STUDY REGARDING THE EFFECT OF DENSITY, FERTILIZATION AND TILLAGE ON SUNFLOWER YIELD UNDER THE CONDITIONS FROM TIMIŞOARA

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Abstract. *The seed yield in sunflower is influenced by the genetic potential of the hybrid and it's interaction with the environmental and technological factors. The study was performed using a split-split plot design with three replications, having density as main, fertilization as second and tillage as third factor. As experimental material was used the sunflower hybrid NK Neoma. The used sowing densities were: 70 x 29 cm, resulting 49261 germinating kernels (g.k.) ha^{-1}; 70 x 26.5 cm, resulting 53908 g.k.ha^{-1}; 70 x 24 cm, resulting 59524 g.k.ha^{-1}; 70 x 21.4 cm, resulting 66756 g.k.ha^{-1}. In order to provide the fertilization treatments, were applied combined fertilizers using doses of 250 kg ha $^{-1}$ (20-20-0) for $N_{50}P_{50}K_0$ and 333 kg ha $^{-1}$ for $N_{50}P_{50}K_{50}$. The three applied tillage were: ploughing, scarification and scarification+ ploughing. The aim of this research was to analyse the main effect and interactions between different technological factors like population density, fertilization and tillage on the sunflower yield, under the conditions from Timisoara. The applied fertilization had a contribution of 78.55% to yield variability, significantly higher compared to density and tillage influences. The increasing of density by reduction of space between plants from 29 to 24 or 21.4 cm has a positive effect to sunflower yield. The application of different treatments with NPK has led to significant yield increases of 45-46% compared to unfertilized plot. It is also noted that on the background of fertilization with $N_{50}P_{50}$ the application of 50 kg potassium had a very small and insignificant effect to yield. On the background of the climatic conditions from the studied period the applied tillage did not significantly influence the sunflower yield.*

Key words: *sunflower, density, fertilization, tillage, yields.*

INTRODUCTION

The sunflower crop has been receiving steady attention because it's premium oil with light colour, which contains very low cholesterol and high unsaturated fatty acid concentration (FLAGELLA *ET AL*., 2002; QAHAR *ET AL*. 2010). Sunflower is not only an important oil crop but is also cultivated for bio-energy purposes such as offering an eco-friendly alternative to diesel fuel (ANTOLIN *ET AL*., 2002; BARNWAL AND SHARMA, 2005). As such, sunflower is a crop with many uses and high adaptability (PAPATHEOHARI *ET AL*., 2016)

The seed yield, oil and protein of sunflower varies widely depending on many environment factors such as: radiation (DOSIO *ET AL*., 2000), temperature (KALEEM *ET AL*., 2009; 2011), rainfall (ASBAG *ET AL*., 2009; OLOWE *ET AL*., 2013), time of sowing (DE LA VEGA AND HALL, 2002; ANJUM *ET AL*., 2012), plant density and nitrogen nutrition (ALI *ET AL*., 2012).

The response of sunflower yield to applied fertilizer could be attributed to availability of nutrients in the soil during the physiological growth and development stages of the plants as reported by YASIN *ET AL*. (2013). Organic fertilizer application significantly increase the seed yield and yield attributes regardless the time of sowing in sunflower (OSHUNDIYA *ET AL*., 2014). Maximum inherent potential of a sunflower cultivar can only be achieved when nutrients are applied in balanced form with proper dose of fertilizers (MURALI *ET AL*.,2009).

Phosphorus deficiency in sunflower lead to a reduction of plant growth and dry matter, low yield and poor quality of seeds (MENGEL AND KIRKBY, 1987). Sunflower responded

strongly to increasing P supply with respect to plant growth and yield (ABBADI AND GERENDÁS, 2011).

Sunflower yield and yield components responded positively to potassium and phosphorus fertilization but the magnitude of response varied with the levels of potassium and phosphorus (KHAN, 2010). Taking into account a direct correlation between potassium and seed yield in sunflower (SIRBU AND AILINCAI, 1992), the optimum yields were obtained with different doses varying from 60 kg (HARMATI 1993) to 150 kg (KHAN *ET AL*., 1999), depending of the soil and weather conditions.

