# DROUGHT EFFECT ON QUANTITATIVE TRAITS OF SUNFLOWER GENOTYPES

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**Abstract:** Quantitative traits (plant height, number of leaves, head diameter, number of achenes per head, achene weight per head thousand seed weight, hectolitre mass of seed and seed yield) of 25 sunflower hybrids, created within AMG-Agroselect Comert LLC were analyzed. Homogeneity of individuals, relative contributions of genotype, environment and genotype environment interaction in determining the variance of the respective traits in different climatic conditions of two growing season (2019, 2020), were assessed.

Some traits such as the head diameter and the number of leaves has practically not changed, and the hectolitre mass even registered a slight increase in 2020 compared to 2019. The parameters achene weight per head and number of achene per head, followed by seed yield have the highest degree of variation related to growing season. The drought conditions in 2020 also caused a decrease in the phenotypic uniformity of sunflower populations according to various traits. Coefficient of variation (CV) of the individuals of a population according to the achene weight per head, registers an increase of almost 6 times, in 2020 compared to 2019. The analysis of variance showed that the achene weight per head, number of achenes per head, seed yield and plant height traits is determined to a greater extent by environmental conditions (E) than by genotype (G). A higher stability of most traits was established for 2019 compared to 2020, which is explained by the unfavorable climatic conditions manifested in 2020.

**Keywords:** *Helianthus annuus* L.; quantitative traits; genotype-environment interaction; climatic conditions.

## INTRODUCTION

Sunflower (*Helianthus annuus* L.) represents one of the most important crops, with a special economic and food significance conditioned by both internal and external markets. Despite the fact that sunflower is considered a drought tolerant plant, more and more intense droughts in some regions of Moldova significantly affects the growth and development of this crop. The negative effects of stress conditions on productivity varies depending on the stages of plant development [16] the intensity and severity of drought stress [12] but also by the genetic characteristics of the cultivated variety [8, 16]. Genetic characteristics of the variety including the ability to adapt the genotype and maintain phenotypic and genotypic characteristics in a certain range of environmental conditions [8, 16, 20].

In the early stages of development and in the phase of flowering and seed filling, sunflower can be susceptible to water deficiency [11, 18]. Thus, Human et al. (1998) [11] found that water stress in the stages of flowering, fertilization and seed filling, caused the highest yield decrease. At the end of the maturation period, water requirements are reduced and therefore the excess rainfall negatively affects the yield [9]. The high variability of quantitative traits of sunflower genotype is a known phenomenon. It is known that water stress conditions the reduction of plant height and number of leaves [2], head diameter, leaf area, thousand seed weight and seed yield in general [1, 7, 25].

Knowing the effect of environmental factors on crop growth and development could reduce significant crop losses and improve the choice of suitable genotypes for certain regions. Different genotypes will react differently to the same environmental conditions and will present different phenotypic variability including yield variability. Due to the variation of agroclimatic conditions in recent years, it is necessary to analyze the interrelation of the genotype with the environment. For breeding purposes, it is necessary to know the ability of the tested hybrids to adapt to certain environmental conditions. Due to instability of climatic conditions, caused by global warming as well as globalization processes, when a producer can sell seeds in all corners of the world, phenotypic stability and adaptability to various environmental conditions becomes a crucial parameter in sunflower breeding.

The aim of the presented research is to evaluate the genotype-environment interaction, yield and stability of sunflower hybrids tested in the same pedological and agrotechnical conditions but in different growing season with different climatic conditions.

## MATERIALS AND METHODS

**Plant material.** A group of 25 sunflower (*Helianthus annuus* L.), single cross hybrids, created by AMG-Agroselect Comert LLC seed company, were studied during two years (2019 and 2020). Eight hybrids, including Codru, Dacia, Talmaz, Zimbru, Doina, Nistru, Cezar and Oscar represent hybrids with high yield, approved in the Republic of Moldova (conventionally placed in the group of commercial hybrids, marked with H1); four genotypes: US235CLP, US237SU, US2472CLP, US2137SU are in testing phase for hybrid performance by the State Commission for Crops Variety Testing (SCCVT) (tested hybrids – H2) and thirteen genotypes: 413, 415, 454, 457, 618, 1583, 1625, 1686, 1718, 1719,1721, 1722 and 1727 representing hybrids trialed in comparative crops in the experimental field (experimental hybrids - H3).

