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SAFFLOWER YIELDS AND QUALITY DEPENDING ON CULTIVATION TECHNOLOGY IN THE IRRIGATED CONDITIONS

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Abstract

The article presents the results of scientific researches devoted to investigation of safflower yields and quality depending on cultivation technology in the irrigated conditions. Field trials were carried out during 2010-2012 at the irrigated lands of the Institute of Rice of the National Academy of Agrarian Sciences of Ukraine in four replications by using the randomized split plot design method. We studied the effect on the crop yield and quality of such cultivation technology elements as: soil tillage, time of sowing, inter-row spacing and mineral fertilizers doses. We determined that all the studied factors had significant effect on the yields of safflower. The highest safflower seed yield averaged to 2.11 t ha^{-1} under the plowing at the depth of 20-22 cm, sowing in the 3^{rd} decade of March with inter-row spacing of 30 cm, application of mineral fertilizers in the dose of $N_{90}P_{90}$. The yield of safflower under the lower dose of mineral fertilizers $N_{60}P_{60}$ averaged to 2.02 t ha^{-1}, however, the difference between the treatment with $N_{90}P_{90}$ was proved to be insignificant. We also established that the studied cultivation technology elements caused significant effect on the safflower seed quality, except of husks content in the seeds. The maximum weight of 1000 seeds of 42.5 g, and the highest oil content of 29.31% were determined under the agrotechnological complex with plowing at the depth of 20-22 cm, sowing in the 3^{rd} decade of March with inter-row spacing of 30 cm, application of mineral fertilizers in the dose of $N_{90}P_{90}$. The husks content in the seeds of the crop fluctuated within the values of 54.2-56.1%.

Key words: *inter-row spacing, mineral fertilization, productivity, soil tillage, time of sowing.*

INTRODUCTION

Safflower (*Carthamus tinctorius* L.) is well-known industrial crop. It is cultivated for the needs of paint and varnish industry (for example, to obtain natural red and yellow dyes), oil industry and medicine (Corleto et al., 1997; Zohary and Hopf, 2000; Singh, 2007). Safflower seeds contains from 30 to 50% of oil (Camas et al., 2007), which is a rich source of fats, minerals and vitamins (Velasco et al., 2005). It might be used as an alternative for sunflower oil. International interest to safflower in the world continues to increase due to its high nutritive and industrial value and specific biological properties, for example, short period of vegetation, drought tolerance etc. Nowadays, safflower is cultivated on the large areas all over the world. The main cultivation areas are situated in the USA, Mexico, India, China, Australia and Argentina. Gross yields of the crop are estimated to be near 500,000 mt per year (Gilbert et al., 2008). Scientists began to investigate the reaction of the crop on different cultivation practices in different climatic and agricultural conditions to supply farmers with scientifically based recommendations on the cultivation of the crop. However, cultivation technology of safflower is not studied sufficiently, especially, for the irrigated conditions. A number of agrotechnological issues still remains unsolved, viz., tillage effects on the crop productivity, influence of mineral fertilizers on yielding capacity and quality of yields, best time of sowing for different climatic zones, etc. The goal of our study was to determine the effect of soil tillage, time of sowing, inter-row spacing and mineral fertilizers on the seed yields and quality of safflower under the irrigated conditions of the South of Ukraine.

MATERIALS AND METHODS

Field trials were conducted during 2010-2012 at the experimental field of the Institute of Rice of the National Academy of Agrarian Sciences of Ukraine. The coordinates of the experimental field are: latitude 46°08′34″N, longitude 32°57′15″E, 8 m above the sea level. The trials were conducted in four replications by using the randomized split plot design method. We studied such cultivation technology elements as:

- A - soil tillage: A1 - disking at the depth of 14-16 cm; A2 - plowing at the depth of 20-22 cm;
- B - time of sowing: B1 - 3rd decade of March; B2 - 2nd decade of April; B3 - 3rd decade of April;
- C - inter-row spacing: C1 - 30 cm; C2 - 45 cm; C3 - 60 cm;
- D - mineral fertilizers dose: D1 - N_0P_0; D2 - $N_{30}P_{30}$; D3 - $N_{60}P_{60}$; D4 - $N_{90}P_{90}$.

