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EFFECTS OF TILLAGE AND NITROGEN RATE ON SUNFLOWER IN THE SPECIFIC CONDITIONS FROM DANUBE MEADOW

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Abstract

Within sunflower crop technology, tillage and nitrogen rate are among the most important factors significantly affecting the grain yield and yielding elements. Therefore, this paper aims to present the results of the performed research regarding the effects of different tillage and nitrogen rates on sunflower grain yield and yielding elements in the specific growing conditions of Danube Meadow from South Romania. In this respect, the research was performed in the years 2023 and 2024, in field experiments under rainfed conditions located in the Danube Meadow from South Romania. The experimental factors were Tillage methods, with 5 variants (a1. Plowing performed with a 4-furrow reversible plough at depth of 25 cm + 2 passes with a disc harrow; a2. Scarifying at a depth of 35 cm + 2 passes with a disc harrow; a3. Cultivation with Gruber Tiger cultivator at a depth of 25 cm; a4. Cultivation with Gruber Tiger cultivator at a depth of 15 cm; a5. Disc harrow at a depth of 15 cm - 2 passes), and Nitrogen rate, with 4 variants (b1. N0 - unfertilized; b2. 60 kg/ha; b3. 90 kg/ha; b4. 120 kg/ha). The obtained results highlighted the better values of the grain yield and yielding elements at deep and reduced tillage (scarifying at 35 cm + 2 disc harrows and Gruber Tiger at 25 cm) in favourable climatic conditions, while in the context of less favourable climatic conditions the best results were obtained in the context of shallow and reduced tillage of Gruber Tiger at 15 cm (2 passes). The obtained results showed that the values for all the analysed yield elements and the grain yield constantly increased with increasing the nitrogen rate from 0 to 60, respectively to 90 and 120 kg/ha, regardless of tillage method and the climatic conditions of the year.

Key words*: sunflower, tillage, nitrogen rate, grains yield, yielding elements.*

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is the most important oil crop, with more than 1 million ha cultivated annually. Sunflower is a versatile crop, this characteristic being given both by the multiple uses of the crop and by the possibility of cultivating it in different environmental and technological conditions (Ion, 2021).

Considerable research has been performed on different tillage systems in agricultural production methods and tillage systems in sunflower and other crop (Sessiz et al., 2008). Sunflower cultivation efficiency is determined by a correct selection of agrotechnical measures applied from soil tillage after previous crop to sunflower sowing (Aksyonov, 2010). Information on soil tillage system is necessary in sunflower cropping for maximize and improve the quality and the level of yield (Petcu et al., 2020).

Within the framework of crop technologies, soil tillage represents an important link and therefore it is necessary to be carried out in the best conditions (Khan et al., 2021). Thus, the farmer must know some particularities and type of soil, the presence of problem weeds, as well as some characteristics of the crops, in order to develop tillage methods, the necessary equipment and execution indices (Carr et al., 2013).

In Europe, there has been a significant change in the way tillage is approached in recent years, this change being due to a growing awareness among farmers, politicians and society as a whole that soil is not a renewable resource in itself (Sojnóczki et al., 2023).

Depending on the crops and local conditions, several tillages can be performed. In addition to the classic tillage system based on ploughing, in order to save energy embedded in field crop technology, to better water conservation in the soil, and to avoid repeated passes with tractors and agricultural machinery, with negative effects on the soil, more and more farmers are accustomed to use a minimum tillage system.

Compared to conventional tillage, zero or reduced or minimum tillage facilitates timely sowing, may increase yield, and reduce production costs and boosts farm income, but on

the other hand, weeds are a major constraint in maize production in reduced tillage practices (Samrat et al., 2021).

Conservation tillage has attracted increased attention in recent years due urgent needs for erosion control and water conservation in various geographic regions of the world (Deng et al., 2022). Soil and water conservation-oriented tillage methods include conservation tillage, strip tillage, and mulch tillage (Galzki et al., 2011).

In many countries all over the world, the increase in fertilizer price in combination with the increasing cost of fossil fuels has caused producers to consider conservation agriculture, which includes lower impact cultivation practices such as no tillage cultivation, permanent crop residues on the surface, and crop rotation (Blanco-Sepúlveda et al., 2021; Wolschick et al., 2021). Conservation tillage is able to significantly improve soil properties (physical, biological, and chemical) and other biotic factors, reduce soil erosion, improve the water infiltration, and help in the reduction of the production costs (Pittelkow et al., 2015; Giller et al., 2015; Tarolli et al., 2019).

