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Sunflower hybrid "Linzi" and its agronomic response to the main soil tillage systems in the region of South Dobrudzha

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Abstract

Sunflower (*Helianthus annuus* – hybrid "Linzi") yield obtained under different main soil tillage systems in 4-field crop rotation (common bean-wheat-sunflower-grain maize), is strongly influenced by the properties of the slightly leached chernozems the (Haplic Chernozems) and the climatic conditions. This study was carried out at the stationary field trial of Dobrudzha Agricultural Institute-General Toshevo from 2016 to 2018. The influence of seven main soil tillage systems (MSTS) on the yield and the physical properties of sunflower seeds were investigated.

The aim of this study was to trace the influence of different types of main soil tillage on seed yield, oil content and seed physical properties of sunflower hybrid ”Linzi”. Regardless of the meteorological conditions during the studied period, the main tillage systems are a powerful agrotechnical tool for managing sunflower productivity in all its aspects. The yield of seeds and kernels of hybrid ”Linzi”, as well as that of their oil content, is highest in years with a relatively favorable distribution of precipitation during the growing season. For the region of haplic Chernozems in Dobrudzha, the most effective systems for sunflower are the systems including the mould board plough of the soil. The best results were obtained when, in the 4-field crop rotation against wheat, deep tillage was replaced by Disking or No-till. The obtained oil yields are respectively: 2420.10 kg/ha (Plowing--Disking); 2280.80 kg/ha (Plowing-No-till) 2244.70 kg/ha (Plowing-Plowing). The largest seeds were obtained in the under permanent shallow treatment against all crops in crop rotation - 62.66 g (Disking-Disking).

The best results for the hectoliter weight were obtained in the two deep treatments with and without turning/inversion of the cultivated layer. However, the heaviest seeds were obtained when deep plowing is interrupted with direct seeding or disking, respectively. The positive correlation with the production of husks and kernels is strongly expressed. Averaged over the period, the correlation between the yield of seeds and that of husks has lower values compared to each of the years.

Key words: main tillage of soil, sunflower, yield, physical properties of seeds

Introduction

This agrotechnical practice is directly related to the degradation of soils on a global scale and, in this connection, to their nutritional regime and their moisture-holding capacity. That is why it is necessary to optimize constantly the known ways and systems of agricultural production. According to Bai et al. (2008) intensive tillage is responsible for about 24% of cropland degradation globally. Tillage has a significant impact on the physical properties of the soil, the fate and rate of decomposition of plant residues, the efficient use of water, the soil microbiota, the organic matter of the soil and a number of other indicators that are dynamic and highly sensitive to the methods of implementation and crop rotation. It is a known fact that annual conventional tillage practices lead to a change in soil structure (Rashidi & Keshavarzpour, 2007). It is an undeniable fact that sustainable use of soil resources is impossible without a reasonable approach to tillage in crop rotation (Lal & Stewart, 2013).

For the Dobrudzha region, it was established that, contrary to conservation methods and no-tillage methods, the long-term application of conventional tillage leads to the destruction of the soil structure, changes in the basic agrochemical parameters, and composition of soil organic matter (Nankova, 2010; Nankova & Yankov, 2013a; Nankova & Yankov, 2013b). Tillage is among the agrotechnical factors with a significant contribution to crop productivity. Khurshid et al., (2006) reported that tillage can contribute up to 20% of crop productivity. In their research, Busari et al (2015) concluded that to achieve sustainable productivity and quality production with minimal impact on soil and atmosphere, soil conservation practices are becoming more important than ever. This means that conservation agriculture requires a specific approach in the choice of conservation practices and in terms of tillage [zero tillage (No-till), reduced (minimum) tillage, mulch tillage, ridge tillage to contour tillage].

As a highly productive oilseed crop, sunflower requires the determination of the most appropriate agrotechnical practices in terms of tillage, especially for conditions and areas suffering from frequent droughts (Sher et al., 2021). The aim of this study was to trace the influence of different types of main tillage on seed yield, oil content and seed physical properties of sunflower hybrid “Linzi”.

Material and methods

This study was carried out at the trial field of Dobrudzha Agricultural Institute-General Toshevo from 2016 to 2018. Conventional sunflower hybrid “Linzi” was included in the present study. It is a single interline hybrid and belongs to the group of middle early hybrids. Thousand seeds weight is 60 g. The percentage of husk content is 20%. The hybrid is resistant to downy mildew /race 731/ and broomrape (Nenova, 2018). The crops in the crop rotation alternate as follows: beans, wheat, sunflower and corn for grain. In this crop rotation, the influence of 7 main soil tillage systems was studied. This field experiment is the successor of a stationary field experiment, including long-term application of 24 tillage systems in a 6-field crop rotation, laid in 1987. After crop harvest in 2013, a reduction in the number of alternate tillage systems was carried out. For experience the basic treatments were selected to be permanently applied in crop rotation for both grain and spring crops: 1. Plowing (for spring crops) - Plowing (for wheat) at a depth of 24-26 cm; 2. Disking-Disking at a depth of 10-12 cm; 3. Cutting-Cutting at a depth of 24-26 cm; 4. No till-No till (direct seeding). Three of the systems involve alternating tillage depending on the crops in the crop rotation: 5. Plowing (for spring crops) – Direct sowing (of wheat); 6. Cutting (for spring crops) - Disking (for wheat) and 7. Plowing (for spring crops) - Disking (for wheat). The mineral fertilization (kg/ha) in the crop rotation was as follows: Common bean – N60P60K60; Wheat – $N_{120}P_{120}K_{60}$; Sunflower - $N_{60}P_{120}K_{120}$ and Maize – $N_{120}P_{60}K_{60}$. Mineral fertilization was done with common ammonium nitrate NH_4NO_3 (34% N), triple superphosphate (46% P_2O_5) and potassium chloride (60 % K_2O).

