

CORRELATION OF SUNFLOWER YIELD WITH HEAD YIELDING ELEMENTS ACCORDING TO ROW SPACING AND PLANT DENSITY

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Abstract

Sunflower grain yield is positively correlated with head yielding elements (head diameter, the number of grains per head, the weight of grains per head and the 1000-grain weight - TGW), but the correlations of grain yield are stronger with some yielding elements and lower with some others. The present paper aims to identify the particular correlation of sunflower grain yield with head yielding elements according to row spacing and plant density. The analysed data were obtained in the research performed in 2019, 2020, and 2021 in field experiments under rainfed conditions located in four locations in Romania (one in East, one in South-East, and two in South Romania). The experimental factors were the following: Factor A – row spacing, with 3 graduations: a1 - 70 cm; a2 - 60 cm; a3 - 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; c2 - NK Neoma; c3 - P64LE25; c4 - Subaro. In the performed research, generally, the coefficient of correlation of sunflower grain yield with the head yielding elements decreases with row spacing decrease and increases with plant density increase. The highest correlation coefficient of grain yield was registered with grain weight per head and TGW regardless of row spacing and plant density. But regardless of plant density, as the row spacing decreases, it decreases the value of the correlation coefficient of grain yield with grain weight per head and increases the value of the correlation coefficient of grain yield with TGW.

Key words: sunflower, correlation coefficient, yield, yielding elements, row spacing, plant density.

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is an important oilseed crop in the world, but mostly in Europe, especially in the Black Sea Basin. It offers a wide adaptability, suitability to mechanization, low labour needs, and high oil and protein contents (Canavar et al., 2010).

Sunflower yield is a complex character which depends on several component yield characters (Manivannan et al., 2005). So, like in the case of other crops, sunflower yield is dependent of yield components which have interrelation among them and affect the seed yield directly or indirectly (Gorgjieva et al., 2015).

The yield and the yield components of the head are specific to each sunflower hybrid, but they are influenced by the different growing factors, such as environmental factors (e.g. soil and climatic conditions) and technological factors

(e.g. row spacing and plant population) (Ion et al., 2015). It is of great importance to know the relationships between yield contributing characters (Clapco et al., 2019).

Correlation studies in sunflower revealed that grain yield is positively associated with yield components (Gouri Shankar et al., 2006). Generally, the grain yield at sunflower is positively correlated with head yielding elements such as head diameter, the number of grains per head, the weight of grains per head and the 1000-grain weight (Alia et al., 2022; Baraiya et al., 2018; Bran, 2022; Clapco et al., 2019; Ionescu et al., 2021; Jalil et al., 2014; Kalukhe et al., 2010; Kaya et al., 2007; Neelima et al., 2012; Pandya et al., 2015; Radic et al., 2013; Sanju et al., 2018; Singh et al., 2018; Sri et al., 2025; Tyag & Khan, 2013; Varalakshmi et al., 2019; Yasin & Singh, 2018). But the correlations of grain yield are stronger with

some yielding elements and lower with some others. For instance, the grain yield is positive but low correlated with the head diameter according to some authors (Bran, 2022; Clapco et al., 2019) even negative correlated (Mola, 2024), while to some others are positive but significant (Baraiya et al., 2018; Gangavati & Kulkarni, 2021; Machikowa & Saetang, 2008; Nirmala et al., 1999; Patil, 2011; Sanju et al., 2018).

Sunflower crop can be grown over different row spacing which is determining the shape of the nutritional space for a given plant population (Ion et al., 2018). Plant population based on row and plant spacing is a major part of agronomic practices (Beg et al., 2007).

Sunflower yield responses to inter-row distances are variable, there being reports showing that reduced distance between rows could be neutral, beneficial or counterproductive (Calviño et al., 2004).

To achieve highest yield potential of a sunflower hybrid, providing ideal or optimum geometry is through best planting density (Sneha et al., 2022). Grain yield had significant differences by plant density (Modanlo et al., 2021). Even plant spacing effects are highly pronounced in sunflower because there is no possibility of covering gaps between plants by branching or tillering (Sneha et al., 2022), sunflower will compensate to a certain extent for differences in plant populations and density through adjustments in head size (Ibrahim et al., 2023). So, regulating planting density stands out among the critical cultivation factors influencing sunflower yield (Li & Liu, 2025).

Correlation describes the mutual relationship between the variables and helps to improve different characters simultaneously (Singh et al., 2018). Correlation coefficient is very important to define the traits that directly affect the seed yield (Gorgjieva et al., 2015). So, it is of interest from different perspectives (e.g. plant breeding, farming) to identify the correlation of yield with yielding elements according to different growing conditions, both environmentally and technologically. In this respect, the present paper aims to identify the particular correlation of sunflower grain yield with head yielding elements according to row spacing and plant density.

