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SUNFLOWER GRAIN YIELD AT DIFFERENT CONDITIONS OF ROW SPACING AND PLANT DENSITY

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Abstract

Sunflower is a major oil crop whose oil is very important in human nutrition as well as for a range of other uses. Grain yield is determined by the plant genetics and it is conditioned by a series of factors among which are counting as important ones the row spacing and plant density. Therefore, find the optimum row spacing and plant density according to cultivated sunflower hybrid and to growing conditions are of interest for sunflower growers.
The aim of this paper is to present the results obtained with respect to the sunflower grain yield at different row spacing and plant densities in the specific growing conditions of Romania. Research was performed under field conditions at four sunflower hybrids under different row spacing (70, 60, and 50 cm) and plant densities (50,000, 60,000, and 70,000 plants/ha). The field experiments were located in four locations in East, South-East and South of Romania in three years (2019, 2020, and 2021). The obtained data showed that under favourable growing conditions for sunflower plants, especially under good water plant supply conditions, the highest grain yields are obtained at row spacing of 70 cm, while under less favourable growing conditions for sunflower plants, the narrower rows (at 60 cm and 50 cm) seem to provide better plant growth and finally higher grain yields. Plant density has to be correlated with the growing conditions of the sunflower plants. Thus, the better growing conditions are the higher plant density should be, as to put into value the available growing factors. In the case there is no correlation between the plant density and growing conditions, the plants density too high becomes a limitative yielding factor.

Key words*: sunflower, grain yield, row spacing, plant density.*

INTRODUCTION

Sunflower is a major oil crop whose oil is very important in human nutrition as well as for a range of other uses. Aside from its current uses, ecosystem services (e.g. bee feeding, soil phytoremediation...) and non-food industrial uses are now expected externalities for the sunflower crop (Debaeke et al., 2021).
Sunflower crop can be characterised as being easy to manage, flexible and economic, but however demanding in terms of establishment and control to achieve a fair satisfaction of its needs (Lecomte & Nolot, 2011).
The sunflower yield is determined by the interaction of the genetics of the hybrid with the environmental factors and the crop technology the farmer can implement.
Agronomic practices in addition to high yielding varieties are important items for higher productivity of the sunflower crop (Beg et al., 2007). In the crop technology, sowing method is one of the most important agronomic practices which affect the performance of sunflower crop by modifying it phenologically and morphologically (Bakheit et al., 2022).
Productivity per unit area of sunflower is determined by many factors including plant population (Hossam, 2012).
Plant population based on row and plant spacing is a major part of agronomic practices (Beg et al., 2007), it affecting primarily the amount of radiation intercepted per plant (Villalobos et al., 1994). One important management consideration is choosing a plant density that will maximize the yield (Holt & Campbell, 1984).
Sunflower can be manipulated over a wide range of plant density and row spacing (Vijayalakshmii et al., 1975).

Plant spacing effects are greatly prominent in various crops including sunflower because there is no option of filling gaps between plants by tillering and branching (Ali et al., 2013; Sneha et al., 2022). Sunflower crop can be grown over different row spacing conditions; for a given plant population, row spacing is determining the shape of the nutritional space (Ion et al., 2018).

Narrow rows make sunflower plants able to use in an efficient way the growing resources, respectively the solar radiation, water and nutrients, but this seems to be influenced by the specific environmental factors (Ion et al., 2015). The experimental results show that different planting patterns sometimes produced higher yield, but not always (Zarea et al., 2005). There are reports showing that reduced distance between rows could be neutral, beneficial or counterproductive (Calviñoa et al., 2004). Thus, there are authors who obtained higher grain yields at row spacing of 75 cm than at row spacing of 50 cm (Diepenbrock et al., 2001; Kazemeini et al., 2009) or obtained higher grain yields at row spacing of 60 cm than at row spacing of 45 or 30 cm (Nawaz et al., 2001), while other authors obtained higher grain yields at narrow rows (Zarea et al., 2005).