Sunflower is a deep-rooted crop, intermediate in water use, which can extract water from below root zones of normal small grain crops. As such, the tillage plays an important effect to plant growth and yield (HALVORSON *ET AL*., 1999).

Regarding the effect of density, the highest yields were obtained at increased plant population under favourable growing conditions. The increasing of plant population under less favourable growing conditions decreased the sunflower yield (ION *ET AL*., 2015).

The aim of this research was to analyse the main effect and interactions between different technological factors like population density, fertilization and tillage on the sunflower yield, under the conditions from Timisoara.

MATERIAL AND METHODS

The study was performed at Banat's University of Agricultural Sciences and Veterinary Medicine Timisoara during 2014, using a split-split plot design with three replications, and plots of 42 m^2 with six rows of 10 m long.

The soil of the experimental field is classified as a cambic black cernosiom weak decarbonated, clay-loamy, on the middle loess deposits, with the following physical-chemical parameters: humus 2,97 %, nitrogen index 2,98, phosphorus 51 ppm, potassium 148 ppm, total porosity 53,35 %, aeration porosity 21,84 %.

Density was used as main factor, fertilization as second and tillage as third factor. As experimental material was used the sunflower hybrid NK Neoma. The used sowing densities were: 70 x 29 cm, resulting 49261 germinating kernels (g.k.) ha^{-1}; 70 x 26.5 cm, resulting 53908 $g.k.ha^{-1}$; 70 x 24 cm, resulting 59524 $g.k.ha^{-1}$; 70 x 21.4 cm, resulting 66756 $g.k.ha^{-1}$. In order to provide the fertilization treatments, were applied combined fertilizers using doses of 250 kg ha^{-1} (20-20-0) for $N_{50}P_{50}K_0$ and 333 kg ha^{-1} for $N_{50}P_{50}K_{50}$. The three applied tillage were: ploughing, scarification and scarification+ ploughing.

For weed control, before emergence was sprayed Dual Gold 960 EC at a rate of 1.5 l ha^{-1}, and after emergence Killer Super 5EC 0.85 l ha^{-1} and Pulsar 40 at 0.85 l ha^{-1}.

The sum of rainfall during the sunflower growing period in 2014, respectively from April to August was 430.9 mm, associated with average temperatures for this period between 12.7 ^oC in April to 22.1 ^oC in July.

Statistical analysis was performed using analysis of variance and t test for a three factor experiment (CIULCA, 2006). The significance of differences was expressed based on symbols (*, ^{0}) and letters, being considered as significant the differences between variants marked with different letters.

RESULTS AND DISCUSSIONS

Taking into account the analysis of variance components (Table 1) it is noticeable that the sowing density and the fertilization have shown a real and high significant influence on the achievement of yield, on the background of homogenous growing conditions in the

experimental design. The applied fertilization had a significantly higher contribution (78.55%) compared to density (9.87%) and tillage (0.06%), on the entire variability from the experience. The different interactions between the three factors showed also statistically assured influences on the yield. In this regard, the most significant effects have been shown by the interaction between density and fertilization. The obtained results were influenced to an extent of 7.88% by other uncontrollable factors.

Table 1

Analysis of variance for the effect of density, fertilization and tillage on sunflower yield

Source of variation	SS	DF	MS	F
Total	30321928	107		
Replications	228558	2	114279	2.18
Density	6598389	3	2199463	42.01**
Residual densities	314102	6	52350	
Fertilization	18764721	2	9382361	334.35**
Density x Fertilization	734625	6	122438	4.36**
Residual fertilizations	448990	16	28062	
Tillage	157761	2	78881	2.71
Density x Tillage	435796	6	72633	2.50*
Fertilization x Tillage	457376	4	114344	3.93**
Density x Fertilization x Tillage	784981	12	65415	2.25*
Residual tillage	1396629	48	29096	

