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Sunflower Seed Yields And Quality Depending On Hybrids, Plant Densities And Foliar Fertilization Under The Rain-Fed Conditions Of The Steppe Zone.

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ABSTRACT

We studied the peculiarities of sunflower productivity and oil content in the seeds depending on hybrids, plant density and foliar fertilization treatments of the crop in the rain-fed conditions of the Steppe zone of Ukraine. The field trials were conducted at the experimental field of the research farm "Kopani" which is situated in Kherson region of Ukraine. The trials were carried out in four replications by using the split plot design method. We established that the highest productivity among the studied hybrids which averaged to 2.19 t/ha was provided by Megasan sunflower hybrid originated by Limagrains company. We also observed that the optimal plant density depended on the hybrid features. The best performance of Megasan and Yason hybrids was obtained under the plant density of 50,000 of plants per hectare, while the best performance of Darii hybrid was on the 40,000 of plants per hectare. Oil content in the seeds decreased in all the studied hybrids with crops thickening (in average, from 35.7 to 34.4%). All the studied foliar fertilizers had positive effect on sunflower seed yields and oil content in the seeds. The maximum yields which averaged to 2.11 t/ha were obtained under the foliar treatment with "Master N₁₈P₂₀K₂₀Mg₃" fertilizer in dose of 1.5 kg/ha at the stage of 5-6 leaves of the crop. The best performance with seed yield of 2.74 t/ha and oil content in the seeds of 39.4% was provided by cultivation of Megasan sunflower hybrid with plant density of 50,000 of plants per hectare under the foliar treatment with Master fertilizer in dose of 1.5 kg/ha at the stage of 5-6 leaves of the crop.

Keywords: sunflower, yields, oil content, cultivation technology.

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INTRODUCTION

Sunflower is one of the strategic crops in Ukraine. It remains the major oil crop and about 90% of plant oils in Ukraine are produced from the sunflower raw material. But sunflower is not a crop of only local importance. It is one of the most widely grown oil and industrial crops in the world with gross yields about 1.56 million tons (National Sunflower Association, 2015; Nasim et al., 2016). Sunflower oil is used in food industry, paint and varnish industry, cosmetology, pharmacy, etc. So, it is important to guarantee stable crop production and increase of its gross yields.

Cultivation technology is one of the major factors of sunflower productivity increase. Sunflower agrotechnology was widely studied by many Ukrainian and foreign scientists. The main factors effecting the productivity of crop and yield quality are hybrids, fertilizers and, of course, irrigation. These factors were proved to have the greatest impact on the crop yields and oil content in seeds, especially, speaking about genetic features of hybrids (Zheljazkov et al., 2009; Diovisalvi et al., 2018) and fertilization system (Shoghi-Kalkhoran et al., 2013; Nasim et al., 2017), particularly, in the non-irrigated conditions. However, a number of questions remains unsolved yet. First of all, it is true for foliar fertilization that is not sufficiently studied on sunflower crops. Besides, new hybrids of the crop require cultivation technology which must be adjusted to their morphological and biological features, and in this case even completely settled problems concerning, for example, plant densities or tillage need revision for the concrete crop hybrid in the concrete soil and climatic conditions. So, the main goal of our investigations was to determine the optimal combination of plant density and foliar fertilization treatment for the most popular in Ukraine sunflower hybrids in the rain-fed conditions of the Steppe zone.

MATERIALS AND METHODS

The field trials were carried out during 2014-2016 years at the experimental field of the research farm “Kopani” (Kherson region of Ukraine; geographical coordinates: latitude 46°47’23”N and longitude 32°20’44”E; altitude – 42 m).

The soil of the field is represented by the dark-chestnut middle-loamy soil with humus content of 2-3%. Content of the main nutrients in the soil samples was determined by using the common methodology (Arinushkina, 1970). Content of the main nutrients in the soil by particular layers is given in the Table 1.

Table 1: Content of the main nutrients in the soil of the experimental field, mg/kg

Soil layer, cm	Nutrients		
	Nitrate nitrogen (determined by Grandval-Liazhu method)	Mobile phosphorus (determined by Machyhin method)	Exchangeable potassium (determined by photometric method)
0-30	10.4	47.3	734
30-50	13.5	48.8	693
50-100	18.3	33.2	617

The climate of the zone is moderately continental. It is characterized as warm and comparatively dry, with a strong tendency to increase of drought periods in the summer (Lykhovyd, 2018). Weather conditions in the years of the trials conduction by the main meteorological indexes are represented in the Table 2.