Climate of the zone of trials is moderately continental. It is highly influenced by the Black Sea. Weather conditions and meteorological indexes were fixed and estimated at the local meteorological station, which had been installed on the experimental field of the Institute of Rice.

The years of the study conduction might be characterized as follows: 2010 - very wet year; 2011 - moderately dry year; 2012 - extremely dry year. The main meteorological indexes for the studied periods are represented in the Table 1.

Table 1. Meteorological indexes during the period of the field trials with safflower

2010			2011			2012			Months
AT, °C	AH, %	PA, mm	AT, °C	AH, %	PA, mm	AT, °C	AH, %	PA, mm	
-3.0	85	33.0	-1.3	88	36.2	-0.3	87	62.9	January
2.0	84	0.0	-2.4	74	4.2	-6.7	85	18.3	February
3.4	79	14.6	2.6	78	17.3	2.7	79	29.0	March
10.7	70	11.0	9.9	73	38.9	12.8	77	12.7	April
17.6	66	77.3	16.7	77	47.3	20.8	74	58.2	May
22.5	65	69.5	22.2	71	68.8	23.8	65	12.3	June
24.7	63	44.9	25.2	71	11.0	26.5	58	13.3	July
26.1	62	44.0	23.2	65	12.3	24.4	62	9.0	August
17.7	68	64.1	19.3	68	7.1	20.1	70	0.1	September
7.8	76	36.2	10.7	77	19.3	15.8	77	17.7	October
10.5	86	43.0	3.1	76	6.0	7.7	85	8.4	November
1.6	88	68.9	4.4	89	27.5	0.4	86	13.5	December
11.8	74.3	506.5	11.1	75.6	295.9	12.3	75.4	255.4	Annual

Note: AT - air temperature; AH - air humidity; PA - precipitation amounts.

The soil in the trials was represented by the dark-chestnut middle-loamy soil. The soil pH fluctuated within the values of 7.0-8.5 points with a tendency to increase in the deeper layers. Natural fertility of the soil is low. The content of humus in the arable layer is just about 1.5%.

Yields assessment was conducted by the entire harvesting method with help of the self-propelled combine harvester "Sampo-130". The yields data were adjusted to the standard seed moisture. We used multi-factorial analysis of variance (ANOVA) to assess reliability of the differences between the treatments in the trials. Statistical estimation was performed for the reliability level of 95% ($p<0.05$). Besides, artificial neural network method was used to generalize the results of the trials.

Cultivation technology of safflower in the trials based on the common recommendations for the crop cultivation in the South of Ukraine. The fore-crop was winter barley. Primary soil tillage was carried out with accordance to the design of the trials. We used safflower cultivar 'Soniachnyi' in the field trials. The crop was sown by the seed drill at the depth of 5-6 cm with an inter-row spacing adjusted to the design of the trials. Sowing was followed by rolling. We carried out pre-sprooting harrowing of the crops. At the stage of 2 leaves we conducted additional harrowing. Two inter-row cultivations were carried out on the plots with wide (60 cm) inter-row spacing. Irrigation of the crops was performed by using the frontal irrigation machine. We maintained moisture of the field at 75-80% of its water-holding capacity.