Although it is a large consumer of nutrients, sunflower utilizes fertilizers less well than wheat or other plants, which is largely due to the high capacity of its root system to extract the necessary nutrients, even those that are poorly soluble, from a deep soil profile (Vrânceanu, 2000). The absorption of nutrients is rapid in sunflower, in relation to the rate of dry matter production during the early stages of development (Bîrnaure, 1991). Sunflower is sensitive to both nitrogen deficiency and excess, especially in the early stages, which will have negative repercussions on the development and growth processes, and of course, on grain yield.

On a global scale, nitrogen is the most used fertilizer nutrient in agriculture. Studies have shown that cultivated plant species use only about 50% of applied N effectively, while the rest is lost through various pathways to the environment (Govindasamy et al., 2023).

Nitrogen is the major nutrient required by sunflowers, and has the greatest impact on seed size, leaf size and number of leaves, test weight and yield (Toosi & Azizi, 2014). The large variation in the response of sunflower to nitrogen fertilization indicates the need for studies to better adjust the optimum levels of this nutrient for production conditions (Coêlho et al., 2022).

This paper aims to present the results of the performed research regarding the effects of different tillage and nitrogen rates on sunflower grain yield and yielding elements in the specific growing conditions of Danube Meadow from South Romania.

MATERIALS AND METHODS

Research was performed in field experiments under rainfed conditions in years 2023 and 2024. The field experiment was located in the Danube Meadow from South Romania, respectively near Oltenița city from Călărași County.

The relief in the area of research bears the imprint of meadow characteristics. This is characterized by a horizontal plane, with a land slope between 0.5 and 2%.

The soil is of alluvial type, and has a medium to heavy texture, an upper horizon of 20-35 cm thick, a dark brown - yellowish colour, and a granular structure.

The temperature values recorded both in 2023 and 2024 are notable for exceeding values in summer time by over 2-3ºC compared to the average for the area (27ºC) (Figure 1). The maximum recorded value was 42.2ºC on August 2024, and the minimum recorded value was -2.9ºC on February 17, 2023. The year 2024 was warmer than the year 2023, especially in the summer and winter seasons.

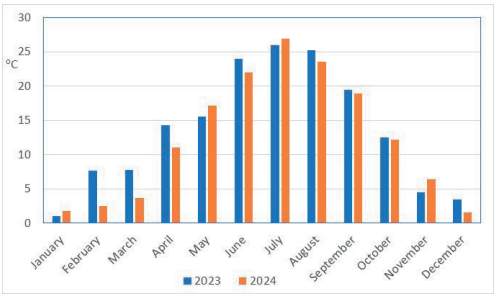

Figure 1. Temperatures in experimental field (2023-2024)

Regarding rainfall, there was a major water deficit in February, but a rainy period in April, while the summer months had small rainfall (Figure 2). From May to July, when sunflower

plants are in the most sensitive period to water stress, the year 2024 was droughter than 2023.

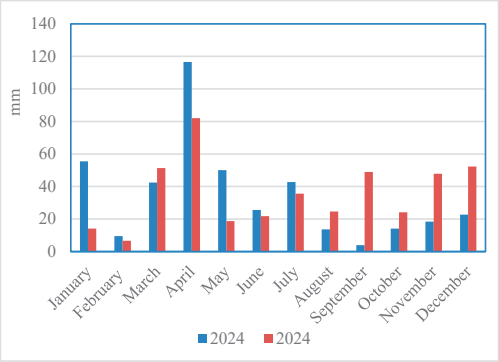

Figure 2. Rainfall in experimental field (2023-2024)

The field experiment was based on the method of subdivided plots into 3 replications, having two experimental factors, respectively:

- Factor A: Tillage method, with 5 variants:
  - a1. Plowing performed with a 4-furrow reversible plough at depth of 25 cm + 2 passes with a disc harrow (Control variant);
  - a2. Scarifying with Artiglio Scarifier at a depth of 35 cm + 2 passes with a disc harrow;
  - a3. Cultivation with Gruber Tiger cultivator at a depth of 25 cm;
  - a4. Cultivation with Gruber Tiger cultivator at a depth of 15 cm;
  - a5. Disc harrow with Horsh Joker Disc at a depth of 15 cm (2 passes).
- Factor B: Nitrogen rate, with 4 variants:
  - b1. N0 - unfertilized (Control variant);
  - b2. 60 kg/ha;
  - b3. 90 kg/ha;
  - b4. 120 kg/ha.

Each experimental variant had 120 m^2, resulting from 20 m length and 6 m width.

The tillage according to the classic system (plowing and scarifying) took place in the previous fall, and the minimum tillage (Gruber Tiger 15 cm, Gruber Tiger 25 cm, Disc harrow (2 passed) were performed in the spring.

