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Research Article (Aaştırma Makalesi)

Effects of Different Main Soil Tillage Methods on The Vertical Distribution of Sunflower Seeds in The Soil Layer and Plant Development

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Keywords
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Plant development.
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Abstract: The investigation was carried out on slightly leached chernozem soil type during 2014 – 2016. The effects of different soil tillage methods for sunflower on the vertical distribution of the seeds in the soil layer and the development of the plants were followed – ploughing at 24-26 cm, chisel ploughing at 24-26 cm, disking with disk harrow at 10-12 cm and no-tillage. The highest percent of sunflower seeds in the zone of the soil layer optimal for sowing (5-7 cm) were significantly placed in the areas cultivated with chisel-ploughing (62.1%). Under the other types of soil tillage, their amount decreased. When sowing was performed at a mean diurnal air temperature close to the norm (10.1 °C), the emergence of the plants in the variants with chisel ploughing, disking and no-tillage occurred significantly slower in comparison to ploughing. At higher mean diurnal air temperature (12.0 °C), only at the beginning of sunflower emergence some delay was observed depending on the type of the applied soil tillage. Under these conditions, a significant difference in the occurrence of the phenophases was determined in the variants with disking and direct sowing, as compared to the areas with ploughing. With the minimizing and exclusion of the soil tillage, the growth of the sunflower plants was significantly retarded at the initial stages of their development. At phenophase flowering, the plant height and the stem diameter were lowest in the areas cultivated with disking. The investigated types of soil tillage did not have a significant effect on the diameter of the sunflower heads.

Farklı Temel Toprak İşleme Yöntemlerinin Ayçiçeği Tohumlarının Toprak Katmanındaki Dikey Dağılımına ve Bitki Gelişimine Etkisi

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Tohumların toprağın derinliğine göre taksimatı,
Temel toprak işletilmesi,
Bitkilerin gelişmesi,
Ayçiçeği.

Öz: Araştırma, 2014-2016 tarihleri arasında General Toşevo kentine bağlı arazide, türünün tipik özelliklerine sahip çernezyom toprak tipi üzerinde gerçekleştirilmiştir. Farklı temel toprak işleme yöntemlerinin ayçiçeği tohumlarının toprak tabakasındaki dikey dağılımına ve bitki gelişimine üzerindeki etkisi gözlemlendi: 24-26 cm derinlikte toprak sürme, 24-26 cm derinlikte devirmeden toprak işleme, 10-12 cm derinlikte diskli toprak işleme ve direkt ekim (sıfır). Ekim için en uygun toprak tabakası alanında (5-7 cm) en yüksek ayçiçeği çekirdeği yüzdesinin devirmeden toprak işlemenin yapıldığı (62.1%) bölgelerde olduğu istatistiksel olarak kanıtlanmıştır. Diğer toprak işleme yöntemleri kullanıldığında, onların miktarı azalır. Normal değerine yakın ortalama günlük hava sıcaklığı koşullarında (10.1 °C) ekim gerçekleştirildiğinde devirmeden toprak işleme, diskli toprak işleme ve sıfır işleme yöntemlerinin, toprağı sürmeye kıyasla istatistiksel olarak daha yavaş ilerlediği tespit edilmiştir. Daha yüksek ortalama günlük hava sıcaklığı koşullarında (12.0 °C), kullanılan toprak işleme türüne bağlı olarak, sadece ayçiçeğin çimlenmesi süreci başlangıcında belirli bir gecikme gözlemlenir. Bu koşullar altında, diskli toprak işleme ve direkt ekim yöntemlerinin, toprak sürme yöntemine kıyasla, bu aşamanın seyrinde istatistiksel olarak kanıtlanmış bir farklılık tespit edilmiştir. Toprak işleme yöntemleri etkisinin en aza indirildiğinde veya göz ardı edildiğinde, ayçiçeği bitkilerinin gelişimlerinin ilk aşamalarındaki büyümeleri, istatiksel olarak yavaşladığı tespit edilmiştir. Çiçeklenme fenofazında, ayçiçeği saplarının yüksekliği ve çapı diskli toprak işleme yöntemi kullanıldığı takdirde en küçük olduğu tespit edilmiştir. İncelenen toprak işleme yöntemlerinin, ayçiçeği tablasının çapı üzerinde istatistiksel olarak kanıtlanmış olan bir etkisi bulunmamaktadır.

