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ANALYSIS OF YIELD AND YIELD RELATED TRAITS IN SOME SUNFLOWER (*Helianthus annuus* L.) HYBRIDS UNDER CONDITIONS OF THE REPUBLIC OF MOLDOVA

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Abstract

The growth and productivity traits of twenty local sunflower hybrids have been evaluated, during two years, under Moldovan environmental conditions. It has been established that yield and yield related traits of analysed combinations depended both on the year of observation and the genotype. Environmental conditions affected especially the number of leaves, number and weight of seeds per head and 1000 seeds weight. Determination of relationships between seed yield and some morpho-physiological parameters, such as plant height, head diameter, leaf number, number and weight of total and full seeds per head and 1000 seeds showed high positive correlations between some traits. The analyses of Pearson correlation coefficients showed that the number and weight of total and full seeds per head and the weight of 1000 seeds had a high positive correlation with seed yield per surface unite. Also, a positive but low correlation with seed yield was found related the head diameter. In both years a significant positive correlation was established between plant height and number of leaves.

Key words*: plant height, head diameter, seed weight, number of achenes per head, sunflower hybrids.*

INTRODUCTION

Helianthus annuus L. is a valuable source of edible vegetal oil due to its high content of oil (40-52%) rich in unsaturated fatty acids (83-91%), vitamins A, D, E, K, tocopherols and phytosterols (Khalifa & Awad, 1997; Velasco et al., 2014). Consumption of sunflower oil leads to the reduction of LDL cholesterol in humans and decreases the risks of heart attack, having positive effects on the health (Hu et al., 2001). Furthermore, sunflower seed cakes contain high concentration of proteins (35%), carbohydrates (18-20%) and could be used for animals feed (Ibrahim, 2012). According to Zagoul'ko et al. (2011) from one hectare of sunflower with a yield of 2.5 tons per hectare 1200 kg of oil, 800 tons of cakes (300 kg of protein), 500 kg of husk (70 kg of yeast), 1500 kg of sunflower heads (1000 kg of qualitative fodder), 25-30 kg of honey, and other useful bio-products could be obtained.

Considering its economic importance and role in human nutrition, the sunflower has become the third most important oilseed crop in the world following soybean and rape, with the average of 18 million hectares sown land and 40.0 million metric tons yield (FAOSTAT, 2015).

A similar trend has been revealed in the Republic of Moldova, where sunflower is grown almost on 25% of the total arable land, after wheat and corn, ranging from 225,000 to 400,000 ha per year (Moroz et al., 2015). In recent years, the area of sunflower in Moldova tripled, while yields have doubled (Sunflowers Excel in Ukraine, Romania, Bulgaria and Moldova in 2017). Sunflower yields varied between 1.5 and 2.1 tons per hectare with an average yield of 1.8 t/ha. The yield is affected by a complex of factors, such as the aggravation of the phytosanitary state due to failure of crop rotation, simplified cultivation technologies, lands degradation, low quality of seeds, as well as unfavorable environmental conditions, including drought, salinity and low temperature stress (Kandakov et al., 2012; Statistical databank). The Republic of Moldova is ranked 15-16th in the World Sunflower Seed Producers Rating (FAO, 2010).

In order to face increased consumer demand for high-quality sunflower seeds the effort of breeders are focused on obtaining of new highly productive hybrids, resistant to biotic

and abiotic factors, characterized by stable yield across different environments affected by climatic change (Mrdja et al., 2012). The main goals of sunflower breeding programs are: the yield over 4 t/ha, the husk share lower than 25%, more than 50% fat content in the seed, higher contents of healthy fatty acids, mostly oleic acid (Škorić, 1989; Kocjan Acko, 2008). Considering that seeds productivity and quality are greatly influenced by genotype, environment and their interaction the creation of new sunflower hybrids requires testing of breeding materials (Mrdja et al., 2012; Cerny et al., 2013). Plant phenology, crop growth period, as well as yield, oil and fatty acid accumulation is influenced by temperature, humidity, light levels and other environmental factors (Kaleem et al., 2010). There are many studies consisting in the evaluation of agronomic traits of different commercial or experimental sunflower hybrids in field conditions (Ullah et al., 2018; Ruzdik et al., 2015). Plant height, head diameter, number of seeds per plant and 1000 seeds weight are the main important parameters that determine yield improvement in sunflower (Kaya, 2015).

It is of great importance to know the relationships between yield contributing characters. Yield components, total leaf area, plant height, total seed per head and 1000 seeds weight were found to correlate with seed yield per plant (Hladni et al., 2004; 2010). Behradfar et al. (2009) reported that seed yield was positively associated with 1000 seeds weight and total seed number per head. According to Škorić (2012) the head diameter influences the number of seeds per head and represents a very important trait in the sunflower seed yield structure. A positive and important interdependence was determined among morpho-physiological traits like total leaf area, plant height, head diameter, mass of 1000 seeds and total number of seeds per head with seed yield and oil yield (Hladni et al., 2008; 2010)

The aim of this study was to evaluate, in two years, the growth and productivity of new sunflower hybrids grown under Moldovan environmental conditions in order to provide an insight into the effects of some weather parameters on productivity and identify the more stable genotypes.