The study included determination of the seed yield as well as the content of kernel (%) and husks (%). On this basis, the yield of the oil of whole seed (%) and those of the kernel and the husk was determined. The oil content of the kernel and husk and the whole seeds was determined by the method of Rujkowski (1957). The physical properties of the obtained production are characterized by determining the 1000 kernel weight (TKW - g) and the test weight (TW - kg).

The resulted data were statistically processed using variance analysis, F test and LSD (Least Significant Difference) test, which are commonly utilized in the multi-criterial statistical analysis. The SPSS version 16.0 statistical package was used. Significance of the treatments' effect was considered at 0.05 probability level. After performing the analysis of variance, the results were compared the means for each treatment using the Waller-Duncan's Multiple Range Test. Finally, Pearson correlation coefficients ("R coefficients") were computed and tested for significance.

Results and discussions

The three years significantly differed by the monthly dynamics of the main meteorological factors (fig. 1). The meteorological conditions for the growth and development of sunflower in 2016 and especially in 2017 can be defined as favorable. The latter is characterized by a very favorable distribution of vegetation precipitation. The beginning of the growing season in both years is characterized by sufficient rainfall to form an optimal amount of over ground biomass.

The conditions for the growth and development of sunflower in 2018 are moderately favorable. Vegetation precipitation at the beginning and especially at the end of the vegetation period is not sufficient and this predetermines disturbances in the filling of the seed. After flowering and until harvesting, precipitation with economic value - in August is only 1.1 mm. However, autumn-winter precipitation is above the norm (300 mm) – 340.0 mm, and this has a favorable effect on the initial phases of sunflower development and growth. The relative humidity of the air also did not reach critical levels causing disturbances in flowering and pollination.

The brief meteorological description shows that the month of August in all three years of research is distinguished by critically low precipitation values, which are of no economic importance. Similar conditions were also observed during flowering (July) in 2016. The high amount of autumn-winter precipitation during the studied period (significantly above the reference values) created a prerequisite not only for excellent soil moisture storage, but also for the maximum expression of productive possibilities of hybrid "Linzi".

In terms of temperature, the sunflower vegetation takes place in the conditions of temperatures typical for the individual months without the presence of extremely high values (over 32^{o} C) for a long period of time (over 4-5 days). In all three years of study, the analysis of variances of seed yield and the accompanying components of their productivity, regardless of the variation in their values, show a high level of statistical significance (p) of the applied MSTS (table 1). The same applies to both indicators characterizing the physical properties of the seeds.

These facts show that the values of the investigated indices, regardless of the conditions for the development of the hybrid "Linzi", are influenced by the tested tillage systems in the crop rotation. On average for the research period, the independent impact of the Years (1) and MSTS (2) factors on the values of the monitored indicators, as well as their interaction, are also distinguished by maximum statistical reliability (table 2).

The minimum and maximum values for the obtained yields (seed and oil) and the physical properties of the seeds varied significantly among years of study. It was found that in 2016 and 2017 the same were below 10 with the exception of oil production from the husk, which is an indication of very high uniformity of the sample. In 2018, the values of the coefficients of variation are slightly higher, but the samples are approximately uniform. The lowest values of the coefficient of variation for 2016-2018 are HW-1.94% and TKW-9.04% (fig. 2). In the sphere of the approximately uniform sample, the values

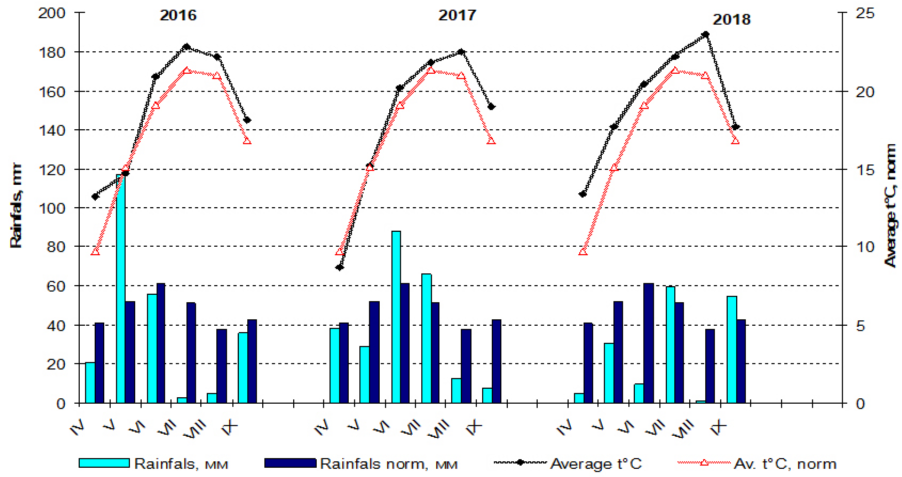


Fig. 1. Monthly sums of rainfall and average air temperature of the studied years and the climatic norms

Table 1. Analysis of the variances of the seed components productivity, oil yields and physical seeds properties according to MSTS by years of investigation