1. Introduction

Sunflower is a main oil seed crop in Bulgaria. The different soil and climatic conditions in the country and the desire of the producers to obtain higher yields at lower cost price are the reasons to seek for cost effective agronomy practices when growing this crop (Yanchev and Kirchev, 2007; Delchev, 2013; Delibaltova and Dallev, 2017; Drumeva and Yankov, 2018). This includes also the ways for main tillage of soil.

During the last decades, wide usage of chemicals in conventional agriculture is being observed. It is based on the great offer and use of various mineral fertilizers and preparations for plant protections. This imposes the necessity to reconsider the significance of deep ploughing as a main means for increasing the effective soil fertility, and for control of weeds, diseases and pests on the grown cultural plants. On the other hand, a tendency towards permanent increase of the prices of fuels is also being observed, and ploughing is one of the most energy-consuming operations in agriculture (Zugec et al., 2000; Sin et al., 2008).

The ways for soil tillage depending on the used soil tillage tools and the technological processes related to them have different effects on the physical, chemical and biological properties of the soil. The main physical characteristics directly influenced by the applied types of soil tillage are the soil structure, the bulk density, the porosity, the moisture and the temperature. They, on their part, are important for the emergence, development and productivity of the grown agricultural crops (Licht and Al-Kaisi, 2005). Under the conditions of Bulgaria, the recommendable optimal depth for sowing of sunflower is from 5 to 7 cm (Klochkov et al., 1988). The applied ways for main and pre-sowing soil tillage have different effects on the percent distribution of the structural agents in the zone of seed planting (Guérifa et al., 2001). Some of them increase the share of the large fractions, while others lead to stronger dusting of soil (Yankov, 2009a). This is a prerequisite a part of the seeds to fall to greater or lower depth (Yankov, 2012; Yankov and Drumeva, 2014).

The physical properties of the seed bed are especially important also for the emergence, the optimal density and the distribution of the plants in the crop, the growth of the plants and the yield obtained from them (Ozpinar and Cay, 2006). In order to emerge fast and uniformly, the sunflower seeds should be placed in a well settled soil, and the upper soil layer should be loose. Thus, a supply of moisture from below and of air from above is ensured, and the penetration of the sprouts to the soil surface is facilitated. It is also necessary to provide good contact of the seeds with soil (Radford and Nielsen, 1985). Investigating the effect of different ways for soil tillage on the development and productivity of sunflower, Sessiz et al. (2008) reported higher percent of emerging plants under conventional tillage, followed by direct sowing, minimal tillage and chisel-ploughing. In an 11-year experiment, Dam et al. (2005) also determined a slower rate of emergence of maize in a variant with direct sowing.

Sessiz et al. (2008) did not find a statistically significant difference for the effect of the different ways of soil tillage on the height of the sunflower plants, the head diameter and the stem. The greatest height, head diameter and stem were measured in the areas with chisel-plough, followed by those with conventional tillage, disking and direct sowing. The different intensity of the chisel plough also influenced these biometrical parameters. Guirguis et al. (2008) determined the highest stem height and head diameter in the variant involving chisel-plough three passes followed by disk-harrow one pass. Lower values of these parameters under direct sowing were also reported by Yalçin et al. (2008).

In spite of the small variations between the conventional and no-tillage, the differences were significant.

The aim of this investigation was to follow the effects of different ways of main tillage methods of the slightly leached chernozem soils on the vertical distribution of the sunflower seeds in the soil layer and the development of the plants.

2. Material and Methods

2.1. Soil and climatic conditions

The investigation was carried out on the territory of General Toshevo during 2014 – 2016. The soils in the region where South Dobrudzha is located, are represented by slightly leached chernozems (Yolevsky et al., 1959). According to their mechanical composition, they are sandy-loamy, with favorable water and air regime. Their bulk density characterizes them as soils with loose structure, without compact horizons down the entire profile. Their soil reaction is neutral. They have a comparatively powerful humic horizon (60-80 cm), with a mean content of humus in the plough layer of 3.7 %. The reserves of P_2O_5 are from low to moderate, and the reserves of K_2O – from moderate to good.

The mean annual temperature in the region is 10.6 ºC. January is the coldest month (–0.3 ºC), and July is the warmest (21.3 ºC). The mean annual precipitation sum is 518.3 mm. The maximum of rainfalls is during May – June, and the minimum – during August – September.

