 ha. It was found out that the values of net photosynthesis (NP) decreased with increasing seeding rate from 2.39 to 1.64 g/m^2/d.

4. The application of mineral fertilizers had significant influence on the formation of leaf area, as well as, on the photosynthetic capacity and yield of dry biomass, and had less impact on the value of net photosynthesis and utilization coefficient of PAR.

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