Scientific Papers. Series A. Agronomy, Vol. LXIII, No. 1, 2020
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

YIELD OF SEEDS AND SOME STRUCTURAL ELEMENTS OF THE PSEUDANTHIUM IN TRIBENURON-METHYL RESISTANT SUNFLOWER HYBRIDS, GROWN UNDER DIFFERENT SOIL NUTRITION REGIME

Adelina GARAPOVA

Agricultural University of Plovdiv, 12 Mendeleev Street, Plovdiv, Bulgaria

Corresponding author email: adelina_garapova@abv.bg

Abstract

In the experimental field of the Department of Crop Science at the Agricultural University - Plovdiv during the two harvest years, a field experiment has been conducted. The experiment has been carried out by the method of split-plots in four replications after the predecessor triticale. The effect of two soil nutrition regimes - lower and higher has been investigated (main plots). Five sunflower hybrids, all from the Tribenuron-methyl resistant hybrids group have been studied: P64LE25 (standard); LG 59.580 SX; Subaro HTS; ES Arcadia SU and Magma SU. Yield of seeds has been calculated from the harvest plots. The following pseudanthium yield components have been investigated: pseudanthium (head) diameter; density of the head and head harvest index. It has been found out that in both years of the study, the factor soil nutrition had a statistically proven positive effect on the yield of seeds. Soil nutritional regime had a positive effect on the diameter of the head by all studied hybrids. By most of the studied hybrids, the higher nutrient contain in soil results in a higher density of the head, an exception is the Magma SU hybrid. The reason for this negative result is the excessively high effect of the higher soil nutritional regime on the diameter of the head by this hybrid, which cannot be compensated by the higher number of seeds.

Key words*: sunflower, tribenuron-methyl resistance, yield, pseudanthium, structural elements.*

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is the most widespread technical crop in Bulgaria. This is not a coincidence, given that sunflower oil is the traditional vegetable oil that has been consumed in Bulgaria over the last 90 years. Increased consumption of vegetable fats in our country is consistent with the global trend of displacement of animal fats, and recently the dietary value of vegetable oils is explained by their antioxidant role in the human body (Stoyanova et al., 1977).

The Plovdiv region falls into an area with unfavorable sunflower growing conditions. However, sunflower here has a significant place in the field of crop rotation due to the lack of alternative crops suitable for cultivation as well as for the predecessor (Tahsin and Yankov, 2015; Yankov and Tahsin, 2015). One of the methods in sunflower farming in recent years is to make it easier to control weeds by introducing herbicide-resistant hybrids (Dochev et al., 2016; Poienaru & Sarpe, 2006).

The use of herbicide resistance crops has been the dominant weed management technology for the past 20 years (Green, 2011). Glyphosate resistant crops became available when growers desperately needed the technology to effectively control problem weeds (Green & Owen, 2011).

Most herbicide tolerance genes are transgenic and therefore must be approved by the appropriate government agencies prior to cultivation. The DuPont™ Express Sun™ trait is a non-transgenic trait and therefore did not require the same approval process as transgenic traits. The DuPont™ ExpressSun™ (Tribenuron-methyl resistant) technology has been a revolution in aiding sunflower growers internationally with a genetic herbicide trait system designed to maximize weed control in sunflower crops, thereby enhancing production and yield (Streit, 2012).

The main indicator that characterizes each sunflower hybrid is its productive potential. Apart from some basic morphological features of the plant (height and thickness of the stem, number of leaves and leaf area, etc.), some structural elements of the sunflower head (pseudanthium) - the diameter of the pseudanthium and its density are most

important parameters which effect on a yield in sunflower (Mizzotti et al., 2015; Fambrini and Pugliesi, 2017).