Table 2: Weather conditions in the years of the trials

Month	Decade	Air temperature, °C			Relative humidity, %			Rainfall, mm		
		2014	2015	2016	2014	2015	2016	2014	2015	2016
April	I	12.4	10.9	14.3	74	72	77	29.2	5.8	45.5
	III	14.5	11.3	12.3	63	72	74	0.3	10.1	10.1

May	I	13.7	13.9	14.5	75	77	72	33.0	13.7	12.7
	II	17.8	17.4	15.3	75	62	79	5.2	2.5	38.3
	III	22.2	19.6	18.5	61	69	77	0.0	70.7	20.7
June	I	22.4	21.3	17.8	64	61	70	13.3	7.1	16.2
	II	20.0	21.3	21.9	58	67	75	28.6	3.4	12.8
	III	20.0	20.0	26.5	64	73	62	22.5	27.8	14.0
July	I	23.5	22.8	22.4	53	74	61	0.0	84.9	21.6
	II	25.5	21.0	25.8	56	66	59	9.4	19.7	0.0
	III	26.1	26.0	25.0	49	67	54	10.0	0.0	24.7
August	I	27.8	26.0	26.0	45	49	55	11.1	0.0	0.6
	II	25.1	23.8	23.3	57	54	58	0.8	12.1	0.0
	III	21.0	22.9	24.7	56	46	62	8.8	0.0	26.1

The field trials were devoted to investigation of the effect of cultivation technology elements on the yield and quality of sunflower seeds. The trials were carried out in four replications using the split plot design method. We studied the following agrotechnological factors in the trials, namely:

Factor A – Hybrids: Megasan, Yason, Darii.

Factor B – Plant density: 30,000; 40,000; 50,000; 60,000 of plants per hectare.

Factor C – Foliar fertilization treatments: no treatment (control); “ROST-concentrate 5:5:5” in dose of 0.5 L/ha; “Vuksal” in dose of 2.0 L/ha; “Master N₁₈P₂₀K₂₀Mg₃” in dose of 1.5 kg/ha (the doses used in the trials were recommended by the producers of these fertilizers).

Sunflower seed yields were determined by the entire hand-made harvesting of the experimental plots with further adjustment of the obtained values to the standard moisture of seeds. Oil content was defined by using the Soxhlet extractor (Jensen, 2007).

The analysis of variance (ANOVA) was used to prove significance of the obtained in the trials differences between the trials variants. The difference was estimated by comparing with the least significant difference (LSD) values at the probability level $p < 0.05$ (Devore, 2011).

The characteristics of the studied sunflower hybrids are given below.

Megasan – sunflower middle-ripening hybrid originated by Limagrain company. Average plants height is 135 cm, average diameter of the head is 15.5 cm. It is characterized as stress tolerant and comparatively resistant to the major diseases. Oil content in the seeds is declared to be at the level of 49-50%.

Yason – sunflower early-ripening hybrid originated by the Institute of Plant Science named after Yuriev of the National Academy of Agrarian Sciences of Ukraine. Average plants height is 160-185 cm, average diameter of the head is 18-24 cm. Oil content in the seeds is declared to be at the level of 49.7-50.1%.

Darii – sunflower middle-early-ripening hybrid originated by the Institute of Plant Science named after Yuriev of the National Academy of Agrarian Sciences of Ukraine. It is characterized as powdery mildew and rot resistant one. Average plants height is 175-180 cm. Oil content in the seeds is declared to be at the level of 50.9%.

The characteristics of the studied fertilizers are given below.

“ROST-concentrate 5:5:5” is a multi-component fertilizer created on the basis of humus acids accompanied with micro and macro nutrients. The fertilizer contains 5% both of nitrogen, phosphorus and potassium in the active substance. It is recommended to be used in foliar applications. The fertilizer was created by the Institute of Soil Science and Agrochemistry named by Sokolovskii (Kharkiv, Ukraine).