RESULTS AND DISCUSSIONS

Safflower yields in 2010 fluctuated from 0.66 to 2.06 t ha^{-1} (Table 2). We determined the clear tendency to decrease in the crop yields with replacement of plowing with disking at the depth of 14-16 cm. The losses of the yield averaged to 0.14 t ha^{-1} or 9.8%. Safflower yields also decreased with wider inter-row spacing of the crops. The maximum yield of 1.60-1.69 t ha^{-1} were obtained at the treatments with inter-row spacing of 30 cm. While widening to 45 and 60 cm led to decrease of the yields down to 16.6-23.8 and 29.0-34.4%, respectively. Analysis of the times of sowing showed that the highest yields of safflower seeds were provided by early sowing in the 3rd decade of March - 1.26-1.85 t ha^{-1}. Delay in sowing of the crop led to significant yield losses, which were estimated to fluctuate within values of 4.0-31.8%. Application of mineral fertilizers provided raise of the crop yields from 1.17 to 1.40-1.59 t ha^{-1}. However, significant improvement in the crop productivity was achieved only by application of mineral fertilizers in doses $N_{30}P_{30}$ and $N_{60}P_{60}$. Further increase in the dose to $N_{90}P_{90}$ caused insignificant enhancement in safflower yields that was estimated only in 0.02 t ha^{-1}. Share of the studied agrotechnological treatments in their effect on the crop productivity was determined by the results of ANOVA as follows: soil tillage - 3.6%, inter-row spacing - 17.7%, mineral fertilizers doses - 26.8%, time of sowing - 42.1%.

Table 2. Safflower yields depending on cultivation technology in 2010 (t ha^{-1})

Inter-row spacing, cm (factor B)	Time of sowing (factor C)	Mineral fertilizers doses (factor D)				Mean values by the factors	
		N_0P_0	$N_{30}P_{30}$	$N_{60}P_{60}$	$N_{90}P_{90}$	C	B
1	2	3	4	5	6	7	8
Disking at the depth of 14-16 cm (factor A)							
30	early	1.42	1.74	1.95	1.85	1.74	1.60
	middle	1.37	1.63	1.82	1.86	1.67	
	late	1.11	1.37	1.58	1.49	1.39	
45	early	1.17	1.43	1.58	1.63	1.45	1.22
	middle	0.99	1.18	1.3	1.32	1.20	
	late	0.78	0.97	1.12	1.15	1.01	
60	early	1.00	1.24	1.38	1.41	1.26	1.05
	middle	0.84	1.02	1.12	1.14	1.03	
	late	0.66	0.82	0.96	0.99	0.86	
Mean value by the factor D		1.04	1.27	1.42	1.43		
Plowing at the depth of 20-22 cm (factor A)							
30	early	1.51	1.83	2.01	2.06	1.85	1.69
	middle	1.45	1.71	1.87	1.89	1.73	
	late	1.19	1.42	1.63	1.65	1.47	
45	early	1.33	1.62	1.82	1.83	1.65	1.41
	middle	1.18	1.36	1.49	1.52	1.39	
	late	0.97	1.11	1.31	1.33	1.18	
60	early	1.15	1.41	1.56	1.60	1.43	1.20
	middle	0.97	1.16	1.28	1.30	1.18	
	late	0.77	0.95	1.11	1.10	0.98	
Mean value by the factor D		1.17	1.40	1.56	1.59		
The least significant difference (LSD) at $p<0.05$: A - 0.034; B - 0.022; C - 0.022; D - 0.053 t ha^{-1}							

The difference in safflower yields between plowing and disking in 2011 was 0.07 t ha^{-1} or 4.7%. Inter-row spacing of 30 cm provided the highest safflower yield of 1.84 t ha^{-1}. Widening of the inter-row spacing to 45 and 60 cm led to decrease in the yields down to 1.46 and 1.24 t ha^{-1}, respectively. As in the previous year, the maximum crop productivity was obtained at the early time of sowing and it averaged to 1.74 t ha^{-1}. Delayed sowing caused significant yield losses - from 13.3 to 25.7%. Mineral fertilizers increased productivity of the crop up to 0.22-

0.43 t ha^{-1} (Table 3). The strongest effect on the yields had mineral fertilizers (with share of 30.1%). Time of sowing was on the second place (28.8%), inter-row spacing was on the third (22.5%), and soil tillage was the last one with share of just 4.9%.