MATERIALS AND METHODS

On the experimental field of the Department of Crop Science at the Agricultural University - Plovdiv during the two harvest years - 2018 and 2019 a field experiment has been conducted. The experiment has been carried out by the method of split-plots in four replications after the predecessor triticale. The effect of two soil nutrition regimes (NR) - lower (NRL) and higher (NRH) has been investigated (main plots). The differences in the content of macronutrients in the soil are a consequence of previous fertilizer experiments conducted on the triticale predecessor (Georgieva, 2019). Five sunflower hybrids, all of the Tribenuron-methyl resistant hybrids group has been studied: P64LE25 - Pioneer® (standard); LG 59.580 SX - Limagrain®; Subaro HTS - Syngenta®; ES Arcadia SU - Euralis®; Magma SU - Caussade semences®. Seed yield has been calculated from the harvest plots in four replications. The following pseudanthium yield components have been investigated:

- Head (pseudanthium) diameter (Hd), cm;
- Density of the head (Ph), number of seeds/cm^2 (1):

(1) $Ph = \frac{Ns}{\pi.r^2}$, where:

Ns is number of seeds per head;
r^2 is head radius^2.

- Head harvest index (HI) (2):

(2) $HI = \frac{S}{H}$, where:

S is mass of the seeds per head;
H is mass of whole head, g.

RESULTS AND DISCUSSIONS

The first year of the study is generally characterized as warmer and more humid compared to the multi-annual data for the area (Figure 1). Compared to the climate norm, the differences in temperature are minimal, during the whole vegetation, except September where they are from 1 to 3 degrees higher.

The amount of rainfall during the first month of vegetation, which coincides with the sowing and emergence of sunflower, is 20 mm less than the climatic norm, but still sufficient for the crop development. In May, June and July, the amount of rainfall exceeds the average multi-year values of the area. Particularly impressive is July, when rainfall is 88.3 mm higher than the climate norm. These rainfall conditions reflect favorably on the growth and development of sunflower, because they coincide with critical periods of the culture. The second harvest year begins with favorable climatic conditions for sowing, characterized by an average monthly temperature of 10.6°C for the month of March, as sowing have been done at the end of the same month. Comparing the temperature sum by months, it is clear from the climatic norm that the second harvest year also stands out as warmer, as with these favorable conditions and higher temperatures in the months of June and July conducive the acceleration of flowering.

The amount of rainfall during the second harvest year is characterized with drastic changes. The first month of vegetation - March is characterized with a very low amount of rainfall (8.8 mm), which is a very low value, considering that for this period culture needs water to germinate. This is the reason why germination occurs in 16 days, contrasting to the first year, when germination occurred in 10 days. However, the month of April differs with 31.5 mm more rainfall compared to the multiannual period and this compensates for the lack of moisture at the beginning of the development of the crop. In the following months of vegetation, higher sums of rainfall, compared to the multiannual period, are of great importance to sunflower, as they coincide with the budding and beginning of flowering phases, when the crop needs more moisture.

In the first year of the study, factor soil nutritional regime had a statistically proven action on yield of seeds (Table 2). In all tested sunflower hybrids, higher soil fertility had a positive effect on the amount of seeds. The most significant effect on yield of seeds is in the ES Arcadia SU hybrid, in which the difference in yield in the higher soil nutrition regime than the lower is 137.2 kg/da (Table 1). The following are P64LE25 (standard) - 114.8

kg/da; Magma SU - 114.5 kg/da; LG 59.580 SX - 94.3 kg/da), and with the lowest effect on the yield, the higher soil regime has by the Subaro HTS hybrid - 74.5 kg/da.

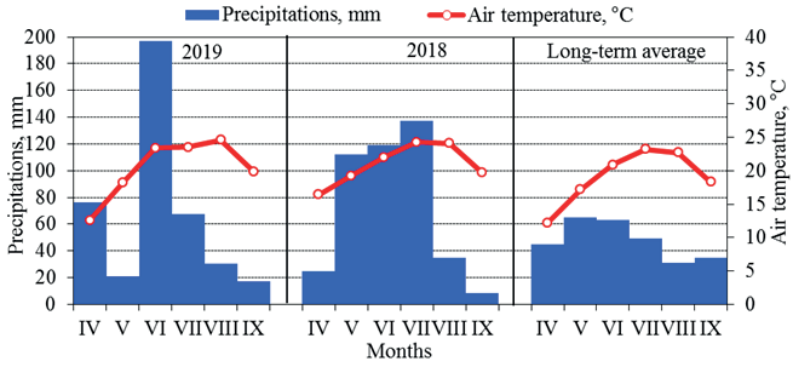

Figure 1. Climatogram of the year and the average for many years

In lower (NRL) soil nutrition regime the highest yield of seed have been reported in the LG 59.580 SX hybrid - 351.4 kg/da, followed by Subaro HTS (337.6 kg/da); P64LE25 (337.5 kg/da); Magma SU (296.9 kg/da) and lowest in the ES Arcadia SU hybrid - 280.3 kg/da.