In all experimental variants, except for Control variant, before seedbed preparation there was applied the complex fertilizer 16:16:16 in a rate of 250 kg/ha, assuring 40 kg/ha as active substance of N, P_2O_5 and K_2O. In May, the nitrogen rate according to the experimental variant was assured by the second fertilization applying the liquid fertilizer UAN (Urea Ammonium Nitrate Solution) containing 32% nitrogen. Thus, in 2023, on 19th of May, and two weeks early in 2024, on 5th of May, there was applied 62,5 l/ha of UAN for the variant b2, 156 l/ha of UAN for the variant b3, and 250 l/ha of UAN for the variant b4.

The sunflower hybrid was Sumiko (resistant to Express herbicide) and the previous plant was maize.

The sowing was carried out on 3rd of May in 2023 and 2 weeks early in 2024, respectively on 20th of April. The sowing was carried out with a John Deer tractor and a Gaspardo Maestro seeder with 8 rows, at a depth of 5-6 cm, a distance between rows of 70 cm and a sowing density of 65,000 germinating grains/ha.

The control of annual and perennial dicotyledonous weeds (including *Xanthium* spp., *Cirsium arvense, Datura stramonium, Solanum nigrum*) was performed by applying the herbicide Express 50 SG (Tribenuron-methyl 500 g/kg) in a rate of 30 g/ha + 250 ml/ha of Trend 90 adhesive. The herbicide was applied in the sunflower plant growing stage of 4-6 leaves (BBCH 14-16), when the weeds were in the 2-4 leaf phase, and the *Cirsium arvense* had maximum 10 cm high.

Against *Sorghum halepense* and other annual monocotyledonous weeds (*Setaria* spp., *Echinochloa crus-galli, Digitaria sanguinalis*), there was used the herbicide Pantera (Quizalofop-P-tefuryl 40 g/l) in a rate of 1 l/ha, applied in the weed stage of 1-3 leaves.

Against pathogens (*Alternariaster helianthi*, *Diaporthe helianthi*, *Sclerotinia sclerotiorum, Botrytis cinerea, Plenodomus lindquistii*), Pictor fungicide (Boscalid 200 g/l + Dimoxystrobin 200 g/l) was used in a rate of 0.5 l/ha in the sunflower plant stage of 6-8 leaves (BBCH 16-18). The treatment was repeated in the flower bud phase.

Harvesting was carried out with the New Holland CR9090 combine on 10th-20th of August (2023-2024).

For each experimental variant, the following determinations were performed at harvest: plant density; the height of plants; the head diameter (cm); the number of grains per head; the grain weight per head (g); Thousand Grains Weight - TWG (g); grain yield (kg/ha).

RESULTS AND DISCUSSIONS

Tillage effects on sunflower grain yield and yielding elements

In the case of the tillage influence on the plant density at harvest, it can be seen from Table 1 that in the case of variants with ploughing, Gruber Tiger (25 cm) and scarifying, there were registered the best plant density in the year 2023, with over 59,000 plants/ha. In the year 2024, the highest plant density was recorded at variant with Gruber Tiger (15 cm), with over 60,000 plants/ha, with close values for the variant with disc harrow. So, in the more favourable climatic conditions of the year 2023, the highest plant densities were registered in the case of deep tillage, while in the less favourable climatic conditions of the year 2024, the highest plant densities were registered in the case of shallow tillage. Plowing was to extremes, with highest plant density in the year 2023, but with the smallest plant density in 2024.

Table 1. Soil tillage effect on sunflower plant density at harvest

Tillage	Plant density (no/ha)		
	2023	2024	*Average*
Plowing (25 cm + 2 passes with disc harrow)	59422	52025	*55724*
Scarifying (35 cm + 2 passes with disc harrow)	59136	53589	*56363*
Gruber Tiger (25 cm)	59375	55276	*57326*
Gruber Tiger (15 cm)	55643	60243	*57943*
Disc harrow (15 cm x 2 passes)	55541	58742	*57142*
Average	*57823*	*55975*	*56900*

As in the case of the plant density, the plant height registered the highest values in 2023 at the variants with ploughing, Gruber Tiger (25 cm) and scarifying, with values over 170 cm (Table 2). In 2024, the highest values were registered at the variants with Gruber Tiger at 25 and 15 cm. Again, in the more favourable climatic conditions of the year 2023, the highest plant heights were registered in the case of deep tillage, while in the less favourable climatic conditions of the year 2024, the highest plant heights were registered in the case of shallow tillage. Plowing was giving the smallest value in the case of the year 2024.