Dependent Variable	2016		2017		2018	
	F	Sig. (p)	F	Sig.(p)	F	Sig.(p)
Seeds yield	7.517	0.000	14.754	0.000	39.938	0.000
TKW	14.305	0.000	12.565	0.000	196.138	0.000
HW	33.416	0.000	56.715	0.000	1034.559	0.000
Kernels yield	6.388	0.001	16.690	0.000	43.262	0.000
Husks yield	13.721	0.000	16.933	0.000	34.829	0.000
Seeds Oil Yield	8.439	0.000	18.104	0.000	49.059	0.000
Kernels Oil Yield	7.539	0.000	20.190	0.000	49.120	0.000
Husks Oil Yield	91.500	0.000	52.245	0.000	120.762	0.000

Table 2. Analysis of the variances of the seed components productivity, oil yields and physical seeds properties according to MSTS for the period 2016-2018

Dependent Variable	Source Years (1)		Source MSTS (2)		1 x 2	
	F	Sig.(p)	F	Sig.(p)	F	Sig.(p)
Seeds yield	26.065	0.000	23.419	0.000	21.681	0.000
TKW	540.586	0.000	91.616	0.000	66.969	0.000
HW	483.378	0.000	123.560	0.000	111.898	0.000
Kernels yield	61.674	0.000	61.674	0.000	23.746	0.000
Husks yield	124.150	0.000	124.150	0.000	20.192	0.000
Seeds Oil Yield	75.297	0.000	75.297	0.000	25.405	0.000
Kernels Oil Yield	79.400	0.000	79.400	0.000	26.147	0.000
Husks Oil Yield	158.176	0.000	158.176	0.000	72.080	0.000

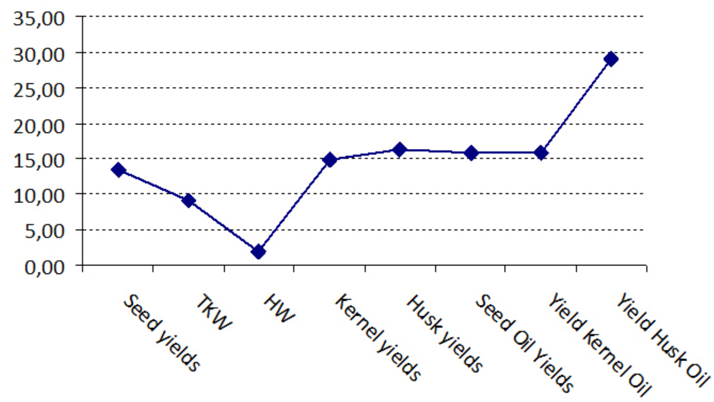


Fig. 2. Coefficients of variation (CV%) of indices for the period 2016-2018

Table 3. Yield of sunflower under studied MSTS per year, kg/ha

Main soil tillage system	2016	2017	2018
Plowing - Plowing	4251.8 bc	4540.9 bc	4842.8 c
Disking - Disking	3849.8 a	4398.7 b	3872.2 b
Cutting - Cutting	3583.5 a	5127.3 d	3784.0 b
No till – No till	4598.8 c	3968.4 a	3423.4 a
Plowing – No till	4294.5 c	4525.4 bc	4840.3 c
Cutting - Disking	3891.3 ab	4751.0 c	3605.2 ab
Plowing - Disking	4303.3 c	4604.4 bc	5629.3 d

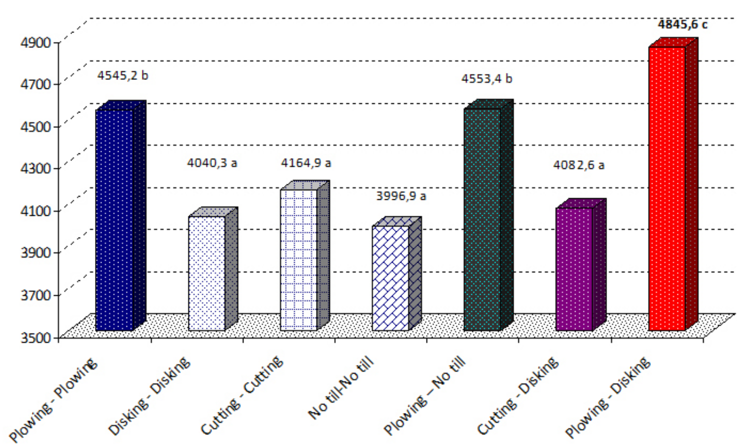


Fig. 3. Average seeds yield (kg/ha) of sunflower by MSTS for the period 2016-2018

of the coefficients of variation for the yields of seeds, kernels, husks and oil content in the seed and kernel remain (from 13.54% to 16.39%). The dispersion of the data both - by years and on average for the studied period, is the highest in oil content from the husk - 28.97%.

The presented statistical results show that the tested systems for basic tillage in all the studied years have a significant and in some cases divergent influence on the obtained seed yields (table 3). For the conditions of 2016, hybrid "Linzi" is distinguished by the lowest productivity in the case of continuous and long-term disking and deep cutting applied in the crop rotation. However, the same one has high productivity with constant No till (4598.8 kg/ha) and alternation of classic plowing with turning the layer with direct seeding or disking.