The aim of this paper is to present the results obtained with respect to the sunflower grain yield at different row spacing and plant densities in the specific growing conditions of Romania.

MATERIALS AND METHODS

Research was performed in field experiments under rainfed conditions in the years 2019, 2020, and 2021. The field experiments were located each year in four locations, among which one in East Romania, one in South-East Romania and two in South Romania, these locations being characterised as follows:

- Negrești, which is located in eastern part of Romania, Vaslui county, Moldavia region; the soil is a cambic chernozem, the average annual temperature is of 9.5ºC, and the average annual rainfall is of 420 mm.
- Cogealac, which is located in southeast part of Romania, Constanța county, Dobruja region; the soil is a chernozem, the average annual temperature is of 10.7ºC, and the average annual rainfall is of 352 mm.
- Dâlga, which is located in southern part of Romania, Călărași county, southeast part of Romanian Plain; the soil is a chernozem, the average annual temperature is of 11.0ºC, and the average annual rainfall is of 503.6 mm.
- Troian, which is located in southern part of Romania, Teleorman county, central-southern part of Romanian Plain; the soil is a chernozem, the average annual temperature is of 10.4ºC, and the average annual rainfall is of 550.1 mm.

The field experiments were based on method of subdivided plots into 3 replications, with the following factors:

- Factor A - row spacing, with 3 graduations:
  - a2 = 70 cm;
  - a3 = 60 cm;
  - a4 = 50 cm.
- Factor B - plant density, with 3 graduations:
  - b1 = 50,000 plants/ha;
  - b2 = 60,000 plants/ha;
  - b3 = 70,000 plants/ha.
- Factor C - sunflower hybrid, with 4 graduations:
  - c1 = KWS Acer (early Clearfield hybrid);
  - c2 = NK Neoma (mid-early Clearfield hybrid);
  - c3 = P64LE25 (mid-early sulfonylurea resistant hybrid);
  - c4 = Subaro (mid-late hybrid).

In all locations and all experimental years, the preceding crop was winter wheat. The fertilisation was performed with 40-60 kg/ha of nitrogen and 40-60 kg/ha of phosphorus by applying 200-300 kg/ha of 20:20:0 complex fertiliser, according to soil conditions in each location. The fertiliser was applied by spreading it before seedbed preparation.

Tillage in the experimental fields consisted in ploughing in autumn, one disk harrow passage in March, and seedbed preparation before sowing made with a combinatory.

Sowing was performed in the first two decades of April except for Troian location where sowing was performed either at the end of April or at beginning of May, and Dâlga location in 2021, when sowing was performed at beginning of May (Table 1).

Table 1. Sowing data in the field experiments according to location and year

Location	Year		
	2019	2020	2021
Negrești	09 of April	06 of April	19 of April
Cogealac	11 of April	10 of April	16 of April
Dâlga	10 of April	14 of April	03 of May
Troian	03 of May	29 of April	05 of May

The weed control was made by applying the herbicide Dual Gold 960 EC (S-metolachlor 960 g/l) in a rate of 1.5 l/ha applied either before seedbed preparation or after sowing, respectively before emergence. For controlling the monocotyledonous weeds, in the vegetation period it was used the herbicide Select Super (Clethodim 120 g/l) in a rate of 0.8-1.3 l/ha, depending on the weeds (annual or perennial) identified in the experimental plot.

The sunflower heads of each experimental variant were harvested in the stage of full maturity and the grain yield was calculated in kg/ha and was expressed at 9% moisture content. The data are presented in this paper as average values for the four studies sunflower hybrids and they were statistically processed by the analysis of variance (ANOVA).

In all locations of experimentation, the year 2020 was the warmest, while the year 2019 was the coldest except for Negresti location where the coldest year was 2021 (Table 2). Among the four locations, the highest average temperatures were registered in Cogealac and Dâlga, while the smallest average temperatures were registered in Troian location.