The meteorological data for the years of the investigation showed that it was carried out under varied climatic conditions (Figure 1). The mean diurnal air temperature in April of 2014 and 2016, when the sunflower plants emerged and started their development, was higher than normal and reached 12 ºC. The air temperature during this period of 2015 was close to the climatic norm (10.1 °C). In July, mass flowering of sunflower occurred. It was warmer in 2015 and 2016 in comparison to the long-term mean diurnal air temperature for this month. In 2014, the air temperature for this period was close to the norm.

In April of 2015, the sum of the rainfalls was close to the climatic norm. During the other two years of the investigation, the rainfalls were lower. The large amount of rainfalls in June of 2014 is noteworthy. It was with 210.0 % above the mean long-term value. In July, the month next in importance for the vegetative growth of sunflower, only year 2014 was close to the climatic norm by amount of the rainfalls. The other two years from the investigation were drier.

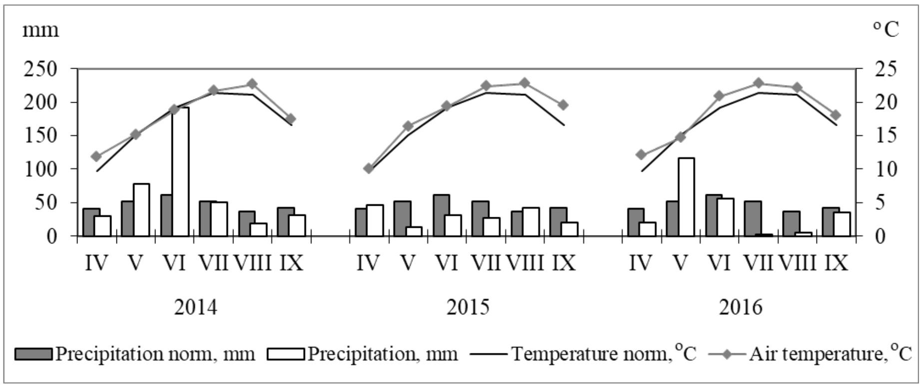


Figure 1. Air temperature and precipitation during the vegetation period from May to September of 2014, 2015 and 2016.

2.2. Field experiment

Four types of main soil tillage methods for sunflower were investigated as ploughing (conventional tillage) at 24-26 cm (CT), chisel ploughing at 24-26 cm (CP), disking with disk harrow at 10-12 cm (DD) and no-tillage (NT). The experiment was designed according to the long plot method. Each variant was tested on plot being 576 m^2, divided in eight equal replications with size of 72 m^2 (12 x 6 m).

The main types of soil tillage for sunflower were performed in August. The pre-sowing tillage of the areas cultivated with ploughing and disking included two times processing with cultivator and harrow. In the other two variants such pre-sowing treatments were not applied. In the variants with chisel-ploughing and no-tillage, a total herbicide was applied for control of weeds. At high infestation with weeds, double spraying with the herbicide was done – one in autumn, and the other one in spring, prior to sowing of sunflower. Only a single pre-sowing spraying with the herbicide was applied at low density of weeds.

Sunflower seeds were sown by use of a pneumatic planting machine setted up for sowing density of 65 000 plants/ha, 0.7 m spaced rows and sowing depth of 6 cm. During the vegetative growth of the crop, the weeds in all tested variants were controlled by using the appropriate herbicide. Mechanical inter-row cultivation of the soil in the studied variants was not done.

2.3. Distribution of the seeds in the soil layer

To determine the depth of seed placement, the etiolated part of the ladder of plants removed from the soil was measured. The measurements were carried out after the end of germination and covered randomly 20 plants from each replication.

2.4. Dynamics of plant emergence

The dynamics of plant emergence was counted daily from two rows with 6 m length for each replication. Plant counts were made in the marked rows from the first emergence until a constant number of germinated plants from each replication of the variants was reached. From the number of total emerged seeds and the number of planted seeds, the percentage of emerged seedling was calculated.

2.5. Biometrical parameters of the plants

The plant height and the stem diameter at budding and full flowering stages were estimated on the plants of each replication from two rows of 6 m, marked at sowing. 20 plants per row were measured. On the same plants the head diameter was measured at stage full flowering.