“Vuksal” is a complex multi-component fertilizer which contains 7.5% of nitrogen, 15% of potassium, 4.5% of magnesium in calculation on the active substance content. Additionally it contains 4.5 g/L of boron, 7.5 g/L of copper, 15.0 g/L of iron, 22.5 g/L of manganese, 0.15 g/L of molybdenum, 15.0 g/L of zinc and 78.0 g/L of sulphur. It is recommended to be used as a foliar fertilizer.

“Master” is a water-soluble fertilizer which is recommended to be used with irrigation water or as a foliar fertilizer. There are a lot of different types of the fertilizer. We used Master with $N_{18}P_{20}K_{20}Mg_3$ content of the nutrients in the active substance.

The cultivation technology used in the trials was common for the rain-fed conditions of the Steppe zone of Ukraine. The fore-crop was winter wheat. After harvesting of the fore-crop we carried out disc harrowing followed by application of nitrogen and phosphorus mineral fertilizers in dose of $N_{30}P_{60}$ by the active substance, and then performed moldboard plowing at the depth of 25-27 cm. The early spring begun with shallow dragging of the soil surface. Sowing of sunflower was carried out in the second or third decade of April at the depth of 5-7 cm and inter-row spacing of 70 cm. *Harnes* herbicide (the active substance is Acetochlor, 900 g/L) was applied straight away after sowing in dose of 2.7 L/ha. Then the soil surface was rolled. Two inter-row cultivations were carried out during the vegetation period of the studied crop. The studied foliar fertilizers were applied by spraying them at the stage of 5-6 leaves of the crop. Harvesting was conducted when seed moisture decreased to 8-9%. Dates of sowing and harvesting of the crop in the trials are given in the Table 3.

Table 3: Dates of sowing and harvesting of sunflower in the trials

Hybrid	Year	Dates of	
		sowing	harvesting
Megasan	2014	April, 16 th	August, 27 th
Yason		April, 16 th	August, 25 th
Darii		April, 16 th	August, 19 th
Megasan	2015	April, 12 th	September, 4 th
Yason		April, 12 th	August, 29 th
Darii		April, 12 th	August, 22 nd
Megasan	2016	April, 23 rd	August, 23 rd
Yason		April, 23 rd	August, 20 th
Darii		April, 23 rd	August, 15 th

RESULTS AND DISCUSSION

The results of the trials showed significant difference in yields and oil content in the seeds of sunflower between the studied variants due to the cultivation technology used (Table 4, 5).

First of all, a comparison of the studied hybrids in productivity showed that the highest seed yields were obtained by cultivation of hybrid Megasan. Seed yield of the above-mentioned hybrid averaged to 2.19 t/ha during the period of the trials. The other hybrids of sunflower formed only 1.90 (Yason) and 1.75 (Darii) t/ha of seeds. So, Megasan surpassed them in productivity on 15.26 and 25.14%, respectively. Moreover, the highest oil content was also determined in the seeds of Megasan hybrid. It averaged to 36.9%, comparatively to only 34.3% of Yason and 35.4% of Darii hybrids. This fact gave us an opportunity to conjecture that Megasan hybrid of sunflower is the most favorable among the studied ones for cultivation in the rain-fed conditions of the Steppe zone of Ukraine.

Table 4: Sunflower seed yields depending on hybrids, plants densities and fertilization treatments (average of 2014-2016)

Hybrid (Factor A)	Plants density, plants per hectare (Factor B)	Fertilization treatments (Factor C)			
		Control (no treatment used)	“ROST-concentrate 5:5:5”	“Vuksal”	“Master N ₁₈ P ₂₀ K ₂₀ Mg ₃ ”
Megasan	30,000	1.68	1.81	1.96	2.14
	40,000	1.96	2.26	2.38	2.57
	50,000	2.05	2.49	2.62	2.74
	60,000	1.78	2.09	2.25	2.31
Yason	30,000	1.56	1.76	1.73	1.93
	40,000	1.82	1.93	2.00	2.29
	50,000	1.90	2.09	2.19	2.37
	60,000	1.57	1.73	1.83	1.76
Dariii	30,000	1.44	1.63	1.68	1.81
	40,000	1.67	1.82	1.99	2.09
	50,000	1.69	1.79	1.95	2.00
	60,000	1.45	1.57	1.70	1.76

Note. The LSD at $p < 0.05$ by the studied factors in t/ha: A – 0.027; B – 0.021; C – 0.039.