**Crop management and experimental design.** Hybrid seeds were sown manually on April 21 (2019) and April 24 (2020) in a randomized complete block design with four replications, on plots with an area of 33.6 $m^2$, 2-3 seeds in pits at 0.20 m from each other within rows. All the recommended agronomic practices

[24], including soil fertilization (70 kg/ha of $N_{16}P_{16}K_{16}$), were carried out during the crop season. Weed and pest controls were applied according to crop needs, Avangard Duo SC (3.0 L/ha) herbicide and the Force (1.5 g - 12.0 kg/ha) insecticide was used. The precursor was straw cereal. The fields cultivated with the studied sunflower hybrids had the same locations in both 2019 and 2020 (Soroca district, Republic of Moldova).

**Measurements.** Data was recorded for ten plants (n=10, 4 repetitions), for eight quantitative traits: plant height (PH, cm), number of leaves (NL) (were recorded during anthesis), head diameter (HD, cm), number of achene per head (APH), achene weight per head (AWH, g), thousand seed weight (TSW, g), Hectolitre Mass of seeds (HMS, kg/hl) and Seed yield (SY, kg/ha) (were recorded during or after harvest).

The height of the sunflower plants was determined in the field, by measuring the stem, from ground level to head insertion. The average number of seeds per head was assessed by counting all the full seeds from the sunflower head. After drying in the air and moisture reaching 11%, the weight of the achene per head was evaluated by weighing them on the laboratory balance, with an accuracy of 0.01 g. Thousand seed weight (TSW) was evaluated after harvest for each variety. The cleaned and air dried achene is randomly taken and gruped in two samples each consisting of 500 achene. Each samples was weighed separately with an accuracy of 0.01g. After which the rezults are added tougether. The hectoliter mass was determined by weighing two samples of a volume of one liter of achene. Plants were harvested individually, after physiological maturity stage (R9), seed yield was adjusted to an 11.0% moisture basis. Seed yield was measured separately from each replication and expressed as kg per hectare.

**Climatic conditions.** According to the Moldovian State Hydrometeorological Service, 2019 was characterized by high temperatures and normal annual amount of precipitation. The agrometeorological conditions during the vegetation period in 2019 were basically satisfactory for most agricultural crops. At the beginning of the vegetation period, due to insufficient precipitation, complicated conditions were created for sowing. The duration of the vegetation period was 263-264 days. The amount of precipitation during the vegetation period was 315-570 mm (80-125% of the multiannual norm). At the Soroca weather station where the study fields are located, the amount of annual precipitation was 540 mm and during the vegetation period 421 mm were recorded (111% of the multiannual norm), the highest amount of precipitation fell in May (108 mm) and June (164 mm). The driest month was August, with 18 mm of rainfall (38% of the multiannual norm) and April with 16 mm (38% of the multiannual norm).

The agrometeorological conditions during the vegetation period in 2020 were generally unfavorable for obtaining a high yield for main crops, due to the high thermal regime and the precipitation deficit. Low rainfall and the high temperatures, which was reported in the cold period preceding the vegetation period, contributed to the significant decrease of the productive moisture reserves in the soil. The duration of the vegetation period was equal to 255-275 days, being 30-35 days longer than usual. The amount of precipitation during the vegetation period, in Soroca district were recorded 344 mm (82% of the multiannual norm).

**Data analysis.** The primary data obtained from the research were subjected to statistical processing using Excel and XLSTAT programs.

Analysis of variance was performed for each trait in each group of hybrids and in each year. Analysis of variation was performed by means of single-factor ANOVA test and two-factor ANOVA test. We worked at the significance level of $\alpha = 0.05$ and P-value <0.01. These tests allowed us to highlight the sources of variation and determine the relative contributions of genotype, environmental factors and environment-genotype interaction, in the variation of eight different traits, after G. W. Snedecor [15]. To determine the phenotypic homogeneity of hybrids we calculated the coefficient of variation CV (standard deviation (SD) divided by the mean and expressed as a percentage) for each hybrid and each traits. The interaction between some traits was calculated using the Pearson correlation coefficient.