2.6. Statistical analysis

All data were analyzed using the analysis of variance (ANOVA) procedure to test the effects of different main soil tillage methods on the measured parameters – distribution of the seeds in the soil layer, dynamics of plant emergence and biometrical parameters of the plants. Mean comparisons were performed using the Fisher’s LSD (the least significant difference) test at $P < 0.05$, 0.01 and 0.001. After performing the analysis of variance, we compared the different main soil tillage methods, using the Duncan’s Multiple Range Test (DMRT). SPSS (2007) was used for statistical data processing.

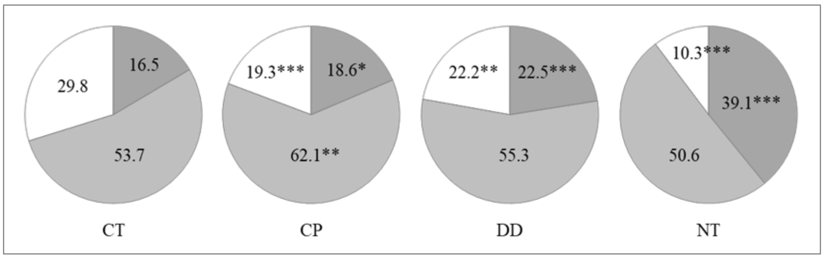
3. Results and Discussion

3.1. Distribution of the seeds in the soil layer

The placement of the seeds at a suitable depth and their even distribution in the soil layer depends on the quality of the soil tillage that has been performed. It had to be uniform down the soil profile, to ensure favorable percentage distribution of the agronomically valuable structural units with a size from 10 to 0.25 mm in the zone of seed placement, to incorporate at the necessary depth the previous crop plant residues.

Depth of sowing has been an important factor in ensuring the uniform germination of plants and the desired density of crops. If the seeds were sown deeply and the soil was cold, germination would be prolonged and would affect the vitality of young plants. Conversely, if the seeds have been laid shallowly, when the surface soil layer dries, their germination has been delayed and even the already germinated seeds would dry out. Therefore, the depth of sowing and its uniformity has to be approached precisely. The omissions or bad quality of this agro-technical practice would be irreparable and difficult to compensate.

The data on the vertical distribution of the sunflower seeds in the soil cultivated in different ways showed that at the optimal depth (5-7 cm), most seeds were placed in the area with chisel-ploughing, followed by that with disking and ploughing (Figure 2). Lowest percent of seeds in this soil layer were determined in the variant with direct sowing. The differences, as compared to ploughing, were statistically significant at P=0.01 for chisel-plough, and statistically not significant for disking and no-tillage. With the reduction of the soil tillage, the amount of seeds placed at a depth lower than the favorable (<5-7 cm) also increased. The differences, as compared to ploughing, were significant at P=0.05 for tillage without turning of the soil layer, and for minimal tillage and no-tillage – at P=0.001. The highest percent of seeds were registered in the variant with ploughing in the soil layer under the optimal for sowing (>5-7 cm). Such a tendency in this soil type has been determined in studies on other crops as well (Yankov, 2012; Yankov and Drumeva, 2014). This variant was followed by minimal tillage, tillage without turning of the soil layer and no-tillage. The differences, as compared to ploughing, were statistically significant at P=0.01 for disking, and for chisel-plough and direct sowing – at P=0.001.



CT – ploughing at 24-26 cm; CP – chisel ploughing at 24-26 cm; DD – disking at 10-12 cm; NT – no-tillage

	Depth, cm	LSD 0.05	LSD 0.01	LSD 0.001
■ (dark grey)	<5-7	2.072	3.139	5.047
■ (light grey)	5-7	3.965	6.006	9.655
□	>5-7	3.190	4.833	7.769

*, **, *** – Significance of effects and variations at P levels 0.05, 0.01 and 0.001, respectively

Figure 2. Distribution of sunflower seeds along depths according to the type of soil tillage (%).

The applied analysis of the variances showed that the performed types of main soil tillage methods have a significant effect on the vertical distribution of the sunflower seeds down the soil profile (Table 1). In the different layers the influence of this factor on the studied parameter was significant at P=0.001.

Table 1. Variance analysis of the investigated index

Index	Depth, cm	df	Mean Square	F	Sig.
	<5-7		315.547	291.499	.000
Soil tillage	5-7	3	70.827	23.472	.000
	>5-7		194.820	71.823	.000

To follow the effect of the tested factor on this agronomy parameter, Duncan test was applied (Table 2). At a depth greater than the recommendable for sowing of sunflower (<5-7 cm), based on the percent distribution of the seeds in the soil layers, a similarity between the separate types of tillage was not found. Each of them fell within a separate group.