Table 2. Soil tillage effect on sunflower plant height

Tillage	Plant height (cm)		
	2023	2024	*Average*
Plowing (25 cm + 2 passes with disc harrow)	170.9	156.7	*163.8*
Scarifying (35 cm + 2 passes with disc harrow)	174.3	162.6	*168.5*
Gruber Tiger (25 cm)	173.2	165.9	*169.5*
Gruber Tiger (15 cm)	164.4	164.7	*164.5*
Disc harrow (15 cm x 2 passes)	168.3	162.8	*165.5*
Average	*170.2*	*162.5*	*166.4*

The head diameter registered values over 17 cm to all experimental variants in the year 2023, except for the variant with disc harrow, where the hear diameter was of 16.6 cm (Table 3). In the year 2024, only variant with Gruber Tiger at 15 cm gave a head diameter over 16 cm (16.8 cm). As average values, the highest value of the head diameter was registered at the variant with Gruber Tiger at 15 cm (17.1 cm), while the smallest value was registered at the variant with disc harrow (15.9 cm).

Table 3. Soil tillage effect on sunflower head diameter

Tillage	Head diameter (cm)		
	2023	2024	*Average*
Plowing (25 cm + 2 passes with disc harrow)	17.0	15.2	*16.1*
Scarifying (35 cm + 2 passes with disc harrow)	17.3	15.2	*16.2*
Gruber Tiger (25 cm)	17.5	15.1	*16.3*
Gruber Tiger (15 cm)	17.3	16.8	*17.1*
Disc harrow (15 cm x 2 passes)	16.6	15.3	*15.9*
Average	*17.1*	*15.5*	*16.3*

The number of grains per head registered the highest values in the year 2023 in the case of tillage reduced and deep variant (scarifying and Gruber Tiger at 25 cm), while in the year 2024 the tillage variant with Gruber Tiger at 15 cm gave the highest number of grains per head (Table 4). The smallest value of the number of grains per head were registered in the year 2023 for the tillage variant with disk harrow (1305 grains per head), while in the year 2024 it was obtained in the case of variant with plowing (1034 grains per head).

Table 4. Soil tillage effect on number of grains per head

Tillage	Number of grains per head		
	2023	2024	*Average*
Plowing (25 cm + 2 passes with disc harrow)	1387	1034	*1211*
Scarifying (35 cm + 2 passes with disc harrow)	1419	1079	*1249*
Gruber Tiger (25 cm)	1401	1057	*1229*
Gruber Tiger (15 cm)	1368	1135	*1252*
Disc harrow (15 cm x 2 passes)	1305	1082	*1194*
Average	*1376*	*1077*	*1227*

The grain weight per head registered the highest value in the year 2023 in the case of tillage variant with scarifying (60.67 g), while in the year 2024 it was obtained at the tillage variant with Gruber Tiger at 15 cm (47.25 g), this variant standing out with a good value also in the year 2023 (Table 5). As in the case of the number of grains per head, the smallest value of the grain weight per head were registered in the year 2023 for the tillage variant with disk harrow (53.77 g), while in the year 2024 it was obtained in the case of variant with plowing (37.65 g).

Table 5. Soil tillage effect on grain weight per head

Tillage	Grain weight per head (g)		
	2023	2024	*Average*
Plowing (25 cm + 2 passes with disc harrow)	56.77	37.65	*47.21*
Scarifying (35 cm + 2 passes with disc harrow)	60.67	38.42	*49.55*
Gruber Tiger (25 cm)	58.15	39.32	*48.74*
Gruber Tiger (15 cm)	59.17	47.25	*53.21*
Disc harrow (15 cm x 2 passes)	53.77	40.11	*46.94*
Average	*57.71*	*40.55*	*49.13*

TGW registered values above 40 g in the year 2024 for all the tillage variants expect for the variant with disk harrow with 39.61 g (Table 6). In the year 2024, the highest value of TGW was registered in the case of variant with Gruber Tiger at 15 cm, this being the only variant with more than 40 g (42.46 g). In the year 2024, the smallest value of TGW was registered in the case of variant with plowing (36.06 g).
The grain yield registered the highest values in the year 2023 in the case of reduced and deep tillage variant (scarifying with 3616 kg/ha and Gruber Tiger at 25 cm with 3492 kg/ha), while in the year 2024 the tillage variant with Gruber Tiger at 15 cm gave the highest grain yield (2921 kg/ha) (Table 7). The smallest value of the grain yield was registered in the year 2023 for the tillage variant with disk harrow (3177 kg/ha), while in the year 2024 it was obtained in the case of variant with plowing (1939 kg/ha, this tillage variant being the only one with less than 2000 kg/ha). It has to be underline that in the favourable climatic conditions of the year 2023, all the tillage variants gave grain yield above 3000 kg/ha.
The less favourable climatic conditions of the year 2024 gave an average grain yield with about 1000 kg/ha compared to the year 2023.