Table 3. Safflower yields depending on cultivation technology in 2011 (t ha^{-1})

Inter-row spacing, cm (factor B)	Time of sowing (factor C)	Mineral fertilizers doses (factor D)				Mean values by the factors	
		N_0P_0	$N_{30}P_{30}$	$N_{60}P_{60}$	$N_{90}P_{90}$	C	B
1	2	3	4	5	6	7	8
Disking at the depth of 14-16 cm (factor A)							
30	early	1.63	1.95	2.16	2.06	1.95	1.77
	middle	1.27	1.84	2.03	2.07	1.80	
	late	1.17	1.58	1.79	1.7	1.56	
45	early	1.32	1.64	1.79	1.84	1.65	1.42
	middle	1.2	1.39	1.51	1.53	1.41	
	late	0.99	1.18	1.33	1.36	1.22	
60	early	1.19	1.45	1.59	1.62	1.46	1.23
	middle	1.05	1.23	1.33	1.35	1.24	
	late	0.87	0.97	1.05	1.07	0.99	
Mean value by the factor D		1.19	1.47	1.62	1.62		
Plowing at the depth of 20-22 cm (factor A)							
30	early	1.70	2.05	2.14	2.33	2.06	1.89
	middle	1.64	1.9	2.06	2.14	1.94	
	late	1.35	1.63	1.88	1.87	1.68	
45	early	1.39	1.74	1.92	1.93	1.75	1.48
	middle	1.19	1.43	1.55	1.61	1.45	
	late	0.98	1.21	1.41	1.43	1.26	
60	early	1.17	1.46	1.61	1.63	1.47	1.24
	middle	0.99	1.18	1.33	1.35	1.21	
	late	0.83	0.98	1.16	1.18	1.04	
Mean value by the factor D		1.25	1.51	1.67	1.72		
The least significant difference (LSD) at $p<0.05$: A - 0,043; B - 0,027; C - 0,027; D - 0,061 t ha^{-1}							

Similar tendencies were observed in 2012. Plowing at the depth of 20-22 cm was considerably better than disking at the depth of 14-16 cm, and provided 0.17 t ha^{-1} higher yield (Table 4). The maximum yields were obtained at the treatment with inter-row spacing of 30 cm where they averaged to 1.52 t ha^{-1}. Increased inter-row spacing led to significant yield losses (in average, 25.2-36.9%). Early sowing in the 3rd decade of March provided the highest productivity of the crop, which averaged to 1.41 t ha^{-1}. Delayed sowing caused yield losses of 13.6-29.1%. Mineral fertilizers application significantly improved safflower yields (up to 19.1-27.8%). However, the difference between the treatments with $N_{60}P_{60}$ and $N_{90}P_{90}$ was insignificant and averaged to 0.03 t ha^{-1} or 2.4%. Therefore, the highest dose of mineral fertilizers cannot be considered as the best agrotechnological treatment due to the very low outlet of the nutrients availability raise in safflower yields. It is interesting that this year the highest share of the effect on the crop productivity belonged to the factor of inter-row spacing - 29.9%. The second place belonged to the dose of applied mineral fertilizers (26.9%), whereas time of sowing was on the third place (22.7%), and soil tillage had the minimum influence on the crop productivity and occupied the least share of 3.4%. The analysis of the average safflower yields for the period of the field trials (2010-2012) approved the above-mentioned tendencies of the crop productivity formation under the studied cultivation technology treatments (Table 5). So, it was determined that plowing is better than disking, early sowing is preferable, the narrowest inter-row spacing provides the highest yields, and application of mineral fertilizers has the highest effect on the crop productivity in the dose of $N_{60}P_{60}$. The highest influence on the crop seed yields in average for three years had time of sowing (share is 31.1%). The next one factor was mineral fertilizers with a share of the effect of 27.9%. The inter-row spacing had slightly less effect than mineral fertilizers (share is 23.4%), and soil tillage occupied the last position in determining safflower productivity (share is 3.9%).