Considering the unilateral effect of density, it is noted that the yield recorded amplitude of 569 kg, ranging from 2208 kg in case of 49261 g.k.ha^{-1}and 2777 kg for 66756 g.k.ha^{-1}. As a result, the reduction of space between the plants in the row from 29 to 21.4 cm caused a significant increase of yield. The recorded increases had values of 67.2 kg cm^{-1} for the change of space between plants from 29 to 26.5 cm, and 156.38 kg cm^{-1} in case of reduction the space from 26.5 to 24 cm, while changing the distance between plants from 24 to 21.4 cm had a small and insignificant impact (3.85 kg cm^{-1}) on the yield. The results are in agreement with the findings of ION *ET AL.* (2015), who reported that the increasing of plant population from 50000 to 60000 and further to 70000 has a positive effect to sunflower yield. An increasing of yield at increased plant population was also found by GUBBELS AND DEDIO (1990) and HOSSAM (2012).

Table 2

The effect of density on sunflower yield

Density (g.k.ha^{-1})	Yield (kg ha^{-1})		Relative values (%)	Difference/ Significance
53908 - 49261	2376	2208	107.61	168*
59524 - 49261	2767	2208	125.32	559***
66756 - 49261	2777	2208	125.77	569***
59524 - 53908	2767	2376	116.46	391***
66756 - 53908	2777	2376	116.88	401***
66756 - 59524	2777	2767	100.36	10

$LSD_{5\%}$=152 kg ha^{-1} $LSD_{1\%}$=231 kg ha^{-1} $LSD_{0,1\%}$=371 kg ha^{-1}

Under the effect of various fertilizations the yield showed variation amplitude of 891 kg, ranging from 1942 kg on unfertilized plot to 2833 kg for $N_{50}P_{50}K_{50}$ treatment, amid 20.17% variability between treatments (Table 3). The application of different treatments with NPK has led to significant yield increases of 45-46% compared to unfertilized plot. It is also noted that on the background of fertilization with $N_{50}P_{50}$ the application of 50 kg potassium had a very

small and insignificant effect to yield. Also, SUZER (2010) reported that the economically optimal seed yield per hectare was obtained at nitrogen doses between 50 an 80 kg.

Table 3

The effect of fertilization on sunflower yield

Fertilization	Yield (kg ha^{-1})		Relative values (%)	Difference/ Significance
$N_{50}P_{50}K_0 - N_0P_0K_0$	2820	1942	145.21	878***
$N_{50}P_{50}K_{50} - N_0P_0K_0$	2833	1942	145.88	891***
$N_{50}P_{50}K_{50} - N_{50}P_{50}K_0$	2833	2820	100.46	13

$LSD_{5\%}$=84 kg ha^{-1} $LSD_{1\%}$=115 kg ha^{-1} $LSD_{0,1\%}$=159 kg ha^{-1}

Regarding the effect of tillage, the yield registered low amplitude, ranging from 2486 kg for scarification to 2562 kg in case of combining scarification and ploughing. Thus, at the level of the whole experience it is confirmed that on the background of the climatic conditions from the studied period the applied tillage did not significantly influence the sunflower yield.

Table 4

The effect of tillage on sunflower yield

Tillage	Yield (kg ha^{-1})		Relative values (%)	Difference/ Significance
Scarification – Ploughing	2486	2548	97.57	-62
(Scarification + Ploughing) – Ploughing	2562	2548	100.55	14
(Scarification + Ploughing) - Scarification	2562	2486	103.06	76

$LSD_{5\%}$=81 kg ha^{-1} $LSD_{1\%}$=108 kg ha^{-1} $LSD_{0,1\%}$=141 kg ha^{-1}

Based on the interaction between densities and fertilizer treatments (Table 5) it is found that in the case of 59524 g.k.ha^{-1} density, the fertilization had the highest influence on the yield, while at 49261 g.k.ha^{-1} the application of different fertilizers combinations had a significant but lower effect to yield achievement. Regardless of crop density, the application of nitrogen and phosphorus or nitrogen, phosphorus and potassium has led to a significant increase of yield with increases between 773 kg for 49261 density and 1167 kg for 59524 g.k.ha^{-1}. Additional fertilization by the application of potassium had little and insignificant effects on the yield.