Table 1. Yield of seeds, kg/da

Year	Soil nutrition regime	Hybrids				
		P64 LE25	LG 59.580 SX	Subaro HTS	ES Arcadia SU	Magma SU
2018	NRL	337.5	351.4	337.6	280.3	296.9
	NRH	452.4	445.7	412.1	417.5	411.4
	± D, cm²	114.8	94.3	74.5	137.2	114.5
2019	NRL	194.9	271.3	203.8	186.5	174.0
	NRH	303.0	316.2	247.8	207.5	247.1
	± D, cm²	108.1	44.9	44.0	21.1	73.1

In higher (NRH) soil nutrition regime the highest yield of seeds have been obtained from the P64LE25 (standard) - 452.4 kg/da, followed by LG 59.580 SX - 445.7 kg/da; ES Arcadia SU - 417.5 kg/da; Subaro HTS - 412.1 kg/da and lowest in the Magma SU hybrid - 411.4 kg/da.

Despite the described differences above, between the individual sunflower hybrids, from the implemented Anova Two-Factor analysis (Table 2), for the factor hybrid, the value of F is less than F crit., which defines this factor as having no proven effect on the yield of seeds. A similar result have been obtained when considering the interaction between the two factors, indicating that the availability of nutrients in the soil is not associated with a dependent change in yield of seeds in the individual sunflower hybrids.

Table 2. Two-way ANOVA analysis of the yield of seeds

Year	*Source of variation*	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
2018	Soil nutrition regime	114639.8	1	114639.8	70.868	0.00*	4.171
	Hybrids	16502.2	4	4125.6	2.550	0.06^{ns}	2.690
	Interaction	4494.5	4	1123.6	0.695	0.60^{ns}	2.690
2019	Soil nutrition regime	33868.9	1	33868.9	38.94	0.00*	4.17
	Hybrids	46178.8	4	11544.7	13.27	0.00*	2.69
	Interaction	8937.9	4	2234.5	2.57	0.06^{ns}	2.69

*Significance at P<0.05, ns - no significance.

During the experienced 2019 year, the impact of soil nutrition regimes on yield of seeds is positive and again statistically proven (Table 2). Compared to the first harvest year, the impact of higher soil nutrition regime on yield of seeds is significantly lower. Higher levels of macronutrients, in all sunflower hybrids, result in a higher amount of seeds. The effect on yield of seeds is most pronounced in the P64LE25 hybrid where the difference in yield in the higher soil nutritional regime versus the lower stock is 108.1 kg/da, followed by the Magma SU hybrid - 73.1 kg/da; LG 59.580 SX - 44.9 kg/da; Subaro HTS - 44.0 kg/da, and the lowest effect on the yield, the higher soil nutrition regime has on the ES Arcadia SU hybrid - 21.1 kg/da. In lower (NRL) soil nutrition regime the highest yield of seeds is again as in the first year by the hybrid LG 59.580 SX - 271.3 kg/da, followed by Subaro HTS - 2 03.8 kg/da and P64LE25 - 194.9 kg/da; while the ES Arcadia SU hybrids - 186.5 kg/da and the

lowest value for the Magma SU hybrid - 174.0 kg/da, exchange their places.

In higher (NRH) soil nutrition regime the highest yield have been obtained in the LG 59.580 SX hybrid - 316.2 kg/da, followed by P64LE25 - 303.0 kg/da, Subaro HTS - 247.8 kg/da, Magma SU - 247.1 kg/da and the lowest for the ES Arcadia SU hybrid - 207.5 kg/da. From the two-factor analysis of variance (Table 2), the influence of the two factors is confirmed, and they independently confirm a proven influence on yield of seeds, but the interaction between them is unproven.

Soil nutritional regime had a positive effect on the diameter of the head by all studied hybrids in both years of the study (Figure 2).