Table 6. Soil tillage effect on TGW

Tillage	TGW (g)		
	2023	2024	*Average*
Plowing (25 cm + 2 passes with disc harrow)	40.77	36.06	*38.42*
Scarifying (35 cm + 2 passes with disc harrow)	42.61	36.27	*39.44*
Gruber Tiger (25 cm)	41.18	37.43	*39.31*
Gruber Tiger (15 cm)	40.30	42.46	*41.38*
Disc harrow (15 cm x 2 passes)	39.61	38.15	*38.88*
Average	*40.89*	*38.07*	*39.49*

Table 7. Soil tillage effect on sunflower grain yield

Tillage	Sunflower grain yield (kg/ha)		
	2023	2024	*Average*
Plowing (25 cm + 2 passes with disc harrow)	3388	1938	*2663*
Scarifying (35 cm + 2 passes with disc harrow)	3616	2098	*2857*
Gruber Tiger (25 cm)	3492	2191	*2842*
Gruber Tiger (15 cm)	3312	2921	*3117*
Disc harrow (15 cm x 2 passes)	3177	2469	*2823*
Average	*3397*	*2323*	*2860*

Nitrogen rate effects on sunflower grain yield and yielding elements

The obtained results showed that the values for all the analysed yield elements and the grain yield constantly increased with increasing the nitrogen rate from 0 to 60, respectively to 90 and 120 kg/ha, regardless of the climatic conditions of the year (Tables 8-14).

Table 8. Nitrogen rate effect on sunflower plant density at harvest

Nitrogen rate (kg/ha)	Plant density (no/ha)		
	2023	2024	*Average*
N0	54228	53639	*53933*
N60	57071	55828	*56450*
N90	59400	57343	*58372*
N120	60595	57090	*58843*
Average	*57823*	*55975*	*56900*

Table 9. Nitrogen rate effect on sunflower plant height

Nitrogen rate (kg/ha)	Plant height (cm)		
	2023	2024	*Average*
N0	157.0	152.0	*154.5*
N60	164.9	159.9	*162.4*
N90	170.9	167.1	*169.0*
N120	188.1	171.1	*179.6*
Average	*170.2*	*162.5*	*166.4*

Table 10. Nitrogen rate effect on sunflower head diameter

Nitrogen rate (kg/ha)	Head diameter (cm)		
	2023	2024	*Average*
N0	15.9	14.4	*15.2*
N60	17.3	15.4	*16.3*
N90	17.4	15.8	*16.6*
N120	17.9	16.5	*17.2*
Average	*17.1*	*15.5*	*16.3*

Table 11. Nitrogen rate effect on number of grains per head

Nitrogen rate (kg/ha)	Number of grains per head		
	2023	2024	*Average*
N0	1144	941	*1043*
N60	1370	1050	*1210*
N90	1474	1093	*1284*
N120	1516	1226	*1371*
Average	*1376*	*1077*	*1227*

Table 12. Nitrogen rate effect on grain weight per head

Nitrogen rate (kg/ha)	Grain weight per head (g)		
	2023	2024	*Average*
N0	42.51	36.61	*39.56*
N60	55.54	39.14	*47.34*
N90	61.64	40.57	*51.11*
N120	71.14	45.87	*58.51*
Average	*57.71*	*40.55*	*49.13*

Table 13. Nitrogen rate effect on TGW

Nitrogen rate (kg/ha)	TGW (g)		
	2023	2024	*Average*
N0	37.27	37.84	*37.56*
N60	40.41	38.02	*39.22*
N90	41.44	37.26	*39.35*
N120	44.45	39.16	*41.81*
Average	*40.89*	*38.07*	*39.49*

Table 14. Nitrogen rate effect on sunflower grain yield

Nitrogen rate (kg/ha)	Grain weight (kg/ha)		
	2023	2024	*Average*
N0	2347	1919	*2133*
N60	3333	2230	*2782*
N90	3592	2357	*2975*
N120	4315	2787	*3551*
Average	*3397*	*2323*	*2860*

Tillage and nitrogen rate effects on sunflower grain yield and yielding elements

In the year 2023, tillage methods combined with nitrogen rate led to a variation of the plant density at harvest from 51237 to 61904 plants/ha, while in the year 2024 this variation was between 50000 to 62357 plants/ha (Table 15). In the year 2023, regardless of tillage variant the plant density increased with nitrogen rate increase, but in the less favourable climatic conditions of the year 2024 this increase was just up to the nitrogen rate of 60 kg/ha, expect for the tillage variants with Grube Tiger at 25 cm and disc harrow.