Table 5

The combined effect of density and fertilization on sunflower yield

Density (g.k.ha^{-1})	Fertilization				
	$N_0P_0K_0$	**$N_{50}P_{50}K_0$**	**$N_{50}P_{50}K_{50}$**	$\bar{x} \pm s_{\bar{x}}$	$S_{\%}$
49261	y 1715 c	x 2488 b	x 2421 b	2208±75	17,08
53908	y 1852 bc	x 2624 b	x 2652 b	2376±76	16,67
59524	y 2024 ab	x 3085 a	x 3191 a	2767±109	20,44
66756	y 2179 a	x 3083 a	x 3069 a	2777±87	16,21
$\bar{x} \pm s_{\bar{x}}$	1942±38	2820±50	2833±58	2532±49	
$S_{\%}$	11,90	10,55	12,26	20,19	

Densities - $LSD_{5\%}$=188 kg ha^{-1} $LSD_{1\%}$=258 kg ha^{-1} $LSD_{0,1\%}$=351 kg ha^{-1} (a,b,c,d)
Fertilizations - $LSD_{5\%}$=167 kg ha^{-1} $LSD_{1\%}$=231 kg ha^{-1} $LSD_{0,1\%}$=317 kg ha^{-1} (x, y, z)

Under unfertilized conditions the yield registered values between 1715 kg for 49261 density and 2179 kg in case of using 66756 g.k.ha^{-1}, with amplitude of 464 kg. As such, under the highest density of the crop the yield were superior to those of the 49261 and 53908 densities. The reduction of the space between plants from 29 to 24 cm has led to a significant increase of yield with 309 kg. Under the application of 50 kg nitrogen and phosphorus it is noted that the yield for densities 59524 and 66756 g.k.ha^{-1} was higher with 459-597 kg

compared to those recorded at 49261 and 53908 g.k.ha^{-1}. The same trend is also found on the background of applying $N_{50}P_{50}K_{50}$ where in case of space between plants by 21.4 to 24 cm are obtained significant yield increases of 417-770 kg compared to the plots were the space between plants was 26.5-29 cm. For all three fertilization treatments, the change of space between plants from 21.4 to 24 cm or 26.5 to 29 cm, did not significantly affect the yield.

Table 6

The combined effect of density and tillage on sunflower yield

Density (g.k.ha^{-1})	Tillage				
	Ploughing	**Scarification**	**Scarification+ Ploughing**	$\bar{x} \pm s_{\bar{x}}$	$S_{\%}$
49261	x 2194 b	x 2221 b	x 2209 c	2208±75	17,08
53908	x 2369 b	x 2318 b	x 2441 b	2376±76	16,67
59524	xy 2813 a	y 2658 a	x 2828 a	2767±109	20,44
66756	x 2816 a	x 2746 a	x 2769 a	2777±87	16,21
$\bar{x} \pm s_{\bar{x}}$	2548±78	2486±88	2562±91	2532±49	
$S_{\%}$	18,40	21,15	21,35	20,19	

Densities - $LSD_{5\%}$=187 kg ha^{-1} $LSD_{1\%}$=254 kg ha^{-1} $LSD_{0,1\%}$=341 kg ha^{-1} (a,b,c,d)
Tillage - $LSD_{5\%}$=162 kg ha^{-1} $LSD_{1\%}$=216 kg ha^{-1} $LSD_{0,1\%}$=282 kg ha^{-1} (x, y, z)

Taking into account the effect of tillage on the yield under different densities (Table 6), it can be noticed that under the use of scarification combined with ploughing, the variability between the yields of different densities was higher, amid amplitude of 2209-2769 kg. In the case of this tillage the use of 21.4-24 cm space between plants has allowed yield increases of 328-619 kg, in comparison with the other two densities. Also, the increase of density by reducing spaces between plants from 29 to 26.5 cm has generated a significant yield increase of 232 kg.