## RESULTS

**Variability of quantitative traits of sunflower.** Plant height (*PH*), which is an important trait that determines the technological properties of sunflower hybrids, varies depending on genotype and environmental conditions (Fig. 1). The average plant height of all hybrids in 2019 is 168.3 cm, and in 2020 - 150.1 cm. No significant differences were found between the size of the three groups of hybrids. The largest height was recorded for the Doina hybrid (186.0 cm in 2019), and the most small - for the Zimbru hybrid (132.0 cm, in 2020).

Thus, unfavorable climatic conditions in 2019 led to a decrease in plant height by about 18 cm (11%), but this decrease is not uniform for all hybrids. For example, the height of plants of hybrids in group H1 decreased by about 16%, those in group H2 - by 12%, and hybrids in group H3 decreased in height by only about 7%. Therefore, the influence of environmental conditions is more evident in approved hybrids (H1). The height of the plants in a series of hybrids (US235CLP, 413, 1721, 454) was not significantly affected to water stress in 2019, keeping practically the same height in both years of study, among them being predominantly hybrids from group H3 and H2 in which both variation the size from year to year and the coefficient of variation within a genotype is very small.

Despite the increased homogeneity according to this index, we would like to mention that the hybrids

from group H1 have a slightly higher CV in both 2019 (0.8%) and 2020 (1.5%) than the hybrids from the other groups. Practically all hybrids have a higher CV in 2020 than in 2019 (Fig. 1A). Thus, we can establish that tested hybrids show uniformity of plant height both according to genotype and depending on the climatic conditions of the year.

Number of leaves (NL), is a trait that indirectly influences the productivity of sunflower plants. From the hybrids included in the study, the Nistru hybrid has the maximum number of leaves per stem, both in 2019 (34 leaves) and in 2020 (36 leaves), a number that exceeds the average for all hybrids tested equal to 29 leaves. The lowest number of leaves in 2019 were identified in two hybrids: Zimbru and 1727 (27 leaves), and in 2020 by three hybrids: Dacia, Oscar and 1727 (26 leaves).

In some hybrids like Dacia, Doina, 415, 1718, under conditions of 2020 NL, a decrease by 3 leaves compared to the same trait in 2019 is noticed. Still in most hybrids, the number of leaves decreases by 1 - 2 leaves. The hybrids Codru and Zimbru, kept the same number of leaves in both years (Fig.1C). Which allowed us to establish that despite different climatic conditions in 2019 and 2020, the number of leaves per stem does not substantially variate.

It can be noticed that the coefficient of variation (CV) calculated in the repetitions of each hybrid increases slightly in 2020, which allows us to establish that unfavorable conditions reduce homogeneity in regard to this trait within the same genotype. If in 2019, the average CV did not exceed 2.8% and the maximum value of this trait was 3.4% (Dacia) then in 2020 the average coefficient of variation for all hybrids was 3.9% (Tab.1). The CV practically does not vary within the groups. So according to the number of leaves on the stem, these sunflower hybrids show an increased homogeneity regardless of the influence of environmental conditions or genotype characteristics.

Head diameter (HD). In 2019 the minimum value of the head diameter was 20 cm (hybrid 1727) and the maximum 24 cm (Nistru hybrid) the average was 22 cm. In 2020 the minimum measured head diameter was 19 cm (Zimbru hybrid) and the maximum 24 cm (Cezar hybrid), with an average of 21 cm. The group with the highest average of HD was the group H1, whose hybrids have on average 22 cm.

The 2020 conditions caused in some hybrids a decrease in the head diameter by 2 cm (Nistru, Zimbru), or 3 cm (1686 hybrid). At the same time, some hybrids have the same diameter (Codru, Talmaz, US2137 SU, 1583) and others recorded an increase of this trait by 2 cm (1727 hybrid). The measured CV is quite small, reaching on average 4.16% in 2019 and 4.41% in 2020 (Fig.1D). Commercial hybrids (group H1) have the highest CV both at hybrid level (6.8% - Cezar hybrid) and at the average per group level of CV (5.2%).