MATERIALS AND METHODS

Research was performed in the years 2019, 2020, and 2021 in four locations in Romania, respectively:

- Negrești, located in eastern part of Romania, in Vaslui County.
- Cogealac, located in southeast part of Romania, in Constanța County.
- Dâlga, located in southern part of Romania, in Călărași County.
- Troian, located in southern part of Romania, in Teleorman County.

Research consisted of field experiments under rainfed conditions organised as subdivided plots with 3 replications. There were studied three experimental factors, respectively:

- Factor A – row spacing, with 3 graduations:
 - a1 = 70 cm;
 - a2 = 60 cm;
 - a3 = 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);
 - NK Neoma (mid-early Clearfield hybrid);
 - P64LE25 (mid-early sulfonylurea resistant hybrid);
 - Subaro (mid-late sulfonylurea resistant hybrid).

The crop technology was the same in all locations and experimental years. Thus, the preceding crop was winter wheat.

Fertilisation consisted of applying 40-60 kg/ha of nitrogen and 40-60 kg/ha of phosphorus by spreading 200-300 kg/ha of 20:20:0 complex fertiliser before seedbed preparation, according to soil conditions in each location.

Tillage consisted in ploughing in autumn, one disk harrow passage in March, and seedbed preparation before sowing.

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 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 performed by applying the herbicide Dual Gold 960 EC (S-metolachlor 960 g/l) in a rate of 1.5 l/ha either before seedbed preparation or after sowing, but before emergence. This was completed by the herbicide Select Super (Clethodim 120 g/l) applied in the growth period of sunflower plants in a rate of 0.8-1.3 l/ha, according to the weeds species (annual or perennial monocotyledonous weeds) identified in the experimental field.

The research covered different climatic conditions in the three years and four locations. Regardless of location and year, the registered

temperatures were higher than the multiannual average specific for each location (Table 2). In all locations of research, the year 2020 was the warmest, while the year 2019 was the coldest except for Negrești location where the coldest year was 2021. Among the four locations, the highest average temperatures were registered in Cogealac and Dâlga, while the smallest average temperatures were registered in Troian location. In all locations of research, the year 2021 was the rainiest year, while the warmest year 2020 was the driest (Table 2). 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).

The research was performed on a soil of chernozem type in all locations except for Negrești location where the soil is of cambic chernozem type.

Table 2. Temperatures and rainfall in the four locations and the three experimental years

Location	2019*	2020	2021	Multiannual average
Temperatures (°C)				
Negrești	12.9	12.2	12.1	9.5
Cogealac	13.3	14.3	13.4	10.7
Dâlga	13.1	14.2	13.8	11.0
Troian	11.1	12.1	11.5	10.4
Rainfall (mm)				
Negrești	539.8	416.1	634.2	420
Cogealac	362.0	340.0	580.0	352
Dâlga	476.5	340.9	851.7	503.6
Troian	535.0	488.0	639.0	550.1

*The climatic data of the experimental years are presented for the period between September of the previous year to August of the current year, when the sunflower vegetation period generally ends or approach the end for the specific growing conditions in Romania.

The grain yield was determined by harvesting the sunflower heads of each experimental variant in the stage of full maturity. The grain yield was calculated in kg/ha and was expressed at 9% moisture content. The yielding elements (head diameter, number of grains per head, weight of grains per head, 1000-grains weight – TGW) were determined for 10 sunflower heads for each experimental variant.

The correlation coefficients were calculated using the Data Analysis Tools of Microsoft Excel.

RESULTS AND DISCUSSIONS

In the performed research, the sunflower grain yield correlated generally positively with the head yielding elements. There are some exceptions, respectively the very weak negative correlations of yield with head diameter at row spacing of 60 cm and density of 50,000 plants/ha ($r = -0.076$) and with the number of grains per head at row spacing of 50 cm and 60,000 plants/ha ($r = -0.057$) (Tables 3-5, Figures 1-3).

Table 3. Correlation coefficient (r) of sunflower yield and head yielding elements at row spacing of 70 cm and at different plant density

50,000 plants/ha					
	Yield (kg/ha)	Head diameter (cm)	No of grains per head	Grain weight per head (g)	TGW (g)
Yield (kg/ha)	1				
Head diameter (cm)	0.431423574	1			
No of grains/head	0.175745388	0.117274076	1		
Grain weight/head (g)	0.513454986	0.180229319	0.570566378	1	
TGW (g)	0.389130328	0.189169027	-0.112894462	0.396766194	1
60,000 plants/ha					
	Yield (kg/ha)	Head diameter (cm)	No of grains per head	Grain weight per head (g)	TGW (g)
Yield (kg/ha)	1				
Head diameter (cm)	0.356366839	1			
No of grains/head	0.288845440	0.157853013	1		
Grain weight/head (g)	0.658864581	0.075407149	0.531337823	1	
TGW (g)	0.588680715	0.371253973	0.055254295	0.408685806	1
70,000 plants/ha					
	Yield (kg/ha)	Head diameter (cm)	No of grains per head	Grain weight per head (g)	TGW (g)
Yield (kg/ha)	1				
Head diameter (cm)	0.517011964	1			
No of grains/head	0.400992154	0.441074204	1		
Grain weight/head (g)	0.775304994	0.214372790	0.358322189	1	
TGW (g)	0.608554930	0.608703411	0.138815241	0.350848041	1