Also in all locations of experimentation, the year 2021 was the rainiest year, while the year 2020 which was the warmest was also the driest (Table 3). Among the four locations, the Negrești and Troian locations were the wettest and the Cogealac and Dâlga were the driest. Dâlga location was exposed to extreme rainfall, with a very dry year 2020 (340.9 mm rainfall) and a very wet year 2021 (851.7 mm rainfall).

Table 2. Average temperatures in the four locations and the three experimental years

Month	Temperatures in Negrești location (ºC)			Temperatures in Cogealac location (ºC)			Temperatures in Dâlga location (ºC)			Temperatures in Troian location (ºC)		
	2018-2019	2019-2020	2020-2021	2018-2019	2019-2020	2020-2021	2018-2019	2019-2020	2020-2021	2018-2019	2019-2020	2020-2021
Sept.	16.0	17.0	18.2	20.2	20.7	21.4	19.8	20.0	20.7	15.7	18.8	20.0
Oct.	11.5	12.7	13.2	15.7	15.2	16.6	14.8	14.6	15.3	12.5	13.2	13.4
Nov.	4.1	8.7	4.4	7.3	13.1	6.6	5.5	12.3	6.4	4.2	8.4	4.4
Dec.	-2.2	1.8	3.6	1.9	6.9	5.6	0.4	3.6	4.3	-1.6	2.1	2.0
Jan.	1.5	-0.9	-0.1	1.9	3.7	4.0	-1.8	1.3	3.9	-2.2	-0.3	-0.2
Feb.	2.8	3.7	-0.4	4.0	6.5	4.9	3.0	5.5	5.4	2.3	4.0	1.9
Mar.	10.0	6.6	3.0	8.7	8.8	5.4	9.7	8.6	6.1	8.2	6.5	3.4
Apr.	14.7	10.1	7.0	10.5	9.9	10.0	11.9	12.4	11.3	9.5	10.3	7.8
May	16.6	13.6	15.7	16.6	15.7	16.2	17.6	16.6	18.7	15.2	15.5	14.9
Jun.	21.7	22.0	20.6	24.3	20.8	19.8	25.5	22.8	21.9	21.8	19.5	19.9
Jul.	28.0	27.0	31.0	23.9	25.2	25.1	25.0	26.3	25.4	22.8	23.0	25.6
Aug.	29.8	23.5	28.6	24.4	25.0	24.6	25.8	26.4	25.7	24.2	23.7	24.3
Mean	*12.9*	*12.2*	*12.1*	*13.3*	*14.3*	*13.4*	*13.1*	*14.2*	*13.8*	*11.1*	*12.1*	*11.5*

RESULTS AND DISCUSSIONS

In three of the four studied locations in Romania, respectively in Negrești, Cogealac and Dâlga, the highest average grain yields were registered at row spacing of 70 cm (Figure 1). Sowing at narrower rows proved to lead at a decreasing of the grain yield, the differences of the grain yield registered at 70 cm row spacing and those obtained at row spacing of 60 cm and 50 cm being the highest in the rainy year 2021. However, for Cogealac location in 2019, when in August was registered 0 mm rainfall and the plants were in the stage of grain filling, the average grain yields obtained at the three studied row spacing were quite close.