Achene per head (APH) values vary significantly, from 805 seeds for the Zimbru hybrid or 810 seeds for the Doina hybrid to 1450 for the 1625 hybrid, in 2020, and from 1650 seeds per head for the Dacia hybrid, to 955 for the 1625 hybrid in 2019 year (Fig. 1E). The average for all hybrids the APH was 1324 seeds in 2019 and 1088 in 2020 year. H1 group of hybrids had the highest average APH value in 2019 (1439 seeds) and the lowest (973) in 2020. Based on the above, we can determine that APH is an sensitive trait to shifting weather conditions. Thus, the average value of APH decreases in 2020 by 17.8% compared to the value of the same trait in 2019 (Tab.1). The most stable from this point of view or proved to be the hybrids 1727 and US237SU which recorded similar values in both years, but these values were below the average value. At group level, commercial hybrids (H1) have the highest APH values in 2019 and at the same time, record the largest decrease in these trait values (on average by 32.3%) in 2020. More resistant to environmental conditions were the hybrids from group H3 that decreased the average value of APH by only 6% but the initial values in 2019 were lower. We determined CV which, like most indices in the study, is higher in 2020 (4.42%) than in 2019 (1.14%).

Achene weight per head (AWH). The average AWH trait for all hybrids was 111.9 g for 2019 and 73 g for 2020. The variations of this trait value were very significant both depending on the year and on the genotype. The genetic potential of most of the tested hybrids could be observed in the conditions of 2019. Thus, in 2019 the highest AWH values were reached by hybrids: Nistru – 148 g and Cezar – 142 g and the lowest values were recorded for the hybrids: 1625 – 81 g, 457 - 82 g, US237 SU – 82 g. In 2020, the maximum values of AWH were reached by the hybrids: 1625 - 103 g and Cezar – 98g, and the minimum values were reached by the hybrids Zimbru – 46 g and Doina – 51 g (Fig. 1G). At group level, commercial hybrids (H1) had the highest average AWH in 2019 -

**Table 1.** Relative contributions of genotype and coefficient of variation

| TRAITS | The difference between 2019 & 2020 (%) | Coefficient of variation, (%) | | | Relative contributions of genotype, (%) | | |
|---|---|---|---|---|---|---|---|
| | | 2019 | 2020 | average for 2 years | 2019 | 2020 | average for 2 years |
| **Seed yield (kg/ha)** | -14.9 | 4.34 | 5.71 | 11.6 | 86.1 | 71.5 | 78.8 |
| **Thousand seed weight (g)** | -9.2 | 4.58 | 300 | 8.7 | 91.6 | 88.2 | 89.9 |
| **Hectolitre mass of seeds (kg/hl)** | +4.5 | 1.18 | 1.47 | 2.7 | 92.9 | 92.9 | 92.9 |
| **Number of leaves** | -4,2 | 2.82 | 3.88 | 4.6 | 77.9 | 77.7 | 77.8 |
| **Plant height (cm)** | -10.8 | 0.57 | 1.37 | 6.0 | 98.1 | 92.5 | 95.3 |
| **Head diameter (cm)** | -2.0 | 4.16 | 4.41 | 5.0 | 47.2 | 61.9 | 54.6 |
| **Achene weight per head (g)** | -34.7 | 1.10 | 6.12 | 23.3 | 89.4 | 87.6 | 88.5 |
| **Number of achene per head** | -17.8 | 1.14 | 4.42 | 12.8 | 98.9 | 88.8 | 93.8 |

127.3 g which exceeded by about 25g the average per group H3 (102 g). Nevertheless, commercial hybrids also recorded the biggest decrease of AWH values in 2020.

Based on the data presented, we note that according to this trait, the most water stress resistant hybrids were from the H3 group who recorded a decrease in AWH on average by 23%. It should be noted that hybrids that show the smallest decreases in AWH, have quite a small initial value. We can state that the change in climatic conditions in 2020 affected mostly commercial hybrids (H1), which also recorded the