Table 4. Correlation coefficient (r) of sunflower yield and head yielding elements at row spacing of 60 cm and at different plant density

	Yield (kg/ha)	Head diameter (cm)	No of grains per head	Grain weight per head (g)	TGW (g)
50,000 plants/ha					
Yield (kg/ha)	1				
Head diameter (cm)	-0.076880	1			
No of grains/head	0.054261	-0.042610	1		
Grain weight/head (g)	0.310268	-0.176700	0.272373	1	
TGW (g)	0.269129	0.149001	-0.136340	0.361068	1
60,000 plants/ha					
Yield (kg/ha)	1				
Head diameter (cm)	0.205915	1			
No of grains/head	0.077994	-0.103230	1		
Grain weight/head (g)	0.579093	-0.012580	0.606142	1	
TGW (g)	0.697858	0.407827	-0.324450	0.261131	1
70,000 plants/ha					
Yield (kg/ha)	1				
Head diameter (cm)	0.140594	1			
No of grains/head	0.200940	0.038788	1		
Grain weight/head (g)	0.676111	0.053928	0.545803	1	
TGW (g)	0.621152	0.296089	-0.073380	0.302772	1

Table 5. Correlation coefficient (r) of sunflower yield and head yielding elements at row spacing of 50 cm and at different plant density

	Yield (kg/ha)	Head diameter (cm)	No of grains per head	Grain weight per head (g)	TGW (g)
50,000 plants/ha					
Yield (kg/ha)	1				
Head diameter (cm)	0.137141	1			
No of grains/head	0.153323	0.227200	1		
Grain weight/head (g)	0.072822	-0.173630	0.32074	1	
TGW (g)	0.343670	0.214444	-0.20684	0.286973	1
60,000 plants/ha					
Yield (kg/ha)	1				
Head diameter (cm)	0.155052	1			
No of grains/head	-0.057520	0.374081	1		
Grain weight/head (g)	0.359730	-0.144600	0.03697	1	
TGW (g)	0.610232	0.306703	-0.32068	0.179304	1
70,000 plants/ha					
Yield (kg/ha)	1				
Head diameter (cm)	0.352839	1			
No of grains/head	0.138444	0.453346	1		
Grain weight/head (g)	0.486980	0.091030	0.021599	1	
TGW (g)	0.548402	0.341524	-0.223650	0.286201	1

Generally, the highest correlation coefficient of grain yield was registered with grain weight per head and TGW regardless of row spacing and plant density, the correlations being moderate and strong. The exception for the grain weight per head was the weak correlations registered at row spacing of 60 cm and density of 50,000 plants/ha and at row spacing of 50 cm and density of 60,000 plants/ha, as well as the very weak correlation registered at 50 cm and density of 50,000 plants/ha. The exception for TGW was the weak correlations registered at row spacing of 60 cm and density of 50,000 plants/ha and at row spacing of 70 cm and density of 50,000 plants/ha (Tables 3-5, Figures 1-3).

These findings are according to those of Marinkovic (1992) who found that the highest direct positive effect on grain yield per plant was exhibited by the weight of 1,000 grains. Also, Öztürk and Ada (2009) found a positive statistically significant relationship between

seed yield and 1000-grain weight, while Kang and Ahman (2014) found the strongest correlation of seed yield with 1000-grain weight ($r = 0.762$) at genotypic level. The results obtained by Mogali and Virupakshappa (1994) revealed that seed yield had highest correlation with number of filled seeds per plant, followed by seed filling percentage and head diameter. At row spacing of 70 cm, the highest correlation coefficient of grain yield was registered with grain weight per head regardless of plant density.

At row spacing of 60 cm, the highest correlation coefficient of grain yield was registered with grain weight per head at densities of 50,000 and 70,000 plants/ha, but at plant density of 60,000 plants/ha the highest correlation coefficient of grain yield was registered with TGW.

At row spacing of 50 cm, the highest correlation coefficient of grain yield was registered with TGW regardless of plant density.