Table 4. Safflower yields depending on cultivation technology in 2012 (t ha^{-1})

Inter-row spacing, cm (factor B)	Time of sowing (factor C)	Mineral fertilizers doses (factor D)				Mean values by the factors	
		N_0P_0	$N_{30}P_{30}$	$N_{60}P_{60}$	$N_{90}P_{90}$	C	B
1	2	3	4	5	6	7	8
Disking at the depth of 14-16 cm (factor A)							
1	2	3	4	5	6	7	8
30	early	1.40	1.52	1.76	1.74	1.61	1.43
	middle	1.22	1.49	1.7	1.73	1.54	
	late	0.82	0.97	1.37	1.41	1.14	
45	early	1.02	1.30	1.35	1.39	1.27	1.05
	middle	0.84	1.03	1.14	1.15	1.04	
	late	0.61	0.81	0.99	1.01	0.85	
60	early	0.84	1.10	1.14	1.18	1.07	0.88
	middle	0.69	0.85	0.94	0.97	0.86	
	late	0.48	0.66	0.87	0.89	0.73	
Mean value by the factor D		0.88	1.08	1.25	1.27		
Plowing at the depth of 20-22 cm (factor A)							
30	early	1.53	1.78	1.91	1.95	1.79	1.61
	middle	1.35	1.58	1.75	1.73	1.60	
	late	1.12	1.39	1.62	1.65	1.45	
45	early	1.19	1.50	1.55	1.60	1.46	1.22
	middle	0.99	1.19	1.3	1.33	1.20	
	late	0.74	0.96	1.14	1.17	1.00	
60	early	1.00	1.29	1.33	1.37	1.25	1.04
	middle	0.82	1.07	1.14	1.15	1.05	
	late	0.60	0.79	0.88	0.98	0.81	
Mean value by the factor D		1.04	1.28	1.40	1.44		
The least significant difference (LSD) at $p<0.05$: A - 0,049; B - 0,033; C - 0,033; D - 0,072 t ha^{-1}							

One of the most important stages of the investigations is estimation of the qualitative parameters of the obtained crop yields. Safflower yields quality was estimated by the indexes of 1000 seeds weight, husks content, and oil content in the seeds. The studied factors significantly effected the weight of 1000 seeds of safflower. The maximum weight of 1000 seeds of the crop reached 42.5 g, and was obtained in the conditions of plowing at the depth of 20-22 cm, sowing in the 3rd decade of March with the inter-row spacing of 30 cm, and application of mineral fertilizers in the dose of $N_{90}P_{90}$ (Table 6). Disking of the soil, delayed sowing, wider inter-row spacings, and lower doses of mineral fertilizers application caused significant decrease of the index, which reached the minimum value of 31.5 g under the disking, followed by the late sowing with the inter-row spacing of 60 cm, and no fertilizers applied.

We determined that the studied cultivation technology treatments did not have any significant effect on the index of husks content of the seeds. The difference between the highest and the lowest values of the index averaged to only 1.1% that cannot be considered as a reliable difference due to the LSD value at the reliability level of 95% (Table 7). So, we conjecture that this qualitative parameter depends mostly on the features of the cultivated cultivar or hybrid of the crop, and cannot be considerably changed by the means of cultivation technology improvement.

Table 5. Safflower yields depending on cultivation technology in average for the studied period (2010-2012) (t ha^{-1})

Inter-row spacing, cm (factor B)	Time of sowing (factor C)	Mineral fertilizers doses (factor D)				Mean values by the factors	
		N_0P_0	$N_{30}P_{30}$	$N_{60}P_{60}$	$N_{90}P_{90}$	C	B
1	2	3	4	5	6	7	8
Disking at the depth of 14-16 cm (factor A)							
30	early	1.48	1.74	1.96	1.88	1.77	1.60
	middle	1.29	1.65	1.85	1.89	1.67	
	late	1.03	1.31	1.58	1.53	1.36	
45	early	1.17	1.46	1.57	1.62	1.46	1.23
	middle	1.01	1.20	1.32	1.33	1.22	
	late	0.79	0.99	1.15	1.17	1.02	
60	early	1.01	1.26	1.37	1.40	1.26	1.05
	middle	0.86	1.03	1.13	1.15	1.04	
	late	0.67	0.82	0.96	0.98	0.86	
Mean value by the factor D		1.04	1.27	1.43	1.44		
Plowing at the depth of 20-22 cm (factor A)							
30	early	1.63	1.89	2.02	2.11	1.91	1.73
	middle	1.48	1.73	1.89	1.92	1.76	
	late	1.22	1.48	1.71	1.72	1.53	
1	2	3	4	5	6	7	8
45	early	1.36	1.62	1.76	1.79	1.63	1.38
	middle	1.12	1.33	1.45	1.49	1.35	
	late	0.90	1.09	1.29	1.31	1.15	
60	early	1.13	1.39	1.50	1.53	1.39	1.16
	middle	0.93	1.14	1.25	1.27	1.15	
	late	0.73	0.91	1.05	1.09	0.94	
Mean value by the factor D		1.17	1.40	1.55	1.58		
The least significant difference (LSD) at $p<0.05$: A - 0.042; B - 0.027; C - 0.027; D - 0.061 t ha^{-1}.							