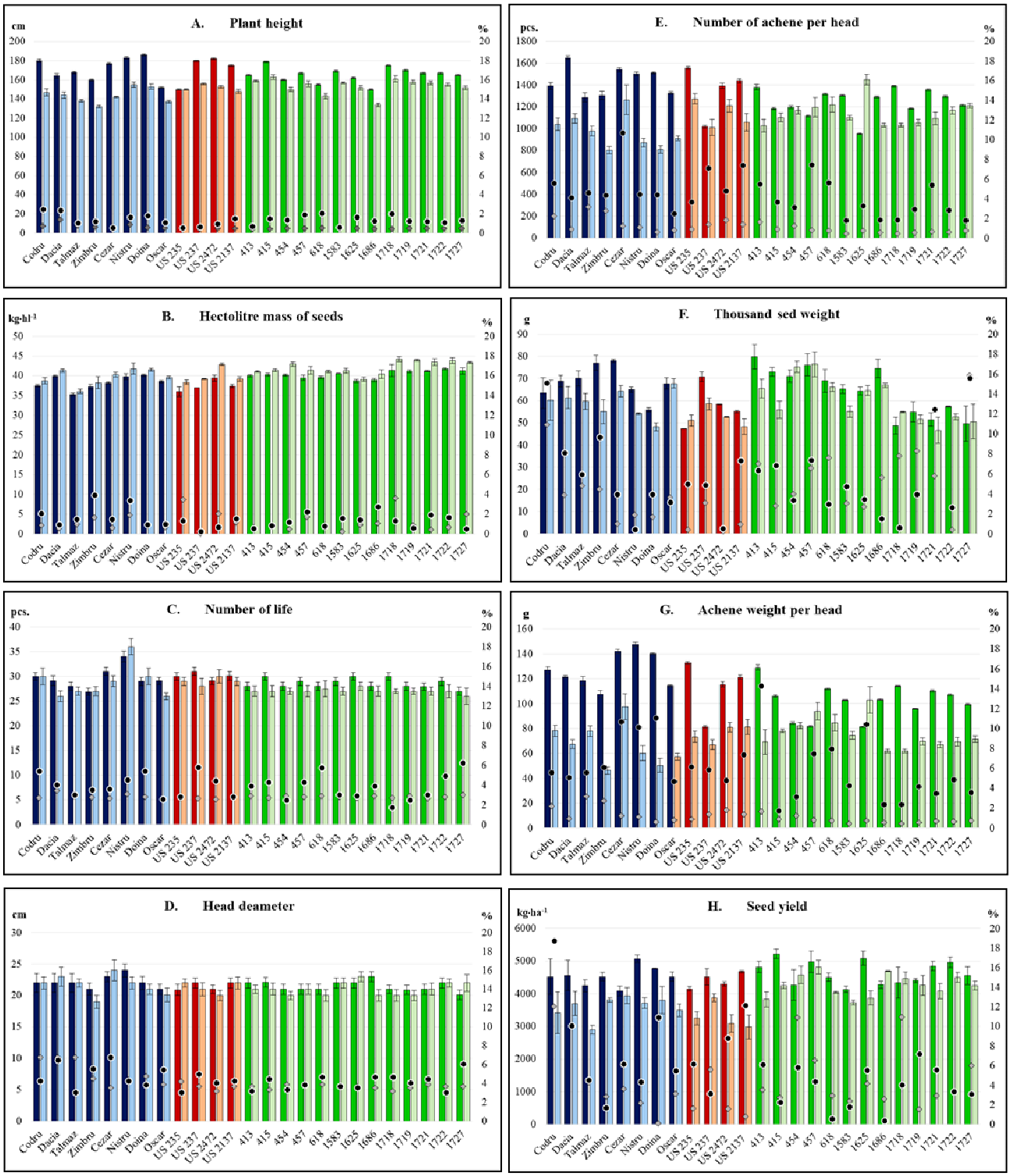


**Figure 1**. Phenotipic traits value & coeficient of deviation of twenty five sunflower hybrids during two experimental periods (2019 and 2020) error bar- standard deviation

highest values of MSC in 2019. Thus, the hybrid Doina reduced AWH from 140 g in 2019 to 51 g in 2020, which is about 64%, and the Nistru hybrid, decreased the value of AWH by 59%.

The 2020 conditions not only reduced the values of AWH and APH but also phenotypic uniformity in regard to these traits. Thus the average CV for all hybrids in 2019 was 1.14% and in 2020 4.42%. The commercial hybrids recorded the highest coefficient of variation (CV) both at genotype level and group level. Doina, Cezar and Nistru hybrids showed a CV of over 10% in 2020, and the average CV per group is 7.4% in 2020. It should be mentioned that, in 2019 conditions, practically all the hybrids in the study proved to be quite uniform within the genotype in regard to AWH, the highest CV values did not exceed 3%.