At the optimal depth (5-7 cm), three groups were formed. Direct sowing fell within the most unfavorable one (a), which was with the lowest amount of seeds placed in this soil layer. The test distributed conventional tillage in this group as well (a), but also classified it to the next better one (b), which, too, included the variant with disking. Chisel plough was in an independent group (c), and in this area the highest percent of seeds at the recommended depth were determined.

Three groups were formed under the soil layer favorable for sowing (>5-7 cm). The first of them (a) included direct sowing, which was with the lowest percent of seeds placed in this horizon. In the next group (b), the test placed the areas with disking and chisel-plough, which occupied an intermediate position with regard to the values of the investigated parameter. The third group (c) included conventional tillage with the highest percent of seeds below the optimal depth.

Table 2. Statistical grouping of soil tillage in the respective depths of the soil layer based on the percent of vertical distribution of sunflower seeds (Duncan)

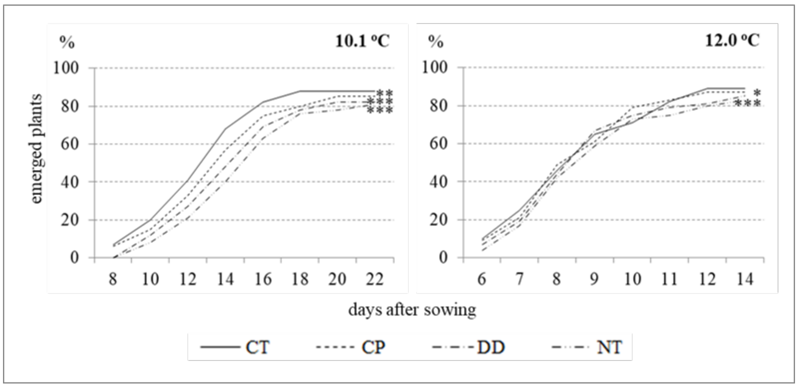
Soil tillage	Depth, cm		
	<5-7 cm	5-7 cm	>5-7 cm
	Groups (Values)		
CT	a (16.5)	a, b (53.7)	c (29.8)
CP	b (18.6)	c (62.1)	b (19.3)
DD	c (22.5)	b (55.3)	b (22.2)
NT	d (39.1)	a (50.6)	a (10.3)

CT – ploughing at 24-26 cm; CP – chisel ploughing at 24-26 cm; DD – disking at 10-12 cm; NT – no-tillage.

Probably the deviations from the optimal depth of seed placement in the variants with ploughing and disking were due to the variation of the depth of the performed pre-sowing cultivation and the looseness of the soil, which increased the percent of seeds sown deeper. Exclusion the tillage of the surface soil layer in the areas with chisel ploughing and no-tillage helped to reduce the microuneven of the terrain. The higher bulk density of the slightly leached chernozems in the areas with direct sowing (Yankov, 2007) conditioned the greater amount of the seeds placed at a shallower depth in the soil profile. The low degree of loosening on soil in variant with chisel plough led to a reduction and exclusion of the destructive effect of intensive tillage on the bulk density and aggregate stability (Abu-Hamdeh, 2004; Barzegar et al., 2003; Yankov, 2007; Yankov, 2009a; Nunes et al., 2020), which benefited a more equal sowing regime.

3.2. Dynamics of plant emergence

The dynamics of the emergence of the plants under the studied types of soil tillage was followed at different mean diurnal air temperatures during the period from sowing to the end of emergence (Figure 3).



CT – ploughing at 24-26 cm; CP – chisel ploughing at 24-26 cm; DD – disking at 10-12 cm; NT – no-tillage

ºC	$LSD_{0.05}$	$LSD_{0.01}$	$LSD_{0.001}$	ºC	$LSD_{0.05}$	$LSD_{0.01}$	$LSD_{0.001}$
10.1	3.339	4.545	6.131	12.0	2.435	3.315	4.472

*, **, *** – Significance of effects and variations at P levels 0.05, 0.01 and 0.001, respectively

Figure 3. Dynamics of sunflower emergence after different soil tillage and day/night air temperature (%).