In 2017, of the independently-applied systems for basic soil treatment, hybrid "Linzi" reacted strongly positively to the systematic implementation of deep non-turning soil layer treatment in the crop rotation - 5127.3 kg/ha. This is also the highest productivity achieved by this hybrid for the conditions of the year. In the systems with alternative alternation of MSTS, its average productivity is 2.62% higher than that reached in their independent application. However, none of the systems, including the alternation of turning and non-turning treatments, reaches the amount of yield obtained in the constant cutting treatment. Interrupting this disking treatment (against wheat) resulted in the next highest yield of 4751.0 kg/ha. The hybrid has the lowest productivity in the constant application of No till in the crop rotation. For the conditions of 2018 hybrid "Linzi" reached its maximum productivity in the Plowing-Disking alternate rotation system (5629.3 kg/ha). The results show a rather wide range in varying the values of the obtained yields depending on the tested methods of soil tillage in the crop rotation. Permanent direct seeding is the most unsuitable agrotechnical practice for this crop. In general, sunflower as a crop (represented by this hybrid) for the conditions of the year demonstrates a highly pronounced response to the tillage system in the crop rotation. The crop shows a strong positive response to the application of deep tillage with turning of soil layer, carried out after harvesting the previous crop, as well as when it is alternated with treatments with partial rotation of the cultivated layer (Disking) or No-till.

On average for the studied period, in the long-term constantly applied MSTS, the most suitable for sunflower productivity is deep plowing with inversion of the layer - 4545.2 kg/ha (fig. 3). The differences between continuously performed No-till, Disking and Cutting (deep tillage without turning the layer) are statistically not proved. They are joined by the Cutting-Disking system. Interruption of plowing with direct seeding or disking has a beneficial effect on sunflower productivity, and with Plowing-Disking the highest yield of seeds for the studied period was obtained - 4845.6 kg/ha.

Depending on the type of MSTS, over the years the yields of the seed components vary significantly depending on their percentage ratio (table 4).

In 2016, the lowest average yields were obtained from kernels and, accordingly, the highest from husks. Regardless of the variation of these two components of the sunflower seed, the average ratio between them varies within narrow limits. The share of the husk in 2016 was 25.13%, 2017 - 26.83%, 2018 - 23.47%, average for the period - 27.72%. In absolute values, the highest yield of kernels was obtained in 2018 - 4576.6 kg/ha with the Plowing-Disking system, followed by that in 2017 - 4066.0 kg/ha with constant Cutting. In 2016, the highest yield of kernels was obtained with No till - No till and Plowing - No till. On average over the study period, the systems with the participation of classic plowing with layer reversal are distinguished by a higher yield of kernels and, accordingly, of husks compared to all other MSTS included in the study (fig. 4). The most favorable influence on the productivity of sunflower seed components is the system in which there is an interruption of constant plowing with disking (against wheat) in the crop rotation. At the same time, the highest yield of kernels was formed, a prerequisite for obtaining a higher yield of sunflower oil. The following are again those

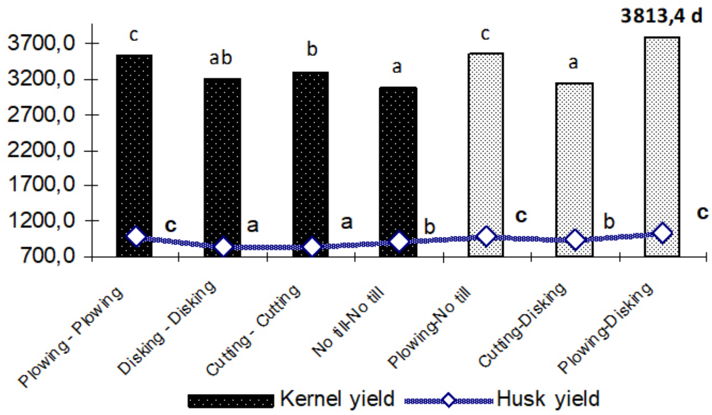


Fig. 4. Average kernel and husk yields for 2016-2018

Table 4. Yields of seed components, kg/ha

Soil tillage system	2016		2017		2018	
	Kernels	Husks	Kernels	Husks	Kernels	Husks
Plowing - Plowing	3142.0 bc	1109.7 cd	3569.2 b	971.7 cd	3946.9 c	896.0 c
Disking - Disking	2952.8 ab	897.0 a	3545.4 b	853.3 a	3121.1 b	751.2 b
Cutting - Cutting	2687.8 a	895.9 a	4066.0 c	1061.4 e	3174.8 b	609.2 a
No till – No till	3398.6 c	1200.3 d	3087.4 a	881.0 ab	2759.3 a	664.1 a
Plowing – No till	3263.9 c	1030.7 bc	3502.6 b	1022.7 de	3901.3 c	939.0 c
Cutting - Disking	2918.6 ab	972.9 ab	3710.5 b	1040.5 e	2815.7 a	789.5 b
Plowing - Disking	3180.0 bc	1123.1 cd	3683.5 b	920.9 bc	4576.6 d	1052.7 d

Table 5. Oil yield from whole seed, according to MSTS over the years, kg/ha

Soil tillage system	2016	2017	2018	2016-2018
Plowing - Plowing	2039.2 bc	2341.9 bc	2572.0 c	2317.7 c
Disking - Disking	1751.6 a	2252.5 b	1982.4 ab	1995.5 a
Cutting - Cutting	1767.6 a	2703.2 d	2051.9 b	2174.2 b
No till – No till	2140.4 c	2061.0 a	1839.2 a	2013.5 a
Plowing – No till	2179.6 c	2295.5 b	2665.8 c	2380.3 c
Cutting - Disking	1933.1 ab	2483.4 c	1809.6 a	2075.4 a
Plowing - Disking	2124.3 c	2385.1 bc	3025.2 d	2511.5 d

systems in which plowing involved - continuous and permanent, as with alternating rotation with No-till.

Whole seed oil yield over the years ranged from 1751.6 kg/ha in 2016 (Disking-Disking) to 3025.2 kg/ha in 2018 (Plowing-Disking) depending on MSTS (table 5). In 2016, three of the tested MSTS gave approximately the same yields (Waller-Dunkan "c") - the systems where plowing alternated in the crop rotation with No-till or Disking, as well as with the constant application of No-till.