Thousand seed weight (TSW), it is the trait that shows a great variation, more depending on the genotype than on the conditions of the year. In 2019 the average TSW for all hybrids was 64.5 g, and in 2020 - 58.5 g. At the genotype level, in 2019, the values ranged from 48.8 g (hybrid 1718), to 79.8 g (hybrid 413) and in 2020 from 48.2 g (hybrid Cezar), to 76.4 g (hybrid 457) (Fig. 1F). Climatic conditions caused changes in the TSW value in a large part of the studied hybrids. A more obvious decrease of TSW was registered in the hybrids Zimbru and 415 at which in 2020 the value of TSW decreased by more than 20% compared to 2019. As well a decrease of more than 10% registers most of the commercial hybrids (H1), the decrease of TSW for this group is the largest and constitutes 13.4%. In general most hybrid populations are homogeneous according to this trait. The average CV on all hybrids in 2019 was 4.5% and for 2020 5.6%. In most hybrids in the study, the CV is higher in 2020.

Hectolitre mass of seeds (HMS) is the only trait that showed a higher average in 2020 (41 kg/hl), compared to 2019 (39.2 kg/hl), which is an increase of 4.5%. The highest HMS is found for the hybrid 1722 (41.75 kg/hl) in 2019 and respectively the hybrid 1718 (44.25 kg/hl) in 2020. The minimum values are recorded by the hybrid Talmaz with (35.3 kg/hl) in 2019 and (36.05 kg/hl) in 2020 (Fig. 1B). No differences greater than 1% were found between HMS averages by groups. Most hybrids have an increased homogeneity of populations, judging by the coefficient of variation of the HMS. The average CV of this trait is below 4% in both years.

Seed yield (*SY*). The highest seed yields were recorded at hybrid 415 (5224.3 kg/ha), hybrid 1625 (5089.4 kg/ha) and hybrid Nistru (5074.3 kg/ha) in 2019 (Fig. 1H). In an attempt to assess the stability of the studied hybrids seed yield, we calculated the coefficient of variability (CV) of the harvest of each hybrid in the two years studied. We mention that a series of hybrids like 457, 1718, 171*,* Doina present a high and stable yield during the years 2019-2020. But the hybrids that presented seed yield of over 5000 kg/ha in 2019 (Nistru, 415, 1625), in unfavorable conditions in 2020, recorded harvests of about 4000 kg/ha. It should be noted that H3 group hybrids have a higher crop stability than commercial hybrids.

**The relative contributions of genotype in trait variability**

All studied trait demonstrate a higher coefficient of variation in 2020 compared to 2019, showing that water stress decreases the homogeneity of hybrids. The monofactorial dispersion analysis allowed us to find that the drought contributed to the reduction of the genotype weight in the variability of most trait, except that of the plant height and head diameter, which practically did not change.

The comparative analysis within the 3 groups of hybrids showed that in the case of the first 2 groups, which represent the commercial and tested hybrids in most cases the relative contributions of genotype in the variability of character decreases, while in experimental hybrids - it increases. Yield performance depends on the genetic yield potential, all those desirable genes that have been incorporated into a cultivar in the course of the breeding process. Yield stability depends on the cultivar's capacity to react to environmental conditions [16]. The variation of trait values included in the study is determined by three sources: the effects of genotype (G), environment (E) and genotype by environment interaction (GEI). GE interaction is the main reason why in different years and (or) in different locations the varieties differ in terms of yield, because different genotypes react differently to the same environment and the same genotypes react differently to different environments. Most studies show significant variability in the contribution of genotype and environmental conditions to changes in quantitative traits [14, 20, 22].

For the analysis of variance, two-factorial ANOVA was used, in which the genotype and the year of cultivation were taken as the source of variance, which implies different environmental conditions. Thus, we find that the variation of AWH, APH, SY and PH traits is determined to a greater extent by environmental conditions (E) than by genotype (G). The genotype by environment interaction (GEI) also has a special role. Genotype is the predominant factor in determining the number of leaves, the head diameter and the hectolitre mass, traits that did not register large variations in 2020 compared to 2019 (Tab. 3).