Table 15. Soil tillage and nitrogen rate effect on sunflower plant density at harvest

Tillage methods	Nitrogen rate	Plant density (no of plants/ha)		
		2023	2024	*Average*
Plowing (25 cm + 2 passes with disc harrow)	N0	57737	50531	*54134*
	N60	58309	54523	*56416*
	N90	59737	53046	*56392*
	N120	61904	50000	*55952*
	Average	*59422*	*52025*	*55724*
Scarifying (35 cm + 2 passes with disc harrow)	N0	54047	53643	*53845*
	N60	59523	54404	*56964*
	N90	61309	54071	*57690*
	N120	61666	52237	*56952*
	Average	*59136*	*53589*	*56363*
Gruber Tiger (25 cm)	N0	54047	50777	*52412*
	N60	60119	51762	*55941*
	N90	61429	58329	*59879*
	N120	61904	60237	*61071*
	Average	*59375*	*55276*	*57326*
Gruber Tiger (15 cm)	N0	54071	58071	*56071*
	N60	55357	62357	*58857*
	N90	56071	59471	*57771*
	N120	57071	61071	*59071*
	Average	*55643*	*60243*	*57943*
Disc harrow (15 cm x 2 passes)	N0	51237	55171	*53204*
	N60	52047	56095	*54071*
	N90	58452	61799	*60126*
	N120	60429	61904	*61167*
	Average	*55541*	58742	*57142*

In the year 2023, tillage methods combined with nitrogen rate led to a variation of the plant height from 151.3 to 205 cm, while in the year 2024 this variation was between 145 to 176 cm

(Table 16). Generally, regardless of tillage variant and climatic conditions of the year, the plant height increased with nitrogen rate increase.

Table 16. Soil tillage and nitrogen rate effect on sunflower plant height

Tillage methods	Nitrogen rate	Plant height (cm)		
		2023	2024	*Average*
Plowing (25 cm + 2 passes with disc harrow)	N0	165.0	145.0	*155.0*
	N60	164.3	154.3	*159.3*
	N90	181.7	161.7	*171.7*
	N120	172.7	165.7	*169.2*
	Average	*170.9*	*156.7*	*163.8*
Scarifying (35 cm + 2 passes with disc harrow)	N0	160.0	153.0	*156.5*
	N60	168.3	158.3	*163.3*
	N90	169.0	169.0	*169.0*
	N120	200.0	170.0	*185.0*
	Average	*174.3*	*162.6*	*168.5*
Gruber Tiger (25 cm)	N0	155.0	155.0	*155.0*
	N60	164.3	164.3	*164.3*
	N90	168.3	168.3	*168.3*
	N120	205.0	176.0	*190.5*
	Average	*173.2*	*165.9*	*169.5*
Gruber Tiger (15 cm)	N0	153.7	155.7	*154.7*
	N60	160.7	161.7	*161.2*
	N90	160.0	168.0	*164.0*
	N120	183.3	173.3	*178.3*
	Average	*164.4*	*164.7*	*164.5*
Disc harrow (15 cm x 2 passes)	N0	151.3	151.3	*151.3*
	N60	166.7	160.7	*163.7*
	N90	175.7	168.7	*172.2*
	N120	179.3	170.3	*174.8*
	Average	*168.3*	*162.8*	*165.5*

In the year 2023, tillage methods combined with nitrogen rate led to a variation of the head diameter from 15.2 to 18.6 cm, while in the year 2024 this variation was between 13.7 to 17.8 cm (Table 17). Generally, regardless of tillage variant and climatic conditions of the year, the head diameter increased with nitrogen rate increase.

In the year 2023, tillage methods combined with nitrogen rate led to a variation of the number of grains per head from 974 to 1591, while in the year 2024 this variation was between 828 to 1362 (Table 18). Generally, regardless of tillage variant and climatic conditions of the year, the number of grains per head increased with nitrogen rate increase.

In the year 2023, tillage methods combined with nitrogen rate led to a variation of the grain weight per head from 36.65 to 77.61 g, while in the year 2024 this variation was between 32.65 to 62.28 g (Table 19). Generally, regardless of tillage variant and climatic conditions of the year, the grain weight per head increased with nitrogen rate increase.