On the background of field preparation by ploughing or scarification it is observed that at high densities (59524-66756 g.k.ha^{-1}) the yield recorded a significant increase of 525-622 kg compared to low densities (49261-53908 g.k.ha^{-1}). The reduction of nutrition space of plant from 0.203 to 0.186 m^2, and from 0.168 to 0.150 m^2, did not significantly affect the yield.

The tillage showed the highest influence on the yield in the case of sowing at 59524 g.k.ha^{-1}, where the use of scarification combined with ploughing afforded a significantly higher yield with 170 kg compared to plots where only scarification was applied. For other densities, the tillage had a small and insignificant influence on yield, generating variations up to 123 kg.

Table 7

The combined effect of fertilization and tillage on sunflower yield

Fertilization	Tillage				
	Ploughing	**Scarification**	**Scarification + Ploughing**	$\bar{x} \pm s_{\bar{x}}$	$S_{\%}$
$N_0P_0K_0$	x 2044 b	y 1838 b	xy 1946 b	1942±38	11,90
$N_{50}P_{50}K_0$	x 2786 a	x 2826 a	x 2847 a	2820±50	10,55
$N_{50}P_{50}K_{50}$	x 2814 a	x 2794 a	x 2892 a	2833±58	12,26
$\bar{x} \pm s_{\bar{x}}$	2548±78	2486±88	2562±91	2532±49	
$S_{\%}$	18,40	21,15	21,35	20,19	

Fertilizations- $LSD_{5\%}$=138 kg ha^{-1} $LSD_{1\%}$=184 kg ha^{-1} $LSD_{0,1\%}$=239 kg ha^{-1} (a,b,c)
Tillage - $LSD_{5\%}$=140 kg ha^{-1} $LSD_{1\%}$=187 kg ha^{-1} $LSD_{0,1\%}$=244 kg ha^{-1} (x, y, z)

Considering the interactions between tillage and fertilization (Table 7) it results that under unfertilized conditions, the tillage showed the highest influence on the yield, amid 206 kg amplitude.

As such, under these conditions the soil preparation using ploughing has allowed a significant yield increase with 11.20 % comparing with scarification. The association between ploughing and scarification did not cause significant variations of yield compared to the unilateral application of tillage. Under the fertilization with $N_{50}P_{50}K_0$ and $N_{50}P_{50}K_{50}$, the tillage did not significantly influence the yield, which showed very low and irregular variation amplitudes.

Regarding the effect of fertilization on yield under different tillage It is noted that the use of ploughing the amplitude (770 kg) and variability (18.40%) between treatments were lower, registering yield increases of 36.3-37.7% by applying fertilization with $N_{50}P_{50}K_0$ şi $N_{50}P_{50}K_{50}$. On the background of land preparation using scarification or scarification and ploughing, the effect of fertilization was higher, being recorded an increase of yield by 46.3-53.7 % compared to unfertilized plots. Additional fertilization by the application of potassium had little and insignificant effects on the yield, regardless of the used tillage.

CONCLUSIONS

The applied fertilization had a contribution of 78.55% to yield variability, significantly higher compared to density and tillage influences. The increasing of density by reduction of space between plants from 29 to 24 or 21.4 cm has a positive effect to sunflower yield. The application of different treatments with NPK has led to significant yield increases of 45-46% compared to unfertilized plot. It is also noted that on the background of fertilization with $N_{50}P_{50}$ the application of 50 kg potassium had a very small and insignificant effect to yield. On the background of the climatic conditions from the studied period the applied tillage did not significantly influence the sunflower yield.

Regardless of crop density, the application of nitrogen and phosphorus or nitrogen, phosphorus and potassium has led to a significant increase of yield, with increases between 773 kg for 49261 and 1167 kg for 59524 plants.

The tillage showed the highest influence on the yield in the case of sowing at 59524 $g.k.ha^{-1}$, where the use of scarification combined with ploughing afforded a significantly higher yield compared to plots where only scarification was applied.

Under unfertilized conditions the soil preparation using ploughing has allowed a significant yield increase with 11.20 % comparing with scarification.

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