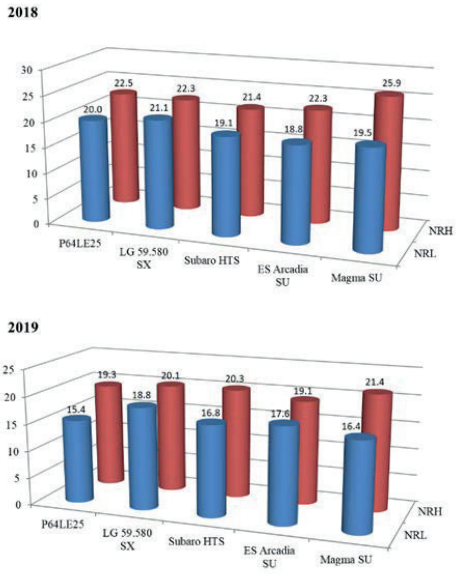

Figure 2. Head (pseudanthium) diameter (Hd), cm

The differences in the content of macronutrients in the soil has the strongest influence on the diameter of the head in the Magma SU hybrid - 6.38 cm larger head than the lower soil nutrition regime (NRL), followed by ES Arcadia SU - 3.15 cm; P64LE25 - 2.46 cm; Subaro HTS - 2.25 cm and LG 59.580 SX - 1.12 cm. In lower (NRL) soil nutritional regime the largest pseudanthium (head) forms LG 59.580 SX hybrid - 21.13 cm, followed by the standard P64LE25 - 20,00 cm; Magma SU - 19.50 cm; Subaro HTS - 19.13 cm and ES Arcadia SU - 18.75 cm.

In higher (NRH) soil nutrition regime the largest head is formed in the Magma SU hybrid - 25.88 cm, followed by the standard P64LE25 - 22.46 cm; ES Arcadia SU - 22.26 cm; LG 59.580 SX - 22.25 cm and Subaro HTS - 21.38 cm.

In the second year of the study (2019), soil nutrition regime again had a positive effect on the diameter of the pseudanthium in all studied hybrids (Figure 2).

Similarly to the first year of this study, soil nutrition regime had the strongest influence on the diameter of the head in the Magma SU hybrid - 21.38 cm in the NRH and 16.38 cm in the NRL; followed by Subaro HTS - 20.25 cm in NRH and 16.75 cm in NRL, as these two hybrids have the largest diameter of the head. The next LG 59.580 SX hybrid does not stand out from them, forming a head with a diameter of 20.13 cm for the NRH, and 18.75 cm for the NRL. The other two hybrids P64LE25 (standard) and ES Arcadia SU, form significantly smaller pseudanthium diameter, with the differences from the one with the highest head accordingly - 2.13 cm and 2.25 cm for the higher (NRH) soil nutrition regime.

Table 3. Two-way Anova analysis of the Head (pseudanthium) diameter

Year	*Source of variation*	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
2018	Soil nutrition regime	98.91	1.00	98.91	86.10	0.00*	4.17
	Hybrids	30.47	4.00	7.62	6.63	0.00*	2.69
	Interaction	31.83	4.00	7.96	6.93	0.00*	2.69
2019	Soil nutrition regime	93.03	1.00	93.03	70.43	0.00*	4.17
	Hybrids	19.56	4.00	4.89	3.70	0.01*	2.69
	Interaction	19.79	4.00	4.95	3.75	0.01*	2.69

*Significance at P <0.05, ns - no significance.

From the performed two-factor analysis (Table 3), it is clear that the value of F for the soil nutrition regime is much greater than F crit, which clearly confirms the strong influence of the soil nutrition on the increase of the head diameter of sunflower. The influence of the hybrid factor has also been proven, which confirms the thesis that hybrids are different because of their distance in terms of their different origins.

In addition to the diameter of the pseudanthium and the quantitative content of seeds in it, basic

importance determining the productive potential of the hybrid is the quantitative ratio of seeds per unit area, determining the density of seeds in the head (Table 4).