Table 6. 1000 seeds weight of safflower depending on cultivation technology in average for the studied period (2010-2012) (g)

Inter-row spacing, cm (factor B)	Time of sowing (factor C)	Mineral fertilizers doses (factor D)				Mean values by the factors	
		N_0P_0	$N_{30}P_{30}$	$N_{60}P_{60}$	$N_{90}P_{90}$	C	B
1	2	3	4	5	6	7	8
Disking at the depth of 14-16 cm (factor A)							
30	early	36.5	38.6	39.9	41.1	39.1	37.8
	middle	36.0	37.5	38.8	40.0	38.1	
	late	34.5	35.6	36.8	37.9	36.2	
45	early	35.3	37.4	38.7	39.8	37.8	36.4
	middle	34.7	36.2	37.4	38.7	36.7	
	late	33.0	34.2	35.3	36.4	34.7	
60	early	34.0	36.1	37.4	38.6	36.5	35.1
	middle	33.4	34.9	36.1	37.3	35.4	
	late	31.5	32.7	33.8	35.0	33.3	
Mean value by the factor D		34.3	35.9	37.1	38.3		
Plowing at the depth of 20-22 cm (factor A)							
30	early	37.9	40.0	41.3	42.5	40.5	39.2
	middle	37.4	38.9	40.2	41.4	39.5	
	late	35.9	37.0	38.2	39.3	37.6	
45	early	36.7	38.8	40.1	41.2	39.2	37.8
	middle	36.1	37.6	38.8	40.1	38.1	
	late	34.4	35.6	36.7	37.8	36.1	
60	early	35.4	37.5	38.8	40.0	37.9	36.5
	middle	34.8	36.3	37.5	38.7	36.8	
	late	32.9	34.1	35.2	36.4	34.7	
Mean value by the factor D		35.7	37.3	38.5	39.7		
The least significant difference (LSD) at $p<0.05$: A - 0.74 ; B - 0.82; C - 0.88; D - 0.94 g.							

Table 7. Husks content in the seeds of safflower depending on cultivation technology in average for the studied period (2010-2012) (%)

Inter-row spacing, cm (factor B)	Time of sowing (factor C)	Mineral fertilizers doses (factor D)				Mean values by the factors	
		N_0P_0	$N_{30}P_{30}$	$N_{60}P_{60}$	$N_{90}P_{90}$	C	B
Disking at the depth of 14-16 cm (factor A)							
30	early	54.7	54.6	54.9	54.8	54.7	54.8
	middle	54.9	54.8	54.6	54.5	54.7	
	late	55.2	55.1	54.9	54.8	55.0	
45	early	55.1	55.0	54.9	54.7	54.9	55.2
	middle	55.3	55.2	55.1	55.2	55.2	
	late	55.6	55.5	55.4	55.3	55.4	
60	early	55.6	55.4	55.3	55.2	55.4	55.7
	middle	55.8	55.6	55.5	55.4	55.6	
	late	56.1	55.9	56.1	56.0	56.0	
Mean value by the factor D		55.4	55.2	55.2	55.1		
Plowing at the depth of 20-22 cm (factor A)							
30	early	54.3	54.2	54.2	54.2	54.2	54.7
	middle	54.5	54.4	54.3	54.4	54.4	
	late	55.7	55.6	55.4	54.9	55.4	
45	early	54.8	54.7	54.5	54.7	54.7	54.9
	middle	55.0	54.9	54.7	54.9	54.9	
	late	55.9	55.8	54.7	54.9	55.3	
60	early	55.2	55.5	54.1	54.7	54.9	55.2
	middle	55.4	55.3	55.2	55.3	55.3	
	late	55.8	55.7	55.5	54.9	55.5	
Mean value by the factor D		55.2	55.1	54.7	54.8		
The least significant difference (LSD) at $p<0.05$: A - 0.55; B - 0.67; C - 0.89; D - 0.92%.							