Table 17. Soil tillage and nitrogen rate effect on sunflower head diameter

Tillage methods	Nitrogen rate	Head diameter (cm)		
		2023	2024	*Average*
Plowing (25 cm + 2 passes with disc harrow)	N0	16.1	14.4	*15.3*
	N60	17.2	15.0	*16.1*
	N90	17.0	15.3	*16.1*
	N120	17.7	16.0	*16.8*
	Average	*17.0*	*15.2*	*16.1*
Scarifying (35 cm + 2 passes with disc harrow)	N0	16.7	14.7	*15.7*
	N60	16.9	14.9	*15.9*
	N90	17.5	15.2	*16.4*
	N120	18.1	16.1	*17.1*
	Average	*17.3*	*15.2*	*16.2*
Gruber Tiger (25 cm)	N0	15.9	14.2	*15.0*
	N60	17.5	14.8	*16.1*
	N90	17.9	15.3	*16.6*
	N120	18.6	16.3	*17.4*
	Average	*17.5*	*15.1*	*16.3*
Gruber Tiger (15 cm)	N0	15.2	15.2	*15.2*
	N60	17.8	16.8	*17.3*
	N90	17.9	17.5	*17.7*
	N120	18.3	17.8	*18.1*
	Average	*17.3*	*16.8*	*17.1*
Disc harrow (15 cm x 2 passes)	N0	15.4	13.7	*14.6*
	N60	17.3	15.3	*16.3*
	N90	16.9	15.9	*16.4*
	N120	16.9	16.1	*16.5*
	Average	*16.6*	*15.3*	*15.9*

Table 18. Soil tillage and nitrogen rate effect on number on grains per head

Tillage methods	Nitrogen rate	Number of grains/head		
		2023	2024	*Average*
Plowing (25 cm + 2 passes with disc harrow)	N0	1195	988	*1092*
	N60	1362	995	*1179*
	N90	1494	1023	*1259*
	N120	1496	1129	*1313*
	Average	*1387*	*1034*	*1211*
Scarifying (35 cm + 2 passes with disc harrow)	N0	1360	926	*1143*
	N60	1312	1045	*1179*
	N90	1474	1127	*1301*
	N120	1528	1219	*1374*
	Average	*1419*	*1079*	*1249*
Gruber Tiger (25 cm)	N0	1086	939	*1013*
	N60	1399	1132	*1266*
	N90	1528	1028	*1278*
	N120	1591	1129	*1360*
	Average	*1401*	*1057*	*1229*
Gruber Tiger (15 cm)	N0	1104	1024	*1064*
	N60	1397	1030	*1214*
	N90	1409	1124	*1267*
	N120	1562	1362	*1462*
	Average	*1368*	*1135*	*1252*
Disc harrow (15 cm x 2 passes)	N0	974	828	*901*
	N60	1380	1046	*1213*
	N90	1463	1163	*1313*
	N120	1402	1292	*1347*
	Average	*1305*	*1082*	*1194*

Table 19. Soil tillage and nitrogen rate effect on grain weight per head

Tillage methods	Nitrogen rate	Grain weight per head (g)		
		2023	2024	*Average*
Plowing (25 cm + 2 passes with disc harrow)	N0	45.01	38.85	*41.93*
	N60	54.74	41.08	*47.91*
	N90	60.96	34.30	*47.63*
	N120	66.37	36.37	*51.37*
	Average	*56.77*	*37.65*	*47.21*
Scarifying (35 cm + 2 passes with disc harrow)	N0	50.98	32.65	*41.82*
	N60	53.38	36.71	*45.05*
	N90	63.13	40.13	*51.63*
	N120	75.17	44.17	*59.67*
	Average	*60.67*	*38.42*	*49.55*
Gruber Tiger (25 cm)	N0	39.92	35.92	*37.92*
	N60	57.55	39.22	*48.39*
	N90	63.28	39.62	*51.45*
	N120	71.85	42.52	*57.19*
	Average	*58.15*	*39.32*	*48.74*
Gruber Tiger (15 cm)	N0	39.99	38.99	*39.49*
	N60	58.10	41.43	*49.77*
	N90	60.96	46.29	*53.63*
	N120	77.61	62.28	*69.95*
	Average	*59.17*	*47.25*	*53.21*
Disc harrow (15 cm x 2 passes)	N0	36.65	36.65	*36.65*
	N60	53.91	37.24	*45.58*
	N90	59.85	42.52	*51.19*
	N120	64.68	44.01	*54.35*
	Average	*53.77*	*40.11*	*46.94*

In the year 2023, tillage methods combined with nitrogen rate led to a variation of the TGW from 36.38 to 49.27 g, while in the year 2024 this variation was between 34.45 to 45.83 g (Table 20).