Table 4. Density of the head (Ph), number of seeds/cm^2

Year	Soil nutrition regime	Hybrids				
		P64LE25	LG 59.580 SX	Subaro HTS	ES Arcadia SU	Magma SU
2018	NRL	2.14	2.65	2.30	1.96	2.19
	NRH	2.35	2.98	2.40	2.05	2.00
	± D, cm^2	0.21	0.33	0.10	0.09	-0.19
2019	NRL	2.26	2.06	1.89	1.65	1.82
	NRH	2.34	2.31	1.98	1.67	1.46
	± D, cm^2	0.08	0.25	0.09	0.02	-0.36

In the first years of the study (2018), the highest density of the head at the first nutritional regime of the soil (NRL) has been reported by the LG 59.580 hybrid - 2.65 seeds per cm^2, followed by Subaro HTS - 2.30 seeds per cm^2. The other three hybrids have lower values ranging between 1.96 (for the ES Arcadia SU hybrid) and 2.19 seeds per cm^2 (for the Magma SU hybrid). Despite the described differences between the hybrids, they are not significantly proven due to the higher level of F-crit., compared to F, which exceeds the level of P several times, showing the unproven effect of the factor "hybrid" (Table 5).

The increased level of macronutrients in the soil leads to a proven effect of the factor on the density of the head (Table 5). In most of the studied hybrids, the higher nutritional regime resulted in a higher density of the pseudanthium, from 0.09 (in the ES Arcadia SU hybrid), to 0.33 seeds per cm^2 in the LG 59.580 SX hybrid. An exception is the Magma SU hybrid, where the higher soil regime leads to 0.19 less seeds in the head. The reason for this negative result is the excessively high effect of the higher soil nutritional regime on the diameter of the head by this hybrid (Figure 2), which cannot be offset by the higher number of seeds.

In the second year of this study (2019), higher soil nutritional regime lend to a proven effect of the factor on the density of the head, as well as the effect of the "hybrid" factor (Table 5). The highest density of the head at the NRL has been recorded in hybrid P64LE25 - 2.26 seeds per cm^2, followed by LG 59.580 SX - 2.06 seeds per cm^2. The other three hybrids have lower values ranging from 1.89 (in the Subaro HTS hybrid) to 1.65 seeds per cm^2 (in the ES Arcadia SU hybrid). Similar to the first nutritional regime of the soil, the second, (NRH) has the same sequence of the most densest head - in hybrid P64LE25 (2.34 seeds per cm^2), followed by LG 59.580 SX (2.31 seeds per cm^2), Subaro HTS (1.98 seeds per cm^2), ES Arcadia SU (1.67 seeds per cm^2) and the lowest density of pseudanthium in a Magma SU hybrid (1.46 seeds per cm^2).

Table 5. Anova: Two-Factor analysis of head density (Ph)

Year	*Source of Variation*	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
2018	Soil nutrition regime	2.026	1	2.026	0.512	0.480^{ns}	4.171
	Hybrids	349.292	4	87.323	22.076	0.000*	2.690
	Interaction	57.543	4	14.386	3.637	0.016*	2.690
2019	Soil nutrition regime	30.695	1.000	30.695	8.366	0.007*	4.171
	Hybrids	354.771	4.000	88.693	24.174	0.000*	2.690
	Interaction	56.652	4.000	14.163	3.860	0.012*	2.690

*Significance at P <0.05, ns - no significance.

Similarly to the first year of this study, the exception to the Magma hybrid is applies again, so higher soil nutritional regime lead to 0.36 seeds less sown in the head. The reason for this negative result is the excessively high effect of the higher soil nutritional regime on the diameter of the head in this hybrid (Figure 2), which cannot be offset by the higher number of seeds.

The different proportion of the organs of the plant is the main reason for the seed content of the total mass of the head, expressed by the harvest index (Table 6). The highest correlation of seeds in head is in the LG 59.580 SX hybrid - between 0.692 and 0.689 relative to the total weight of the head, followed by the P64LE25 (standard) - between 0.651 and 0.603; Magma SU - between 0.622 and 0.512; Subaro HTS - between 0.615 and 0.611 and the smallest harvest index have been reported by the ES Arcadia SU hybrid- between 0.579-0.580. Only in the last hybrids, the harvest index is higher in the NRH soil nutrition regime than the NRL. In all other hybrids, the higher soil stock has negative effects on this indicator.