Only the conditions of 2016 enable the hybrid to demonstrate such high productivity with constant direct seeding. Linsey's 2017 tillage response clearly highlights the advantage of deep tillage without turning the soil layer (2703.2 kg/ha) or its rotation with disking (2483.4 kg/ha). These two systems outperform the application of permanent plowing in the crop rotation by 15.42% and 6.04%, respectively. In the last two years of the study, the lowest yield of oil from the whole seed was obtained with the constant application of No-till. In 2018, by far the highest yield of oil was obtained from the alternative rotation of Plowing-Disking (3025.2 kg/ha), and the excess compared to permanent plowing was 17.62%. On average for the research period, the highest yields of oil in the whole seed were consistently obtained from the systems based on deep plowing with inversion of the cultivated layer: Plowing - Disking, Plowing - No till, Plowing - Plowing.

Regarding the values of the average yield of oil from the kernel, the conditions of 2017 (2287.2 kg/ha) and 2018 (2185.4 kg/ha) are favorable (table 6). In 2016, the oil produced from kernels averaged 1916.1 kg/ha. This result shows that on this indicator 2017 outperforms 2016 by 19.36%, and 2018's superiority is by 14.05%. The obtained oil yields from the kernels under the studied tillage systems follow the reactions of the hybrid commented over the years regarding oil yield from the whole seed. The data on the obtained oil yields from the kernels during the years of research are quite different, depending on the MSTS. Definitely the most oil remains in the meal in 2018 (92.61 kg/ha). Comparing the average results of the obtained oil yields in 2016 and 2017, we find that in 2017 the kernel oil was 371.01 kg/ha more compared to 2016. The latter was distinguished by 1.50 kg/ha more oil in the husk compared to 2017.

On average for the study period, the kernels were characterized by the highest yield of oil in the Plowing-Disking system (fig. 5). The remaining systems that include plowing also lead to higher oil yields compared to the others.

The highest amount of oil in the sunflower meal was observed in the variants of the Cutting-Disking system (100.97 kg/ha) and the lowest - the constant application of shallow tillage with partial turning of the cultivated layer (Disking-Disking) - 57.47 kg/ha. We found that the tested factors (Years and MSTS) influence at the maximum level of statistical reliability on the studied productivity indices - seed and oil. The same applies to their interaction. Both individually and in combination, the strength of their influence on the obtained values for each of the studied indicators is different (fig. 6). Irrespective of what type of yield the comment is about, the strength of the independent impact of tillage methods exceeds the strength of influence of the meteorological factor. This shows the extremely important role of this factor on crop productivity, regardless of the conditions during the sunflower vegetation. Moreover, tillage has a significant influence on increasing the strength of the interaction between the two factors.

The strength of the independent action of the Years factor is between 15.03% and 23.98%, being best expressed in the extraction of oil content from the kernels. Certainly, the strength of interaction between the two factors has the strongest influence on the values of the indicated indices. The same is with the greatest degree of expression in the yield of seeds - 57.46%.

The 2016 conditions contribute to a credible influence of the tested MSTS on the values of physical characteristics of the seed. Hybrid "Linzi" in the conditions of this year forms a large seed, with an average value of the indicator 53.31 g (table 7). The differentiation in TKW values depending on the tillage system is highly pronounced. The seed is the largest in the Cutting - Cutting and Plowing-Disking systems. On the values of the indicator, the influence of permanent direct sowing is the most unfavorable (51.0 g). Hybrid "Linzi" in the conditions of 2017 formed an even bigger seed, with an average value of the indicator 58.33 g. The seed is the bigger in the Plowing-Plowing and Disking-Disking systems, and the constant direct sowing has the most unfavorable influence on the values of the indicator (55.32 g). In 2018, hybrid "Linzi" formed the largest seeds with constant application of disking cultivation in the crop

Table 6. Yields of oil from the components of the seed, in each variant of MSTS over the years, kg/ha

Main Soil tillage systems	2016		2017		2018	
	Kernels	Husks	Kernels	Husks	Kernels	Husks
Plowing - Plowing	1963.8 bc	75.5 c	2259.3 bc	82.6 e	2451.0 c	121.0 c
Disking - Disking	1706.7 a	44.9 a	2191.0 b	61.4 b	1916.3 ab	66.1 a
Cutting - Cutting	1709.4 a	58.2 b	2647.0 d	56.3 a	1984.3 b	67.6 a
No till – No till	2052.7 c	87.7 d	1985.2 a	75.8 d	1752.2 a	69.5 a
Plowing – No till	2108.5 c	71.1 c	2213.7 b	81.8 e	2520.2 c	87.0 b
Cutting - Disking	1862.1 ab	71.0 c	2397.0 c	86.4 e	1740.1 a	145.5 d
Plowing - Disking	2009.8 bc	114.6 e	2316.9 bc	68.2 c	2933.6 d	91.6 b

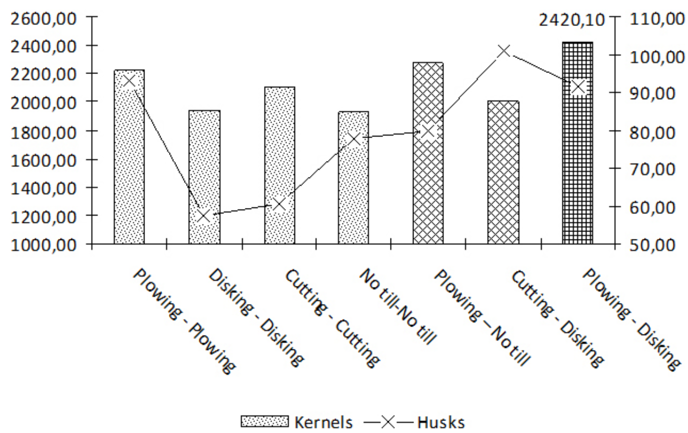


Fig. 5. Oil kernel and husk yields average for 2016-2018

rotation (74.55 g). This is also the highest value for this indicator during the research period, as this year the average values for TKW are 61.61 g, and the increase compared to 2016 is by 15.57%, and compared to 2017 - by 5.62%.