Table 20. Soil tillage and nitrogen rate effect on TGW

Tillage methods	Nitrogen rate	TGW (g)		
		2023	2024	*Average*
Plowing (25 cm + 2 passes with disc harrow)	N0	37.83	36.31	*37.07*
	N60	40.28	36.32	*38.30*
	N90	40.83	34.45	*37.64*
	N120	44.15	37.15	*40.65*
	Average	*40.77*	*36.06*	*38.42*
Scarifying (35 cm + 2 passes with disc harrow)	N0	37.57	35.32	*36.45*
	N60	40.73	37.18	*38.96*
	N90	42.87	35.65	*39.26*
	N120	49.27	36.91	*43.09*
	Average	*42.61*	*36.27*	*39.44*
Gruber Tiger (25 cm)	N0	36.86	37.93	*37.40*
	N60	41.22	36.65	*38.94*
	N90	41.39	37.39	*39.39*
	N120	45.25	37.73	*41.49*
	Average	*41.18*	*37.43*	*39.31*
Gruber Tiger (15 cm)	N0	36.38	42.4	*39.39*
	N60	40.54	40.38	*40.46*
	N90	41.8	41.23	*41.52*
	N120	42.46	45.83	*44.15*
	Average	*40.30*	*42.46*	*41.38*
Disc harrow (15 cm x 2 passes)	N0	37.72	37.24	*37.48*
	N60	39.29	39.58	*39.44*
	N90	40.3	37.6	*38.95*
	N120	41.12	38.19	*39.66*
	Average	*39.61*	*38.15*	*38.88*

Generally, regardless of tillage variant and climatic conditions of the year, the TGW increased with nitrogen rate increase.

In the year 2023, tillage methods combined with nitrogen rate led to a variation of the grain yield from 1988 kg/ha (for the variant combining disc harrow with 0 kg/ha of nitrogen) to 4660 kg/ha (for the variant combining scarifying with 120 kg/ha of nitrogen), while in the year 2024 this variation was between 1701 kg/ha (for the variant combining disc harrow with 0 kg/ha of nitrogen) to 3813 kg/ha (for the variant combining Gruber Tiger at 15 cm with 120 kg/ha of nitrogen) (Table 21). Generally, regardless of tillage variant and climatic conditions of the year, the grain yield increased with nitrogen rate increase.

Table 21. Soil tillage and nitrogen rate effect on sunflower grain yield

Tillage methods	Nitrogen rate	Grain yield (kg/ha)		
		2023	2024	*Average*
Plowing (25 cm + 2 passes with disc harrow)	N0	2448	1813	*2131*
	N60	3280	1971	*2626*
	N90	3738	1869	*2804*
	N120	4087	2098	*3093*
	Average	*3388*	*1938*	*2663*
Scarifying (35 cm + 2 passes with disc harrow)	N0	2881	1755	*2318*
	N60	3280	2114	*2697*
	N90	3644	2172	*2908*
	N120	4660	2351	*3506*
	Average	*3616*	*2098*	*2857*
Gruber Tiger (25 cm)	N0	2165	1808	*1987*
	N60	3545	2148	*2847*
	N90	3801	2243	*3022*
	N120	4456	2567	*3512*
	Average	*3492*	*2191*	*2842*
Gruber Tiger (15 cm)	N0	2251	2520	*2386*
	N60	3215	2595	*2905*
	N90	3433	2756	*3095*
	N120	4348	3813	*4081*
	Average	*3312*	*2921*	*3117*
Disc harrow (15 cm x 2 passes)	N0	1988	1701	*1845*
	N60	3346	2323	*2835*
	N90	3346	2746	*3046*
	N120	4026	3104	*3565*
	Average	*3177*	*2469*	*2823*

CONCLUSIONS

The obtained results highlighted the better values of the grain yield and yielding elements at deep and reduced tillage (scarifying at 35 cm + 2 disc harrows and Gruber Tiger at 25 cm) in favourable climatic conditions, while in the context of less favourable climatic conditions the best results were obtained in the context of

shallow and reduced tillage of Gruber Tiger at 15 cm (2 passes).

The worst results were obtained in the case of tillage with disc harrow at 15 cm (2 passes) in favourable climatic conditions, and in the case of tillage with plowing at 25 cm + disc harrow (2 passes) less favourable climatic conditions.

The obtained results showed that the values for all the analysed yield elements and the grain yield constantly increased with increasing the nitrogen rate from 0 to 60, respectively to 90 and 120 kg/ha, regardless of tillage method and the climatic conditions of the year.

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