If we analyze relative contribution of sources of variance by groups of hybrids, we find that according to yield traits the hybrids from group H3 are least influenced by environmental conditions and the most sensitive to environmental conditions are commercial hybrids (H1). But ANOVA tests show that the variance of the harvest in H3 group hybrids is still much influenced (32.6%) by GEI.

However, hybrids from group H3 have a lower weight of environmental conditions on the variance of the studied traits than the hybrids from the other groups. So, we can assume that in the group of H3 hybrids are perspective and show drought resistance as

**Table 2.** Relative contributions of genotype per group of hybrids

| Genotype group | Number of genotype | SY | TSW | HMS | NL | PH | HD | AWH | APH |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 2019 | | | | |
| **H1** | 8 | 60.6 | 86.1 | 95 | 85.9 | 89.7 | 40.7 | 97.6 | 96.4 |
| **H2** | 4 | 76.3 | 98.8 | 79.1 | 43.2 | 99.6 | 32.6 | 99.4 | 99.2 |
| **H3** | 13 | 73.9 | 90.2 | 80.0 | 59.3 | 99.0 | 49.6 | 99.6 | 99.3 |
| | | | | | 2020 | | | | |
| **H1** | 8 | 56.7 | 71.1 | 87.1 | 87.5 | 89.1 | 65.9 | 90.3 | 86.4 |
| **H2** | 4 | 73.4 | 75.5 | 96.1 | 27.8 | 74.3 | 49.5 | 64.2 | 75.1 |
| **H3** | 13 | 82.4 | 92.7 | 90.0 | 14.2 | 90.8 | 56.6 | 84.6 | 86.3 |

**Table 3.** Relative contribution of sources of variance of quantitative traits

| Traits | Genotype (G) | Environment (E) | Interaction (GEI) |
|---|---|---|---|
| **Seed yield (kg/ha)** | 32.2 | 34.3 | 21.3 |
| **Thousand Seed weight (g)** | 49.3 | 11.3 | 19.8 |
| **Hectolitre mass of seeds (kg/hl)** | 74.1 | 16.9 | 3.2 |
| **Number of leaves** | 62.2 | 8.5 | 9.0 |
| **Plant height (cm)** | 36.1 | 48.0 | 14.0 |
| **Head diameter (cm)** | 35.7 | 2.5 | 18.9 |
| **Achene weight per head (g)** | 23.3 | 36.8 | 19.5 |
| **Number of achene per head** | 21.4 | 35.6 | 39.1 |

well as high phenotypic uniformity. The two-factorial dispersion analysis highlighted that in various environmental conditions the genotype determines the variability in 3 of the 8 studied traits, including HMS, TSW and that the environment influences quite considerably the variability of 4 traits including PH, AWH, APH and SY.

## DISCUSSION

The leaf surface is an important indicator of plant growth, being related to the accumulation of dry matter, transpiration, photosynthetic capacity and production [19, 21]. Usually the higher hybrids have a larger number of leaves. For the relatively favorable conditions in 2019, there is a positive correlation (r = 0.51) between the height of the plant and the number of leaves, but in conditions of drought, manifested especially in the first part of the vegetation period, this correlation is much lower, the same findings were obtained by Clapco et al. (2019) [6]. Water stress decreases the number of leaves but Clapco et al. (2019) [6] mentions a decrease in the number of leaves by about 20% and our results signal a decrease of only 7%. This discordance among results for correlations is most likely associated with differences in the environmental conditions used in studies.

The most intense increase in plant height is attested in the period from the formation of the flower bud to flowering, the period corresponding to June, and the first decade of July. During this period, in 2020, there was scarce rainfall, which lead to the decrease of plant height by an average of 11%. Tabara et al. (2018) [22] mentions that water stress conditions caused a 23% decrease in sunflower plant height. Marinkovic (1992) [14] and Tahir et al. (2002) [23] reported that plant height had a positive effect on seed yield. In our studies, no significant correlations between plant height and seeds yield have been established, the data being in accordance with those obtained by Clapco et al. (2019) [6] and Papatheohari et al. (2016) [18].

If the height is mainly determined by environmental conditions, then the number of leaves is mainly determined by genotype and the number of leaves does not vary much from year to year.