Changes in TW values depending on tillage systems for the conditions of the research period are statistically reliable. The range of variation of the values of the hectoliter in the hybrid "Linzi" is highly pronounced. In 2016, the yield obtained is distinguished by higher average values of TW compared to the other years. The seeds are the heaviest in the Plowing-Disking system. In 2017, both for the commented yields and the TW, the best results were obtained with the permanent deep no-turn soil layer tillage. Overall, however, this is the year with the lowest values of TW. According to the average values of this indicator, 2018 occupies an intermediate position, and permanent plowing stands out with the highest values.

On average for the research period, the indicators characterizing the physical properties of the seeds are very clearly differentiated, especially in the constantly applied soil treatments (fig. 7).

The largest seeds were obtained in the constant shallow treatment against all crops in the crop rotation - 62.66 g (Disking-Disking), with which it was ahead of all other tested MSTS. The maximum close to this result is obtained with the permanent deep no-turn soil layer tillage. In all other systems, the values of this indicator are significantly lower, and the smallest is the seed in No-till - No-till.

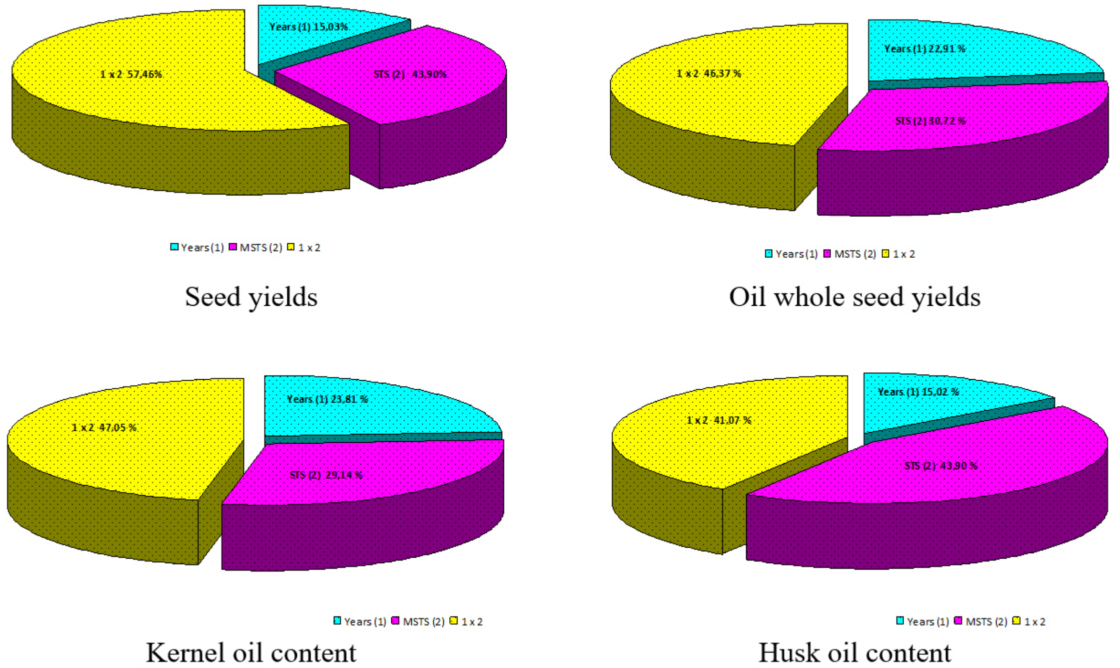
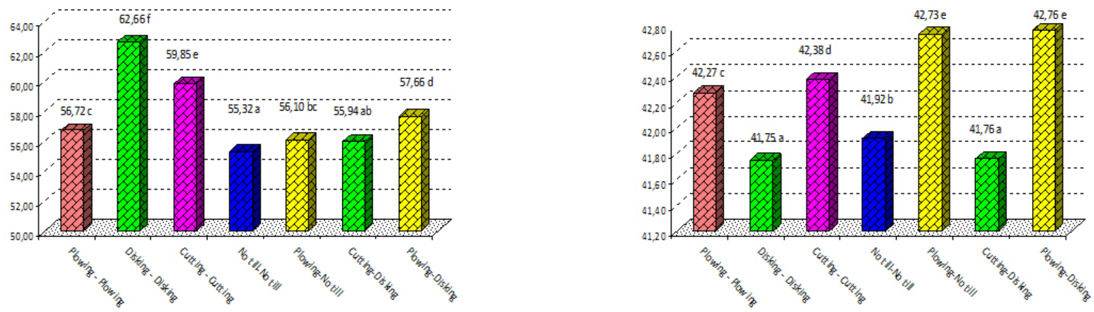


Fig. 6. Strength of effect of the factors on the seed yield and oil content, averaged for 2016 – 2018