At mean diurnal air temperature close to the norm (10.1 °C), the emergence of sunflower in the areas with disking and direct sowing started with 1-2 days later. The replacement of conventional ploughing with minimal and no-tillage also decreased the dynamics of emergence, which was especially well expressed at the initial periods. Later, the differences in the rate of emergence between the variants decreased. Under chisel-plough and disking, the emergence of sunflower was completed within two days, and under direct sowing – with four days later than under ploughing. At the end of this phenophase, regardless of its later and slower rate of occurrence, the percent of emerging plants was approximately the same under the different ways for tillage of soil. The differences in the occurrence of this phase under alternative types of soil tillage, as compared to ploughing, were significant at P=0.01 for chisel-plough, and for disking and direct sowing – at P=0.001.

Under the conditions of a higher mean diurnal air temperature (12.0 °C), some delay was observed only at the beginning of the sunflower emergence depending on the type of the used soil tillage. On the 7th day after sowing, the highest number of emerging plants were registered under ploughing. With the reduction of the soil tillage types, their number decreased. After the 9th day, a relative uniformity in the percent of emerging plants was observed under the investigated types of soil tillage methods. Under these more favorable temperature conditions, there was no significant difference between ploughing and chisel plough during the occurrence of this phenophase. A significant difference noted in the other two variants. In the areas with disking, it was significant at P=0.05, and in the areas with direct sowing – at P=0.001.

The applied analysis of variances showed that the factors "soil tillage", "mean diurnal air temperature" and the combination between them had a statistically significant effect on the dynamics of the emergence of the sunflower plants (Table 3). The effect of the factors on the investigated trait was significant at P=0.001.

Table 3. Analysis of variance of soil tillage (A) $_x$ mean diurnal temperature (B) in dynamic of sunflower emergency

Indices	df	Mean Square	F	Sig.
Soil tillage (A)	3	320.068	46.834	.000
Mean diurnal temperature (B)	1	508.805	74.450	.000
A $_x$ B	3	86.602	12.672	.000

The Duncan test, with regard to the effect of the investigated types of tillage on the dynamics of the plant emergence, placed at the beginning of this phenophase ploughing and chisel-plough in the same group (b), (Table 4). To the next group with a lower number of emerging plan (a) belonged disking and direct sowing.

In the middle of the phase, the test formed three groups. The most unfavorable one (a) included direct sowing, which was with the lowest number of registered plants. The areas with disking and chisel plough fell within the second, better group (b). Those with applied ploughing were classified separately (c), and they were with the highest percent of emerging plants.

Table 4. Statistical grouping of soil tillage based on the dynamics of sunflower emergence (Duncan)

Soil tillage	Dynamics of sunflower emergence (%)		
	at the beginning of the phenophase	in the middle of the phenophase	at the end of the phenophase
	Groups (Values)		
CT	b (8.50)	c (66.50)	b (88.50)
CP	b (7.50)	b (59.00)	a, b (86.00)
DD	a (3.55)	b (57.50)	a (83.50)
NT	a (2.05)	a (49.50)	a (82.00)

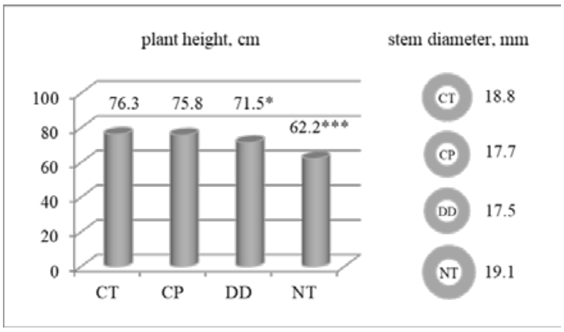
CT – ploughing at 24-26 cm; CP – chisel ploughing at 24-26 cm; DD – disking at 10-12 cm; NT – no-tillage.

At the end of the emergence phenophase, again two groups were formed. One of them (a) included disking and direct sowing, in which a smaller end number of sunflower plants were determined. The test placed chisel-plough in this group as well, but at the same time classified it in the next better group (b), where the variant with conventional tillage was placed. This allowed the conclusion that under favorable temperature and water regime, chisel plough may be recommended as an alternative to conventional ploughing with regard to the studied trait. The lower percent of emerging plants and the slower occurrence of this phenophase in the tested ways for alternative soil tillage, as compared to the conventional one, were probably due to the less favorable thermal conditions and aeration of the surface soil layer in these areas (Yankov, 2007; Yankov, 2009b). Sessiz et al. (2008) also reported a higher percent of emerging plants under ploughing.