Table 6. Head harvest index (HI)

harvest	Soil nutrition regime	Hybrids				
		P64LE25	LG 59.580 SX	Subaro HTS	ES Arcadia SU	Magma SU
2018	NRL	0.651	0.692	0.615	0.579	0.622
	NRH	0.603	0.689	0.611	0.580	0.512
2019	NRL	0.633	0.575	0.568	0.563	0.598
	NRH	0.625	0.583	0.488	0.523	0.528

In the second harvest year, the standard P64LE25 has the highest correlation of seeds in the pseudantium - between 0.633 and 0.625 relative to the total weight of the head; followed by Magma SU - between 0.588 and 0.528; LG 59.580 SX - between 0.575 and 0.583; Subaro HTS - between 0.568 and 0.488 and the smallest harvest index again as in the first year by the ES Arcadia SU hybrid- between 0.563 and 0.523. Only in one of the hybrids (LG 59.580 SX), the harvest index is higher in the NRH soil nutrition regime than the lower. In the other four hybrids, better soil conservation of microelements, again has a negative effect on this indicator.

CONCLUSIONS

Yield of seeds in all studied sunflower hybrids was positively affected by higher soil fertility and by the more favorable climatic conditions of the year. The hybrid Arcadia differs with the highest yield in the first year and in the second- hybrid P64LE25. The structural elements of the yield (pseudanthium) of the studied sunflower hybrids are affected differently depending on the nutrient storage of the soil. The higher nutrition regime found out to have a positive effect on the indicator the diameter of the head. The density of the pseudanthium is also positively affected, with exception only of the Magma hybrid, where the higher soil fertility has a negative effect.

ACKNOWLEDGEMENTS

This research work was carried out with the support of Agricultural University - Plovdiv, Bulgaria, Department of Crop Science and also was financed from PhD research program.

REFERENCES

Dochev, C., Mitkov, A., Yanev, M., Neshev, N., Tonev, T. (2016). Herbicide control of wild hemp (*Cannabis sativa* L.) at sunflower grown by "Express Sun" technology. *VII International Scientific Agriculture Symposium, "Agrosym 2016", 6-9 October 2016, Jahorina, Bosnia And Herzegovina. Proceedings*, 1339–1344.

Fambrini, M., Pugliesi, C. (2017). CYCLOIDEA 2 Clade Genes: Key Players in the Control of Floral Symmetry, Inflorescence Architecture, and Reproductive Organ Development. *Plant Molecular Biology Reporter*, *35*(1), 20–36.

Georgieva, R. (2019). Alteration of yield components of triticale depending on treatment with plant stimulants in the condition of different soil nutrition regime. *Journal of Mountain Agriculture on the Balkans*, *22*(1), 130–138.

Green, J.M. (2011). Outlook on weed management in herbicide-resistance crops: need for diversification. *Outlooks on Pest Management, 22*, 100–104.

Green, J. M. and Owen, M.D.K. (2011). Herbicide-resistant crops: Utilities and limitations for herbicide-resistant weed management. *J. Agric. Food Chem*., *59*, 5819–5829.

Mizzotti, S., Fambrini, M., Caporali, E., Masiero, S., Pugliesi, C. (2015). A CYCLOIDEA-like gene mutation in sunflower determines an unusual floret type able to produce filled achenes at the periphery of the pseudanthium. *Botany*, *93*(3), 171–181.

Poienaru, S., Sarpe, N. (2006). Selectivity, efficacy and yield of PR64E83 sunflower hybrid treated with Express 50 SG herbicide. *Lucrari Stiintifice, Universitatea De Stiinte Agricole Si Medicina Veterinara "Ion Ionescu De La Brad" Iasi, Seria Agronomie*, *49*, 151–156.

Stoyanova, J., Simeonov, B., Sabev, G., Petrov, D., Georgiev, I., Dimitrov, I., Georgieva-Todorova, J., Rangelov, L., Petrova, M., Ivanov, P., Palazov, P., Kontev, C. (1977). *Sunflower in Bulgaria*. BAS. Sofia (in BG).

Streit, L. (2012). Du Pont™ Express Sun™ Herbicide Technology in Sunflower. In: *Proc. 18th Sunflower Conf., Mar del Plata-Balcarce, Argentina,* 143–149.

Tahsin, N., Yankov, B. (2015). Performance of some sunflower's genotypes grown in South Bulgaria. *Journal of Central European Agriculture*, *16*(3), 299–306.

Yankov, B., Tahsin, N. (2015). Genetic variability and correlation studies in some genotypes of sunflower (*Helianthus annuus* L.). *Journal of Central European Agriculture, 16*(2), 212–220.