Oil content in safflower seeds was characterized as comparatively stable qualitative index. It fluctuated from 26.34 to 29.31% (Table 8). We determined that soil tillage treatments did not significantly effect the oil content. The difference between the treatments with plowing at the depth of 20-22 cm and disking at the depth of 14-16 cm was proved to be insignificant by the results of ANOVA. Sowing of the crop with the inter-row spacing of 30 cm slightly increased oil content in the seeds (in average, up to 2.9%). The effect of the sowing time was slight too. The key factor of the oil content increase was application of higher doses of mineral fertilizers. Application of mineral fertilizers in doses $N_{60-90}P_{60-90}$ improved oil content in the seeds of safflower up to 2.2-2.4%, respectively, in comparison with the non-fertilized treatments.

Table 8. Oil content in the seeds of safflower depending on cultivation technology in average for the studied period (2010-2012) (%)

Inter-row spacing, cm (factor B)	Time of sowing (factor C)	Mineral fertilizers doses (factor D)				Mean values by the factors	
		N_0P_0	$N_{30}P_{30}$	$N_{60}P_{60}$	$N_{90}P_{90}$	C	B
Disking at the depth of 14-16 cm (factor A)							
30	early	28.14	28.27	28.39	28.52	28.33	27.95
	middle	27.94	28.07	28.21	28.34	28.14	
	late	27.22	27.34	27.45	27.57	27.39	
45	early	28.19	28.32	28.44	28.57	28.38	27.85
	middle	27.51	27.64	28.31	28.44	27.98	
	late	27.03	27.15	27.26	27.38	27.20	
60	early	27.31	27.44	27.56	27.69	27.50	27.13
	middle	27.19	27.32	27.46	27.59	27.39	
	late	26.34	26.46	26.57	26.69	26.52	
Mean value by the factor D		27.43	27.55	27.74	27.86		
Plowing at the depth of 20-22 cm (factor A)							
30	early	27.51	28.34	29.21	29.31	28.59	28.12
	middle	28.00	28.15	28.39	28.46	28.25	
	late	27.28	27.41	27.64	27.69	27.51	
45	early	28.25	28.39	28.63	28.77	28.51	27.97
	middle	27.57	27.72	28.50	28.57	28.09	
	late	27.09	27.22	27.45	27.50	27.32	
60	early	27.37	27.51	28.15	27.81	27.71	27.54
	middle	27.25	27.40	27.64	27.71	27.50	
	late	27.11	27.35	27.52	27.64	27.41	
Mean value by the factor D		27.49	27.72	28.12	28.16		
The least significant difference (LSD) at $p<0.05$: A - 0,.9; B - 0.34; C - 0.29; D - 0.25							

We studied the effects of different cultivation technology elements on the yields and seed quality of safflower in the irrigated conditions. It was proved that safflower is a quite tolerant crop to the moisture deficit, and it could be cultivated under the conditions of deficit irrigation schedule (Bassil and Kaffka, 2002; Lovelli et al., 2007). However, water stress yet can lead to depression of the crop growth and deterioration of the oil quality, especially, in the dry conditions of the South of Ukraine (Istanbulluoglu et al., 2009; Ashrafi and Razmjoo, 2010; Hojati et al., 2011). Water deficit in important development stages of the crop has very unfavorable effect on its performance (Nabipour, 2007). Therefore we decided to conduct the field trials at the irrigated lands to provide the crop with favorable conditions during its vegetation period.