Another important trait in the sunflower seed yield structure is the size of the head diameter, which influences the number of flowers and seeds per head and directly affects the seed yield per plant [3, 14, 16]. The values of the diameter ranged between 19 - 24 cm and is within the average values reported by other authors [3, 6, 13]. In our research, water stress had effect on head diameter. This was in accordance with the finding of Mirshekari (2012) [17] and Tabără (2018) [22]. In contrast to our results many researchers observed a significant positive correlation between seed yield and head diameter [5, 6, 23].

According to Hladni (2010) [10] the diameter of the calatidium has a positive correlation with APH and AWH, a fact confirmed in the present study. The value of APH and AWH decreased significantly in 2020 compared to 2019. The AWH decreases the most by about 34%. We can assume that unfavorable conditions influence the seed filling processes by decreasing their mass per head, APH is less influenced by environmental conditions because the values of this index decrease by 17%.

The ANOVA tests allowed us to observe that if for the HD and the NL the influence of the genotype is more important than for AWH and APH a decisive role is played by the effects of environmental conditions and genotype by environment interaction. TSW, like APH, is significantly influenced by thermal and water stress. Khan et al. (2018) [13] concluded that these traits show a decreasing trend at the same time as the severity of stress caused by high temperatures and insufficient humidity. TSW is the third most important trait and is quite variable, being affected by both genetic and environmental factors [12]. TSW is a trait

that reflects the efficiency of the seed filling process. High-mass seeds indicate that the plant has used environmental conditions effectively and has accumulated sufficient nutrient reserves in the seed. At the same time, TSW is genetically determined because it also depends on the size of the seed specific to each genotype.

Yield is the main purpose of most agricultural activities and crop level and stability are one of the basic descriptors of the commercial value of hybrids. As we found, the seed yield value vary a lot both depending on the genotype and the agrometeorological conditions of the year. Nevertheless, an important feature is the ability of the hybrid to present a similar performance in various environmental conditions. In our study, seed yield level was higher than those reported in other studies [4, 6, 22] in this particular region of the Republic of Moldova. These differences in seed yield values could be explained by different genotype potential and environment conditions.

Using the coefficient of variation (CV), we quantified the homogeneity of the populations of each hybrid for each year. Even if the coefficient of variation for most traits and hybrids was small enough (<10%) to be able to say that the studied genotypes are homogeneous, the conditions of 2020 caused a higher phenotypic heterogeneity between individuals of the same hybrid. We can say that most traits are significantly determined by the genetic potential of the hybrid, which is a natural thing, but the size of the effect of the genotype varies depending on the conditions of the year.

The effect of unfavorable conditions in 2020 was the time distribution of weather characteristics and not the sum values of meteorological indices. During critical periods for sunflower development, various unfavorable conditions were attested. In April, the precipitation rate reached 9 mm compared to 42 mm, which is the multiannual average. The lack of moisture in the soil together with minimum temperatures below $0^{o}$ C recorded several days in a row caused the shift of the sowing and germination period. In the first decade of June, there was insufficient rainfall of about 13.5 mm and low temperatures, especially at night. Due to the movement of the sowing period, these conditions coincided with the formation of floral buds. The first 2 decades of July were very dry, with rainfall that did not exceed 10 mm, during this period there was flowering, and water stress is a limiting factor for the process of seed formation.

Water stress decreases the yield of hybrids affecting practically all traits included in the study. AWH, which decreased by 32% and APH, which decreased by 18%, were mostly affected. SY decreased in 2020 compared to 2019, on average by about 15%. The H2 hybrid group was more vulnerable to water stress, yield decreased by 25%. Surprisingly, the hybrids in group H3, which reduced the yield by only about 8%, were more resistant to drought than the commercial hybrids in group H1, in which the yield decreased by 20%. The group of experimental hybrids (H3) showed an increased stability to environmental factors, so from this group we can mention the perspective hybrids (457*,* 1718, 1719) that showed a high and stable yield in both years of study.

Water stress also manifested itself on the phenotypic uniformity of individuals. Thus, the degree of variation of the studied traits depends on the genotype and the year of cultivation. It was found that the coefficient of variation for 4 traits (HD, NL, HMS and PH) varies insignificantly, while other 4 parameters reveal a coefficient of variation from 0.6 to 7.0, depending on the genotype and year of cultivation. All the studied indices demonstrated a higher coefficient of variation in 2020 compared to 2019, proving that water stress reduces the homogeneity of hybrids.

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