3.3. Biometrical parameters of the plants

The effect of the studied ways for soil tillage on the vegetative development of sunflower was followed by measuring the plant height and the stem diameter at stages budding and full flowering. At phenophase full flowering, the head diameter was measured since it was one of the parameters determining the yield from this crop.

The height of the sunflower measured at budding stage was highest under conventional tillage, followed by chisel plough (Figure 4). With the reduction of the tilths, the plant height decreased statistically significant under disking (P=0.05) and direct sowing (P=0.001). During these phenophases, in the variant with no-tillage, the highest stem diameter was read. The differences in the values of this parameter between the separate ways of soil tillage were not significant.



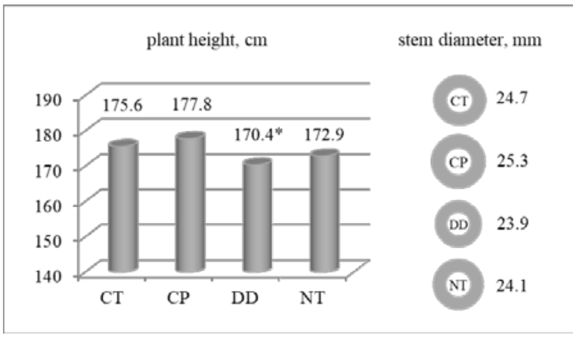
CT – ploughing at 24-26 cm; CP – chisel ploughing at 24-26 cm; DD – disking at 10-12 cm; NT – no-tillage

Indices	$LSD_{0.05}$	$LSD_{0.01}$	$LSD_{0.001}$
plant height, cm	3.450	5.225	8.340
stem diameter, mm	2.234	3.899	5.874

*, **, *** – Significance of effects and variations at P levels 0.05, 0.01 and 0.001, respectively

Figure 4. Effect of soil tillage on plant height and stem diameter at budding stages of sunflower.

At phenophase full flowering, in the variant with chisel plough, the greatest height of sunflower was registered. Next came ploughing and direct sowing. Lowest were the plants in the areas with disking, statistically significant at P=0.05 (Figure 5). The lowest stem diameter was also measured in this variant. The statistical differences in the values of this parameter during this phenophase were not significant between the separate ways of soil tillage.



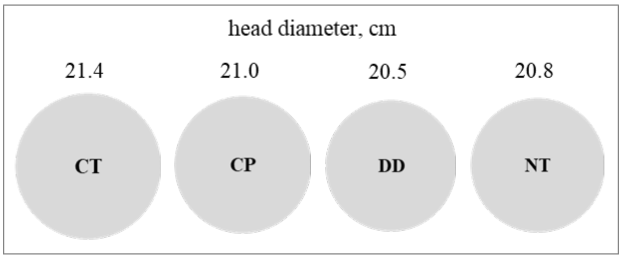
CT – ploughing at 24-26 cm; CP – chisel ploughing at 24-26 cm; DD – disking at 10-12 cm; NT – no-tillage

Indices	LSD 0.05	LSD 0.01	LSD 0.001
plant height, cm	5.082	7.698	12.375
stem diameter, mm	2.066	3.129	5.031

*, **, *** – Significance of effects and variations at P levels 0.05, 0.01 and 0.001, respectively

Figure 5. Effect of soil tillage on stem height and diameter at blooming stages of sunflower plant development.

The differences in the head diameter between the applied types of soil tillage at stage full flowering were also not significant (Figure 6).



CT – ploughing at 24-26 cm; CP – chisel ploughing at 24-26 cm; DD – disking at 10-12 cm; NT – no-tillage

LSD 0.05	LSD 0.01	LSD 0.001
3.299	4.997	8.033

*, **, *** – Significance of effects and variations at P levels 0.05, 0.01 and 0.001, respectively

Figure 6. Effect of soil tillage on head diameter at blooming stages of sunflower.

The applied analyses of variances showed that the factor "soil tillage" had a significant effect on sunflower height (P=0.001), (Table 5). It did not have a significant effect on the diameter of stems and heads. The factor "vegetative stage of development" influenced the height of the plants and the diameter of their stems significantly at P=0.001. The combination of the two factors – soil tillage and vegetative phase of development had a statistically significant effect only on the height of plants (P=0.05).