Table 7. Physical properties of seeds per years

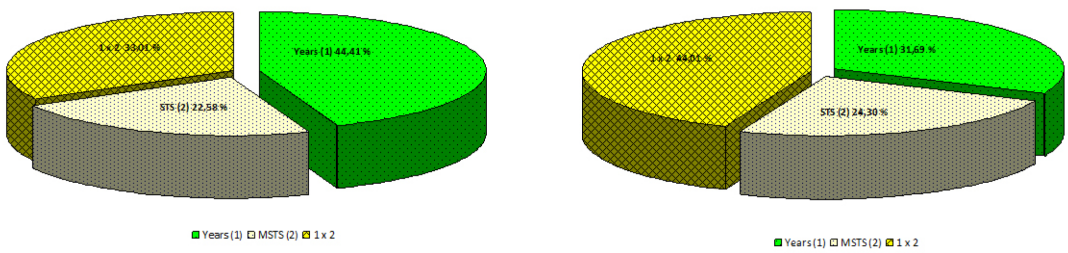
Main soil tillage systems	2016	2017	2018
		1000 kernel weight (TKW), g	
Plowing - Plowing	52.50 b	60.94 e	56.72 ab
Disking - Disking	53.91 cd	59.53 d	74.55 e
Cutting - Cutting	55.78 e	57.19 b	66.57 d
No till – No till	51.10 a	55.32 a	59.53 c
Plowing – No till	52.03 ab	58.60 cd	57.66 b
Cutting - Disking	52.97 bc	59.07 cd	55.78 a
Plowing - Disking	54.85 de	57.66 bc	60.47 c
		Test weight (TW), kg	
Plowing - Plowing	42.50 b	41.03 a	43.28 f
Disking - Disking	42.18 a	42.05 b	41.03 b
Cutting - Cutting	42.38 ab	42.30 c	42.48 c
No till – No till	42.80 c	41.93 b	41.03 b
Plowing – No till	43.30 d	41.90 b	43.00 e
Cutting - Disking	43.18 d	41.18 a	40.93 a
Plowing - Disking	43.60 e	42.05 b	42.63 f



1000 kernel weight, g

Test weight, kg

Fig. 7. Physical properties of seeds for the period 2016-2018



1000 kernel weight

Test weight

Fig. 8. Strength (%) of effect of the factors on the seed's physical properties, averaged for 2016 – 2018

The TW of seeds as a characteristic of commodity production shows quite interesting trends. Of the independently and continuously applied soil treatments, the best results were obtained with both deep treatments without and with turning of the cultivated layer. The heaviest seeds are, however, in the alternation of plowing, respectively with direct sowing or disking.

The strength of influence of the tested factors on the values of the physical characteristics of the seeds for both indicators is greater in relation to the Years factor, compared to MSTS (fig. 8). The meteorological factor was found to have a stronger influence on the TKW values than on the TW values, while the tested tillage systems had practically the same influence. The interaction between the two factors affects the TW values significantly more strongly than the TKW.

Over the years of research, the values of the correlation coefficients between the studied indicators varied significantly (table 8). Seed yield showed a highly pronounced positive correlation with husk and kernel which is quite natural, due to the fact that they are a structural component of the seed. Over the years, the strength of the relationship was subject to some variation, with the correlation between seed yield and that of husks being lower (0.645**) compared to each of the years on average over the period. Seed yield has a strong positive correlation with seed oil yield, which in the last two years is r=0.992. The values of the correlation coefficients with oil yield from

Table 8. Pearson correlation coefficients between sunflower seeds yield, 1000 kernel weight (TKW) and test weight (TW) over years