Table 3. Average rainfall in the four locations and the three experimental years

Month	Rainfall in Negrești location (mm)			Rainfall in Cogealac location (mm)			Rainfall in Dâlga location (mm)			Rainfall in Troian location (mm)		
	2018-2019	2019-2020	2020-2021	2018-2019	2019-2020	2020-2021	2018-2019	2019-2020	2020-2021	2018-2019	2019-2020	2020-2021
Sept.	37.6	41.4	46.8	3.0	24.0	13.0	15.0	31.0	70.2	25.0	2.0	27.0
Oct.	2.2	34.2	74.0	11.0	61.0	26.0	10.0	43.0	33.0	8.0	20.0	69.0
Nov.	37.7	9.7	6.7	59.0	36.0	15.0	70.0	25.5	33.5	50.0	62.0	24.0
Dec.	34.2	11.8	58.0	30.0	7.0	78.0	52.0	18.0	88.0	58.0	13.0	46.0
Jan.	37.0	5.6	26.4	45.0	26.0	83.0	30.0	2.5	94.5	31.0	7.0	113.0
Feb.	23.5	26.1	17.4	11.0	0	32.0	14.0	28.8	28.0	24.0	52.0	9.0
Mar.	0	8.4	31.2	22.0	33.0	38.0	20.5	8.0	78.5	23.0	56.0	84.0
Apr.	81.6	0	38.6	15.0	3.0	34.0	59.0	11.0	28.0	55.0	13.0	48.0
May	72.0	100.6	35.3	44.0	17.0	42.0	57.5	51.5	67.0	45.0	127.0	82.0
Jun.	121.0	112.3	118.8	48.0	64.0	141.0	73.5	53.6	250.0	137.0	107.0	48.0
Jul.	36.0	7.5	65.0	74.0	22.0	28.0	32.0	65.0	34.0	79.0	6.0	22.0
Aug.	57.0	58.5	116.0	0	47.0	50.0	43.0	3.0	47.0	0	23.0	67.0
Sum	*539.8*	*416.1*	*634.2*	*362.0*	*340.0*	*580.0*	*476.5*	*340.9*	*851.7*	*535.0*	*488.0*	*639.0*

At Troian location where in all studied years the sowing was delayed being performed either at the end of April or at beginning of May, the average grain yield was higher at narrow rows, respectively at 60 cm and 50 cm between rows, the smallest yields being registered at row spacing of 70 cm. The yield differences were more evident in years 2019 and 2020 characterised by drought in July and August (0 mm rainfall in August in 2019 and 6 mm rainfall in July and 23 mm rainfall in August in 2020), respectively when the plants were in the stage of grain filling. In the rainy year 2021, even the highest average grain yield was registered at row spacing of 60 cm, the yields were quite close (Figure 1).

These findings are according to those found also for Romanian growing conditions for sunflower by Ion at al. (2015), respectively that under less favourable growing conditions the narrow rows seem to make sunflower plants to use the growing factors in a more efficient way which is reflected into higher values for the yield components of the head and finely into higher grain yields.

In two of the four studied locations in Romania, respectively in Negrești and Dâlga, the average grain yields increased with increasing of plant density, the highest yields being registered at plant density of 70,000 plants/ha (Figure 2). This situation was found also at Troian location in 2019, as well as Cogealac location in 2019 but with highest yield obtained at 60,000 plants/ha. In all the other cases, the average grain yields were close at the three plant densities or even decreased with increasing of plant density. This is proving that plant density has to be correlated with the growing conditions of the sunflower plants in searching for the optimum plant density. In the case there is no correlation between the plant density and growing conditions, the plants density too high becomes a limitative yielding factor.

Generally, the increasing of plant density from 50,000 plants/ha to 60,000 plants/ha and 70,000 plants/ha determined an increased grain yield at all the three row spacing, with an evident effect in locations Negrești and Dâlga, but with a limited effect in locations Cogealac and Troian (Figure 3). There was an exception in Cogealac location for row spacing of 70 cm and 50 cm, where increasing of plant density was associated with a decreased grain yield.

Compared to the grain yield obtained at row spacing of 70 cm and plant density of 50,000 plants/ha which was taken as control variant, it has to be underline the positive differences statistically significant registered at all row spacing in Troian location in 2019 (Table 4) and in Dâlga location in 2020 (Table 5), as well as those registered in Dâlga location in 2021 for row spacing of 70 cm and for row spacing of 60 cm but only for plant density of 60,000 plants/ha (Table 6).