The next point of our trials was plant density. It was established by a number of scientific and research works that this technological factor sometimes has crucial effect on seed yields of sunflower (Mojiri and Arzani, 2003). Besides, the optimal plant density relies on hybrid biological and morphological features and cultivation conditions, especially, water availability for the crop. However, it is true both for irrigated and non-irrigated conditions that sunflower yields and seed quality tend to decrease in thickened crops (Barros et al., 2004). Our researches just approved this point. We determined that the highest productivity of Megasan and Yason hybrids was provided by forming the plant density of 50,000 of plants per hectare, while Dariii hybrid showed the best yields under 40,000 of plants per hectare. Further thickening of the crops led to significant decrease of the yields. We also established that the highest oil content in the seeds was guaranteed by the lowest plant density of 30,000 of plants per hectare and averaged to 35.7%. Plant density of 60,000 of plants per hectare led to decrease of the oil content in the seeds of all the studied hybrids in average to 34.4%.

Table 5: Oil content in sunflower seeds depending on hybrids, plants densities and fertilization treatments (average of 2014-2016)

Hybrid (Factor A)	Plants density, plants per hectare (Factor B)	Fertilization treatments (Factor C)			
		Control (no treatment used)	“ROST-concentrate 5:5:5”	“Vuksal”	“Master N ₁₈ P ₂₀ K ₂₀ Mg ₃ ”
Megasan	30,000	34.8	36.2	39.4	39.5
	40,000	34.9	36.0	38.5	39.4
	50,000	34.7	36.3	37.2	39.4
	60,000	33.2	35.8	37.8	37.6
Yason	30,000	32.9	34.3	36.8	37.0
	40,000	32.6	33.9	36.0	36.3
	50,000	32.2	32.9	35.5	36.5
	60,000	31.1	32.0	33.9	35.7
Dariii	30,000	33.8	35.4	36.9	37.8
	40,000	33.6	35.0	36.9	37.5
	50,000	33.5	34.9	35.5	38.3
	60,000	32.1	33.5	33.8	37.2

Note. The LSD at $p < 0.05$ by the studied factors in %: A – 0.62; B – 0.89; C – 0.70.

Sunflower yields were proved to increase due to the use of foliar fertilization with micro-nutrients

(Babaeian et al., 2011). The results of our trials confirm this statement. All the foliar fertilizers applied in the trials significantly increased yields and oil content in the seeds of sunflower. The maximum positive effect on the crop productivity and yield quality was achieved by using “Master N₁₈P₂₀K₂₀Mg₃” fertilizer (yields averaged to 2.11 t/ha). The increase of yields in comparison with the control variant averaged to 26.35%, and increase in the oil content in the seeds averaged to 13.21%, correspondingly. The effect of “ROST-concentrate 5:5:5” and “Vuksal” was considerably lower and averaged to 11.98 and 19.16% on the yields, and 4.20 and 9.61% on the oil content in the seeds, respectively.

The results of the trials allow to improve sunflower cultivation technology in the conditions of the Steppe zone of Ukraine. However, the trials were limited in the studied factors volume and further investigations should be carried on to settle the problem of sunflower cultivation, especially, taking into account emergency of new high-productive hybrids of the crop and innovative micro and macro fertilizers.

CONCLUSIONS

The maximum yield of sunflower seeds (2.74 t/ha) was formed by hybrid Megasan under the plant density of 50,000 of plants per hectare and foliar treatment with “Master N₁₈P₂₀K₂₀Mg₃” fertilizer in dose of 1.5 kg/ha. It was also established that the optimal plant density for hybrids Megasan and Yason is 50,000 of plants per hectare, and for hybrid Darii – 40,000 of plants per hectare. The highest oil content in the seeds was determined in hybrid Megasan where this index fluctuated between 37.6 and 39.5% under the treatment with “Master N₁₈P₂₀K₂₀Mg₃” fertilizer. The most efficient fertilizer of the studied was “Master N₁₈P₂₀K₂₀Mg₃” that provided the highest yield and oil content increase.

We recommend farmers to grow sunflower hybrid Megasan with plant density of 50,000 of plants per hectare under the foliar treatment at the stage of 5-6 leaves of the crop with “Master N₁₈P₂₀K₂₀Mg₃” fertilizer in dose of 1.5 kg/ha. The above-mentioned cultivation technology complex provides the highest crop productivity under the rain-fed conditions of the Steppe zone of Ukraine.

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