Table 5. Analysis of variance of soil tillage (A) x vegetative phase of development (B) in sunflower for plant height, stem diameter and head diameter

Indices	df	Mean Square	F	Sig.
plant height				
Soil tillage (A)	3	113.794	20.349	.000
Vegetative phase of development (B)	1	62689.482	12.121	.000
A * B	3	44.661	7.986	.002
stem diameter				
Soil tillage (A)	3	1.324	.728	.550
Vegetative phase of development (B)	1	232.504	127,925	.000
A * B	3	1.764	.970	.431
head diameter				
Soil tillage (A)	3	.427	.208	.888

The Duncan test, regarding the effect of the investigated ways for soil tillage on the vegetative development of plants, placed the studied variants in different groups only by the parameter plant height (Table 6). At phenophase budding, three groups were formed. The most favorable of them (c) included ploughing and chisel-plough. Disking was referred to the next group with shorter plants (b). Direct sowing belonged to the least favorable group (a) and in this group the sunflower plants were the shortest.

At phenophase flowering, the differences decreased and two groups were formed. One of them (b) included chisel-plough, ploughing and no-tillage, in which the height of the plants was approximately the same. Other authors also reported greater plant height of sunflower in the variant with chisel-plough (Guirguis et al., 2008; Sessiz et al., 2008). The other two types of tillage were placed by the test also in the next less favorable group (a), to which disking was referred separately. In the areas of this variant, the plants were shortest during this phase. Opposite were the findings of Sessiz et al. (2008), who determined greater plant height of sunflower under disking in comparison to direct sowing.

For the other two parameters, diameter of stems and heads, the test placed all investigated types of tillage in one group (a). Sessiz et al. (2008) also did not find statistical significance concerning the effect of the different types of soil tillage on these parameters. Opposite were the results of Yalçin et al. (2008) according to them the differences were significant in spite of the small variations in the values.

Table 6. Statistical grouping of soil tillage based on the vegetative development of sunflower (Duncan)

Soil tillage	Groups (Values)	
	budding stages	blooming stages
	plant height	
CT	c (76.3)	a, b (175.6)
CP	c (75.8)	b (177.8)
DD	b (71.5)	a (170.4)
NT	a (62.2)	a, b (172.9)
	stem diameter	
CT	a (18.8)	a (24.7)
CP	a (17.7)	a (25.3)
DD	a (17.5)	a (23.9)
NT	a (19.1)	a (24.1)
	head diameter	
CT	a (21.4)	
CP	a (21.0)	
DD	a (20.5)	
NT	a (20.8)	

CT – ploughing at 24-26 cm; CP – chisel ploughing at 24-26 cm; DD – disking at 10-12 cm; NT – no-tillage.

In the investigated alternative ways of main soil tillage, the lower height of the plants at phenophase budding was probably due to the lower soil temperatures at the end of the spring and the beginning of summer, as well as to the higher bulk density of the soil layer. The complex effect of these factors suppressed the upward growth of sunflower. At phenophase flowering, the lower plant height and stem diameter in the variant with disking were probably due to the weaker roots of the plants because of the higher bulk density of the soil layer to the depth to which this type of tillage was performed (Yankov, 2007; Osman et al., 2011; Gbadamosi, 2013; Nargish et al., 2014). A similar tendency in the same soil type and way of soil tillage has been established in another spring crop – grain maize (Yankov and Drumeva, 2017).

4. Conclusion

The highest percent of sunflower seeds in the zone of the soil layer optimal for sowing (5-7 cm) were placed when cultivation with chisel-plough was applied. Under the other types of soil tillage, their amount decreased. In the variants with disking and direct sowing, the percent of the seeds placed at a depth lower than the favorable one (<5-7 cm) increased. Under the layer optimal for sowing (>5-7 cm), the highest amount of seeds were determined in the ploughed areas.

When sowing was performed at a mean diurnal air temperature close to the norm, the emergence of the plants in the variants with chisel plough, disking and no-tillage occurred significantly slower in comparison to ploughing. In these areas the phenophase was with 2 to 4 days longer. At higher mean diurnal air temperature, only at the beginning of sunflower emergence some delay was observed depending on the type of the applied soil tillage. Under these conditions, a significant difference in the occurrence of the phenophases was determined in the variants with disking and direct sowing, as compared to the areas with ploughing.

With the minimizing and exclusion of the soil tillage, the growth of the sunflower plants was significantly retarded at the initial stages of their development. At phenophase flowering, the plant height and the stem diameter were lowest in the areas cultivated with disking. The investigated types of soil tillage did not have a significant effect on the diameter of the sunflower heads.

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