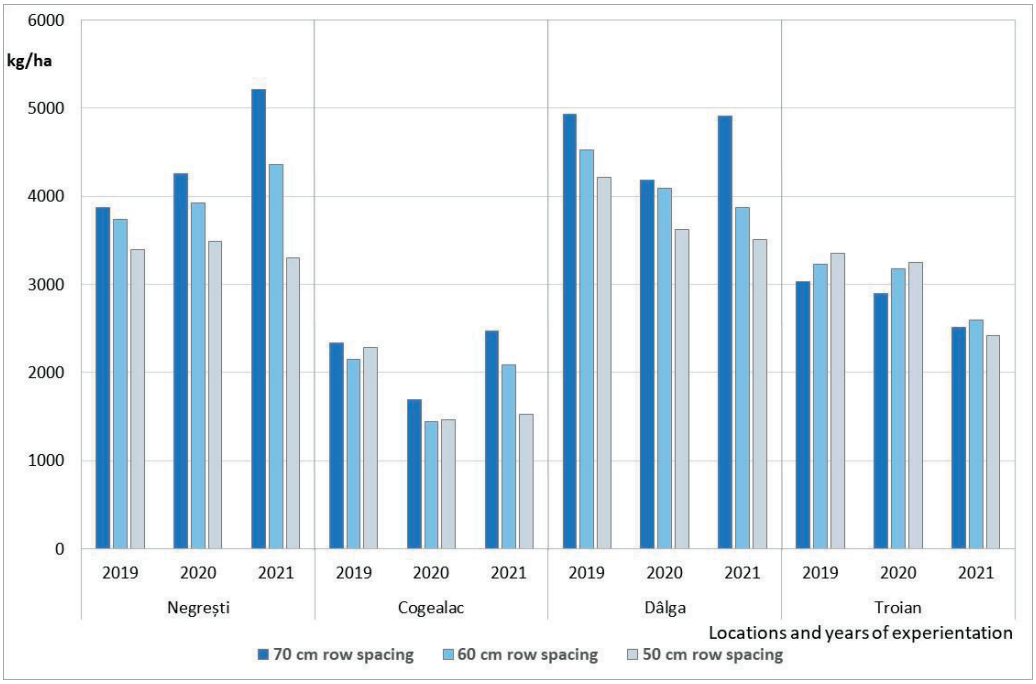

Figure 1. Sunflower grain yield at different row spacing in different years and locations in Romania

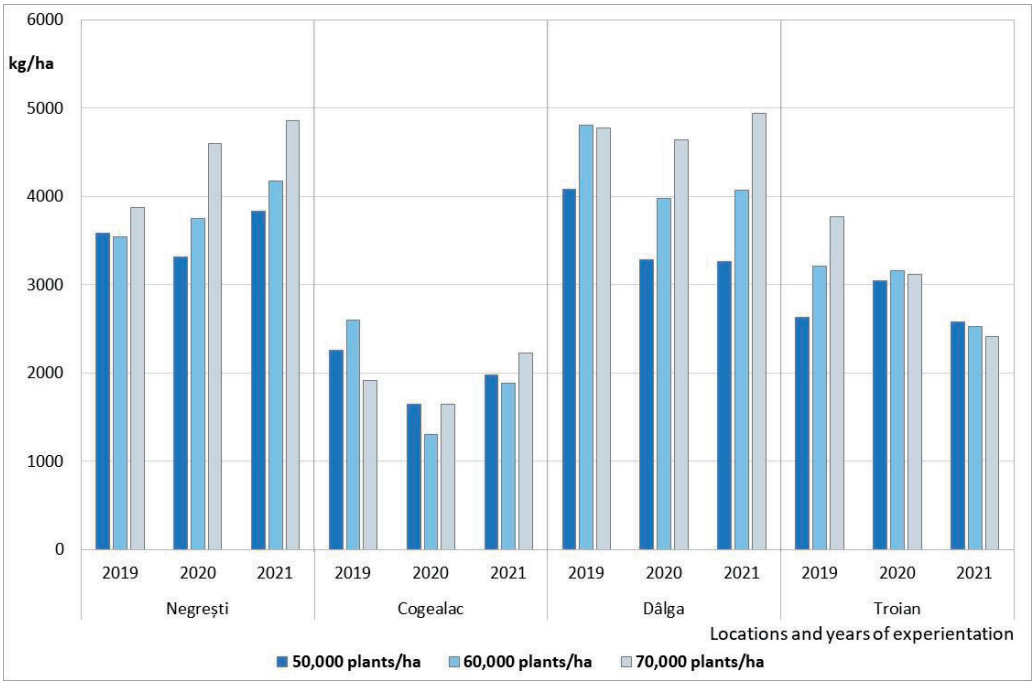

Figure 2. Sunflower grain yield at different plant densities in different years and locations in Romania