Indices	Seeds yield	TKW	TW	Kernel Yields	Husk Yields	Seed Oil Yields	Kernel Oil Yields	Husk Oil Yields
				2016				
Seed yields	1	-0.567(**)	0.318	0.990(**)	0.948(**)	0.931(**)	0.931(**)	0.644(**)
TKW	-0.567(**)	1	-0.150	-0.580(**)	-0.495(**)	-0.489(**)	-0.518(**)	-0.092
TW	0.318	-0.150	1	0.294	0.348	0.541(**)	0.502(**)	0.704(**)
Kernel yields	0.990(**)	-0.580(**)	0.294	1	0.892(**)	0.920(**)	0.929(**)	0.552(**)
Husk yields	0.948(**)	-0.495(**)	0.348	0.892(**)	1	0.888(**)	0.867(**)	0.771(**)
Seed Oil Yields	0.931(**)	-0.489(**)	0.541(**)	0.920(**)	0.888(**)	1	0.996(**)	0.714(**)
Kernel Oil Yields	0.931(**)	-0.518(**)	0.502(**)	0.929(**)	0.867(**)	0.996(**)	1	0.651(**)
Husk Oil Yields	0.644(**)	-0.092	0.704(**)	0.552(**)	0.771(**)	0.714(**)	0.651(**)	1
				2017				
Seed yields	1	0.187	0.074	0.987(**)	0.815(**)	0.992(**)	0.989(**)	-0.158
TKW	0.187	1	-0.540(**)	0.200	0.098	0.127	0.112	0.246
TW	0.074	-0.540(**)	1	0.137	-0.169	0.079	0.119	-0.759(**)
Kernel yields	0.987(**)	0.200	0.137	1	0.564(**)	0.980(**)	0.984(**)	-0.363
Husk yields	0.815(**)	0.098	-0.169	0.564(**)	1	0.669(**)	0.629(**)	0.419(*)
Seed Oil Yields	0.992(**)	0.127	0.079	0.980(**)	0.669(**)	1	0.998(**)	-0.277
Kernel Oil Yields	0.989(**)	0.112	0.119	0.984(**)	0.629(**)	0.998(**)	1	-0.336
Husk Oil Yields	-0.158	0.246	-0.759(**)	-0.363	0.419(*)	-0.277	-0.336	1
				2018				
Seed yields	1	-0.245	0.728(**)	0.996(**)	0.923(**)	0.992(**)	0.993(**)	0.603(**)
TKW	-0.245	1	-0.310	-0.208	-0.380(*)	-0.257	-0.233	-0.533(**)
TW	0.728(**)	-0.310	1	0.764(**)	0.507(**)	0.777(**)	0.763(**)	0.703(**)
Kernel yields	0.996(**)	-0.208	0.764(**)	1	0.797(**)	0.994(**)	0.997(**)	0.569(**)
Husk yields	0.923(**)	-0.380(*)	0.507(**)	0.797(**)	1	0.808(**)	0.800(**)	0.610(**)
Seed Oil Yields	0.992(**)	-0.257	0.777(**)	0.994(**)	0.808(**)	1	0.999(**)	0.633(**)
Kernel Oil Yields	0.993(**)	-0.233	0.763(**)	0.997(**)	0.800(**)	0.999(**)	1	0.593(**)
Husk Oil Yields	0.603(**)	-0.533(**)	0.703(**)	0.569(**)	0.610(**)	0.633(**)	0.593(**)	1
				2016-2018				
Seed yields	1	-0.058	0.276(*)	0.972(**)	0.645(**)	0.960(**)	0.961(**)	0.429(**)
TKW	-0.058	1	-0.484(**)	0.104	-0.561(**)	0.089	0.096	-0.069
TW	0.276(*)	-0.484(**)	1	0.193	0.421(**)	0.213	0.195	0.359(**)
Kernel yields	0.972(**)	0.104	0.193	1	0.448(**)	0.986(**)	0.988(**)	0.425(**)
Husk yields	0.645(**)	-0.561(**)	0.421(**)	0.448(**)	1	0.446(**)	0.444(**)	0.249(*)
Seed Oil Yields	0.960(**)	0.089	0.213	0.986(**)	0.446(**)	1	0.998(**)	0.495(**)
Kernel Oil Yields	0.961(**)	0.096	0.195	0.988(**)	0.444(**)	0.998(**)	1	0.443(**)
Husk Oil Yields	0.429(**)	-0.069	0.359(**)	0.425(**)	0.249(*)	0.495(**)	0.443(**)	1

*Correlation is significant at the 0.05 level (2-tailed)
**Correlation is significant at the 0.01 level (2-tailed)

the kernels are also very high, while with the oil yield from the husks in 2017 (the year with the highest yields) the relationship is statistically unreliable. The average for the period this connection is 0.429**. The correlation dependences with the physical characteristics of the seeds are significantly less pronounced and in most cases statistically unreliable. In 2016, when the lower yields were obtained, the correlation of yield with TKW was significantly negative. In the following years, as well as on average for the period, such a statistically reliable relationship was not established. The relationship between seed yield and their TW is insignificant in the first two years of the study and very strongly expressed (+0.728**) in 2018, characterized by the great drought July-August.

A statistically significant negative correlation was found between TKW and TW in 2017 and on average for the studied period. Regardless of the level of evidence, the relationship between these two indicators is in a negative direction. Seed size in 2016 was strongly negatively correlated with the yield of seed components as well as with the considered oil yields. Under the favorable conditions of 2017, no significant correlative dependences in this direction were established. In 2018, there is a negative correlation with the production of husks, which is strengthened with the production of oil from husks. Averaged over the study period, seed size was statistically negatively correlated only with oil yield from husks.

Conclusions

Regardless of the meteorological conditions during the study period, the main tillage systems are a powerful agrotechnical tool for managing sunflower productivity in all its aspects. The yield of seeds and kernels in hybrid "Linzi", as well as that of oil from them, is the highest in years with a relatively favorable distribution of precipitation during the growing season.

For Haplic Chernozem from Dobrudzha region, the most effective systems for sunflower are the systems including the deep turning of the soil layer. Of all of them, definitely the best results were obtained when, in the 4-crop rotation against wheat, deep tillage was replaced by Disking or No-till. The obtained oil yields are respectively: 2420.10 kg/ha (Plowing-Disking); 2280.80 kg/ha (Plowing-No till) 2244.70 kg/ha (Plowing-Plowing). The agronomic responsiveness of sunflower to permanent application of shallow tillage or No till in the study average was not satisfactory.

Over the years, the values of the physical properties of the seeds have been very clearly differentiated, especially with the independent and constant application of tillage. The biggest seeds were obtained in the constant shallow treatment against all crops in the seedbed - 62.66 g (Disking-Disking), with which it was ahead of all other tested MSTS. The best results for the test weight were obtained in the two deep treatments with and without inversion of the cultivated layer. However, the heaviest seeds were obtained in the alternate plowing rotation, with direct seeding or disking, respectively. In all other systems, the values of this indicator are significantly lower, and the smallest is the seed in the No-till - No-till system

Under the conditions of the year, statistically significant correlative dependences were established between the obtained yields - seed and oil and the physical characteristics of the commodity production. The positive correlation with the production of husks and kernels is strongly expressed. These relationships are subject to substantial variation. Averaged over the period, the correlation between the yield of seeds and that of kernels has lower values compared to each of the years. There is a strong positive correlation with the yield of oil from the seeds and that from the kernels. In years of high productivity, yield does not correlate statistically significantly with husks oil yield. The correlation dependences with the physical characteristics of the seeds are significantly less pronounced and in most cases statistically unreliable.

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