A comparison of our results with results of other scientific studies devoted to safflower cultivation technology shows absence of the common opinion concerning the optimal agrotechnological treatments for the crop. For example, according to the results of our field trials safflower yields and quality indexes, such as 1000 seeds weight and oil content in the seeds, are significantly effected by the inter-row spacing of the crops. However, a number of foreign scientific works report about slight and insignificant influence of this cultivation technology parameter on the above-mentioned qualitative indexes of safflower seeds (Kolsarici and Eda, 2002; Naseri et al., 2010). At the same time some of them report the fact of obtaining the highest seed yields in the conditions of 30 cm inter-row spacing of the crops, which is in consonant with our results (Naseri et al., 2010). Besides, some other scientific works prove considerable changes in safflower yields due to the regulation of the crops inter-row spacing (Özel et al., 2004; Amoghein et al., 2012). All in all, the question remains open and needs further thorough and complex investigations to be finally settled.

So as to mineral fertilizers, the general point of most scientists is that application of nutrients in higher doses improves safflower yields and seed quality. The difference is only in the optimal doses of nutrients that should be applied. For example, some scientists recommend to apply Nitrogen in dose of N_{100} (Zareie et al., 2011), others claim that the best performance of the crop might be achieved under the application of N_{160} (Kolsarici and Eda, 2002), or even $N_{150-200}$ (Rastgou et al., 2013). The results of our study proved that the highest crop yields could be obtained by application of Nitrogen in dose of N_{90}. However, we find it unreasonable to apply this amount of fertilizers under the conditions of very slight and insignificant increase in safflower yields and quality, which was proved by the results of ANOVA. Besides, it was determined that Nitrogen fertilization promotes the crop growth and affects the yields of safflower both in the rain-fed (Dordas and Sioulas, 2008) and irrigated conditions (Dordas and Sioulas, 2009).

Time of sowing is another disputable question. It was proved that this element of cultivation technology has significant effect on productivity of safflower (Mateaş and Tabără, 2010; Khalil et al., 2013).

We determined significant improvement in the crop yields and seed quality with the earliest time of sowing. However, some studies report about significant increase in oil content in the seeds of safflower with late sowing (Samancı and Özkaynak, 2003). We agree with Cosge et al. (2007), who claimed that the optimal time of sowing for the crop greatly depends on the peculiarities of particular zone of crop cultivation, especially, on its climatic conditions. All in all safflower productivity highly vary depending on the ecological conditions of the cultivation environment (Demir and Kara, 2018).

As it was mentioned above, cultivation technology of safflower is still insufficiently studied. A number of questions are quite debatable and remain unsettled. Soil tillage gets very little attention, time of sowing and inter-row spacing need to be adjusted to concrete agro-environmental conditions.

So, further investigations in the field of safflower cultivation technology are required to provide rational and substantiated recommendations for agricultural producers, especially, taking into account high industrial and nutritive value of the crop (Dajue and Mindel, 1996; Emongor, 2010).

CONCLUSIONS

The best performance of safflower in the trials was provided by the plowing at the depth of 20-22 cm, early sowing in the 3rd decade of March, inter-row spacing of 30 cm, and application of mineral fertilizers in dose of $N_{60-90}P_{60-90}$. The yileds of the crop under the above-mentioned agrotechnology reached the value of 2.02-2.11 t ha^{-1}. The maximum weight of 1000 seeds (41.3-42.5 g) and oil content (29.21-29.31%) in the seeds also were provided by the above-mentioned agrotechnological complex. The content of husks in the seeds of safflower was not effected by the studied agricultural treatments. We recommend to cultivate safflower in the irrigated conditions by using the agrotechnological complex with plowing at the depth of 20-22 cm, sowing in the 3rd decade of March with the inter-row spacing of 30 cm, and application of mineral fertilizers in dose of $N_{60}P_{60}$ to guarantee stable yields of high-quality seeds at the level of 2.0-2.2 t ha^{-1}.

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