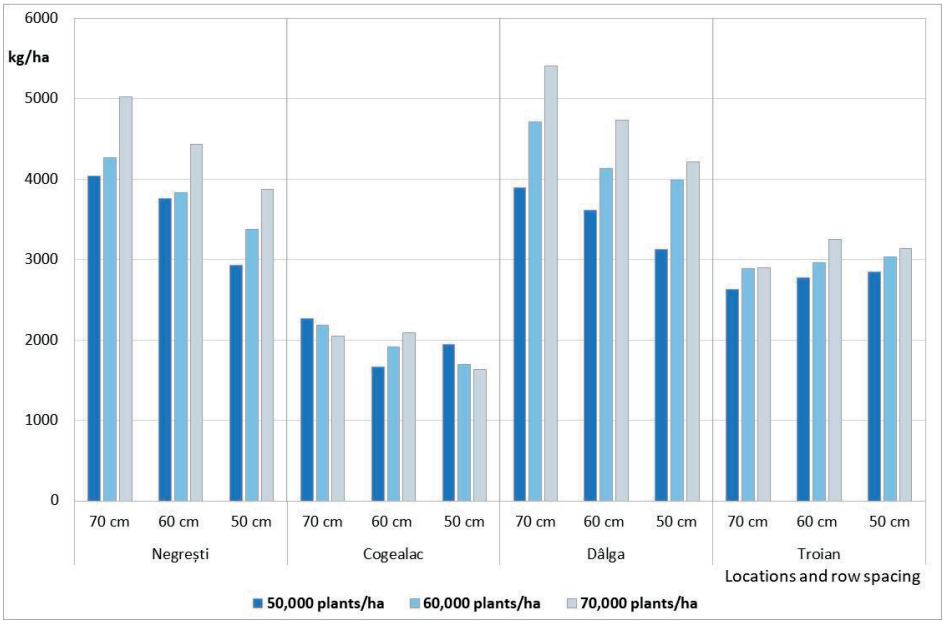

Figure 3. Sunflower grain yield at different plant densities and row spacing in different locations in Romania

Table 4. Sunflower grain yield at different row spacing and plant densities in 2019 and in different locations in Romania

Experimental factors		Negreşti location		Cogealac location		Dâlga location		Troian location	
Row spacing	Plant density	Yield (kg/ha)	Difference (kg)	Yield (kg/ha)	Difference (kg)	Yield (kg/ha)	Difference (kg)	Yield (kg/ha)	Difference (kg)
70 cm	50,000 plants/ha	3735	Control	2098	Control	4301	Control	2480	Control
	60,000 plants/ha	3699	-36	2726	628 *	5146	845 **	3075	595 ***
	70,000 plants/ha	4174	439	2198	100	5341	1040 ***	3523	1043 ***
60 cm	50,000 plants/ha	3544	-191	2159	61	4345	44	2593	113
	60,000 plants/ha	3721	-14	2472	374	4461	160	3167	687 ***
	70,000 plants/ha	3949	214	1818	-280	4758	457	3932	1452 ***
50 cm	50,000 plants/ha	3462	-273	2525	427	3609	-692 °°	2805	325 *
	60,000 plants/ha	3220	-515	2611	513	4800	499 *	3395	915 ***
	70,000 plants/ha	3497	-238	1713	-385	4218	-83	3860	1380 ***
DL5%		-	*788.50*	-	*613.04*	-	*492.47*	-	*318.44*
DL1%		-	*1064.78*	-	*827.85*	-	*665.03*	-	*430.18*
DL0.1%		-	*1417.91*	-	*1102.41*	-	*885.58*	-	*572.63*