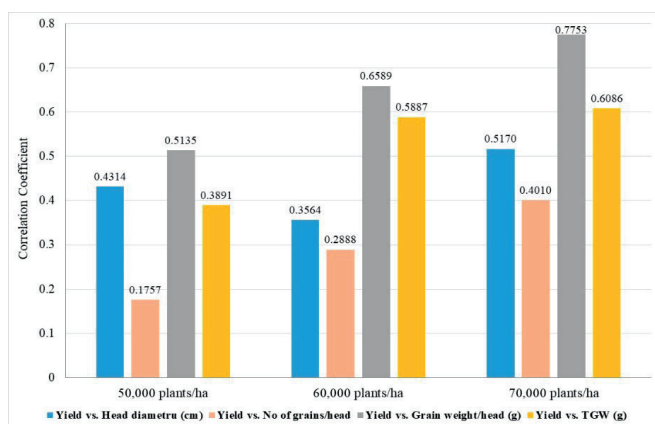


Figure 1. Correlation coefficient (r) of sunflower yield with head yielding elements at row spacing of 70 cm and at different plant density

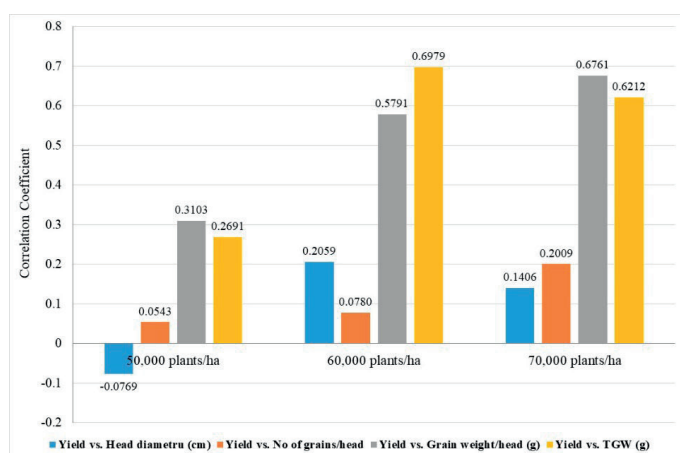


Figure 2. Correlation coefficient (r) of sunflower yield with head yielding elements at row spacing of 60 cm and at different plant density

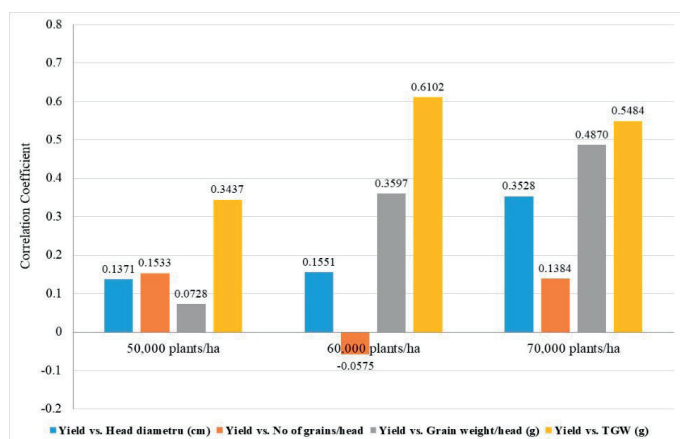


Figure 3. Correlation coefficient (r) of sunflower yield with head yielding elements at row spacing of 50 cm and at different plant density

The smallest coefficient of correlation of grain yield was registered with the number of grains per head at row spacing of 70 cm and 50 cm, and at row spacing of 60 cm and density of 60,000 plants/ha. Also a small coefficient of variation of grain yield was registered with the head diameter, especially in the case of row spacing of 60 cm and densities of 50,000 and 70,000 plants/ha (Tables 3-5, Figures 1-3).

The findings regarding the weak association of the grain yield with the head diameter, even a negative one in the case of the row spacing of 60 cm and density of 50,000 plants/ha are in accordance with those of Hladni et al. (2004) who found that the head diameter has a negative direct effect on seed yield per plant.

Generally, the coefficient of correlation of sunflower grain yield with the head yielding elements decreases with row spacing decrease and increases with plant density increase. In this respect and regarding the TGW, these findings are according to those of Dušanic et al. (2004) who found positive correlations between 1000-seed weight and seed yield, but a highly significant one was found only in the maximum density.

CONCLUSIONS

In the performed research, generally, the coefficient of correlation of sunflower grain yield with the head yielding elements decreases with row spacing decrease and increases with plant density increase.

The highest correlation coefficient of grain yield was registered with grain weight per head and TGW regardless of row spacing and plant density, the correlations being moderate and strong. But regardless of plant density, as the row spacing decreases, it decreases the value of the correlation coefficient of grain yield with grain weight per head and increases the value of the correlation coefficient of grain yield with TGW.

The smallest coefficient of correlation of grain yield was registered with the number of grains per head, and secondly with the head diameter, regardless row spacing and plant density.

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