Table 5. Sunflower grain yield at different row spacing and plant densities in 2020 and in different locations in Romania

Experimental factors		Negreşti location		Cogealac location		Dâlga location		Troian location	
Row spacing	Plant density	Yield (kg/ha)	Difference (kg)	Yield (kg/ha)	Difference (kg)	Yield (kg/ha)	Difference (kg)	Yield (kg/ha)	Difference (kg)
70 cm	50,000 plants/ha	3786	Control	1874	Control	3458	Control	2831	Control
	60,000 plants/ha	4045	259	1563	-311	4104	646 ***	3123	292
	70,000 plants/ha	4928	1142 *	1644	-230	4991	1533 ***	2727	-104
60 cm	50,000 plants/ha	3520	-266	1526	-348	3374	-84	3084	253
	60,000 plants/ha	3532	-254	1226	-648 º	4135	677 ***	3108	277
	70,000 plants/ha	4713	927 *	1564	-310	4756	1298 ***	3337	506 *
50 cm	50,000 plants/ha	2631	-1155 º	1544	-330	3015	-443 °°°	3235	404
	60,000 plants/ha	3673	-113	1133	-741 º	3678	220 *	3234	403
	70,000 plants/ha	4152	366	1726	-148	4171	713 ***	3278	447 *
DL5%		-	*895.96*	-	*600.74*	-	*197.73*	-	*443.11*
DL1%		-	*1209.90*	-	*812.24*	-	*267.01*	-	*598.37*
DL0.1%		-	*1611.16*	-	*1080.28*	-	*355.57*	-	*796.82*

Table 6. Sunflower grain yield at different row spacing and plant densities in 2021 and in different locations in Romania

Experimental factors		Negrești location		Cogealac location		Dâlga location		Troian location	
Row spacing	Plant density	Yield (kg/ha)	Difference (kg)	Yield (kg/ha)	Difference (kg)	Yield (kg/ha)	Difference (kg)	Yield (kg/ha)	Difference (kg)
70 cm	50,000 plants/ha	4594	Control	2833	Control	3922	Control	2591	Control
	60,000 plants/ha	5051	457	2257	-576 °	4906	984 ***	2485	-106
	70,000 plants/ha	5972	1378 **	2307	-526	5903	1981 ***	2458	-133
60 cm	50,000 plants/ha	4209	-385	1326	-1507 °°°	3114	-808 °°°	2656	65
	60,000 plants/ha	4233	-361	2040	-793 °°	3815	-107	2624	33
	70,000 plants/ha	4640	46	2880	47	4683	761 ***	2498	-93
50 cm	50,000 plants/ha	2709	-1885 °°°	1768	-1065 °°°	2759	-1163 °°°	2496	-95
	60,000 plants/ha	3238	-1356 °°	1343	-1490 °°°	3502	-420 °°°	2476	-115
	70,000 plants/ha	3968	-626	1480	-1353 °°°	4252	330 **	2292	-299
DL5%		-	951.47	-	540.40	-	215.84	-	390.03
DL1%		-	1284.86	-	729.76	-	291.47	-	526.70
DL0.1%		-	1710.98	-	971.78	-	388.14	-	701.38

CONCLUSIONS

The obtained data showed that under favourable growing conditions for sunflower plants, especially under good water plant supply conditions, the highest grain yields are obtained at row spacing of 70 cm, which is the row spacing generalized in Romania for sunflower crop. However, under less favourable growing conditions for sunflower plants, the narrower rows (at 60 cm and 50 cm) seem to provide better plant growth and finally higher grain yields compared to the row spacing of 70 cm.

Plant density has to be correlated with the growing conditions of the sunflower plants in searching for the optimum plant density. Thus, the better growing conditions are the higher plant density should be as to put into value the available growing factors. In the case there is no correlation between the plant density and growing conditions, the plants density too high becomes a limitative yielding factor.

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