MATERIALS AND METHODS

For the study were used 20 experimental sunflower hybrids created by the Company AMG-Agroselect Comert, Republic of Moldova (noted conventionally HM1-HM20). The experiment was performed during the growing seasons 2017 and 2018 in the field of AMG-Agroselect Comert Company, in Soroca district, Republic of Moldova, using the same growing technology in both years. The experimental field is located on the first terraces of the right bank of the Nistru River, at an altitude ranging from 53 to 77 m above sea level.

The trial design was randomized blocks with three replications. Each experimental plot consisted of 6 rows. The seeds were sown manually at a spacing of 0.35 m between plants and 0.70 m between the rows.

Plant height, head diameter, leaf number, number and weight of total and full seeds per head and 1000 seeds weight were established. At the stage of physiological maturity, ten plants were randomly selected from each replication and their height was measured from ground level to the top edge of the head and then their average was calculated. The head diameter was determined by measurements made for 10 plants in each block and repetitions in the field and calculation of average. Number of seeds per head was recorded from ten plants taken randomly from each replication and then their average was calculated.

To obtain thousand seed weight, 100 seeds taken randomly from each plot and replications were weighted using an electronic balance with an accuracy of 0.001 g and then multiplied by 10. Seed yield was measured separately from each plot and expressed as kg per hectare.

The meteorological data, monthly precipitation and daily temperature, as well as multiannual monthly average, were obtained from State Hydrometeorological Service of the Republic of Moldova.

To determine the relationships among the analysed traits the Pearson correlation coefficient between morphological characters (plant height, number of leafs, head diameter) and yield were obtained.

RESULTS AND DISCUSSIONS

The effect of the year on the sunflower yield differed due to different environmental conditions, such as soil or/and weather. According to Mijić et al. (2012) and Liović et al. (2006) rainfall and temperature are both important before and during the vegetation period, contributing to the replenishing of water reserves of soils or directly influencing the vegetative and generative development and, respectively, yield in sunflower. In order to study the influence of the year on sunflower yield and yield related parameters, the temperatures and rainfall amounts in 2017 and 2018 growing seasons were evaluated (Figures 1 and 2). The average annual temperature in 2017 growing season was 11.8°C, with lows of -5.1°C in January and highs of 22.5°C in August. In 2018 the average temperature was 11.5°C, with minimal value of -2.7°C in February and maximum 21.6°C in August (Figures 1a, 2a).

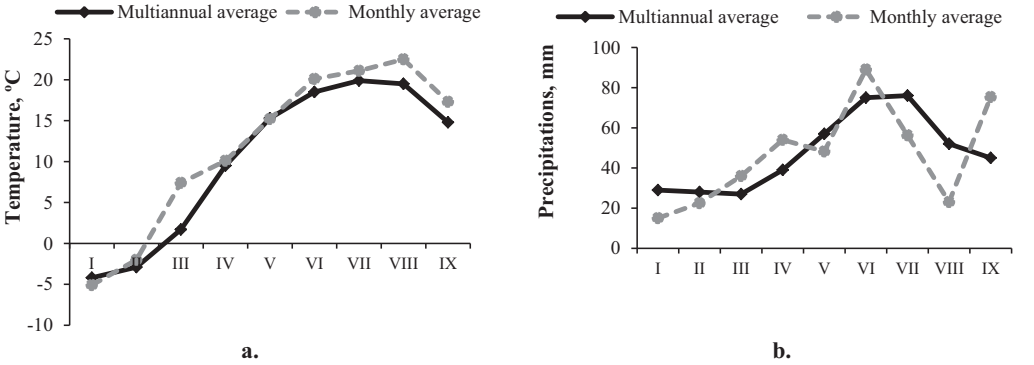


Figure 1. Average monthly temperatures (a) and amount of precipitations (b) for the growing season 2017 and multianual data

Generally, in both growing seasons the average temperature was higher by 1.3-1.6ºC compared to previous years, with increased temperatures, especially in summer months throughout the generative phase of sunflower. The average temperature in winter was -2.6ºC analogic with the multiannual data of -2.8ºC in 2017 and higher (-0.7ºC) in 2018.

Spring was characterised as warm with an average temperature of 11.0°C in both analyzed years exceeding the multiannual average by 2.2°C. In the summer, temperature was higher compared to previous years, with average values of 21.2ºC and 20.9ºC per season, respectively in 2017 and 2018, by 1.6-1.9ºC higher than the multiannual average. As described above, temperature values in both agricultural years are similar.

Most often precipitation comes in the form of rain, with an average of about 419.4 mm in 2017 and 307.5 mm in 2018 gowing season, being 8.6 mm and, respectively, 120.5 mm lower than multiannual data (Figures 1b, 2b).

Spring (April, May) and summer (June, August) months were characterized by a humidity deficiency, lower by 25-51.77 then the multiannual monthly average.

The analysis of some agro-morphological traits of new sunflower hybrids developed by the local company AMG-Agroselect Comert, in the experimental field, during 2017 and 2018 seasons, revealed that growth and yield parameters varied significantly. Since the genotypes were grown in the same field environment, applying similar agronomic practices, the difference in plant height, number of leaves, head diameter, seed number and seed weight per head, 1000 seeds weight, as well as seed yield of analyzed sunflower hybrids, in one year of investigation, could be explain by their different genetic potential and the differences in both years are additionally determined by deferentiated weather conditions.

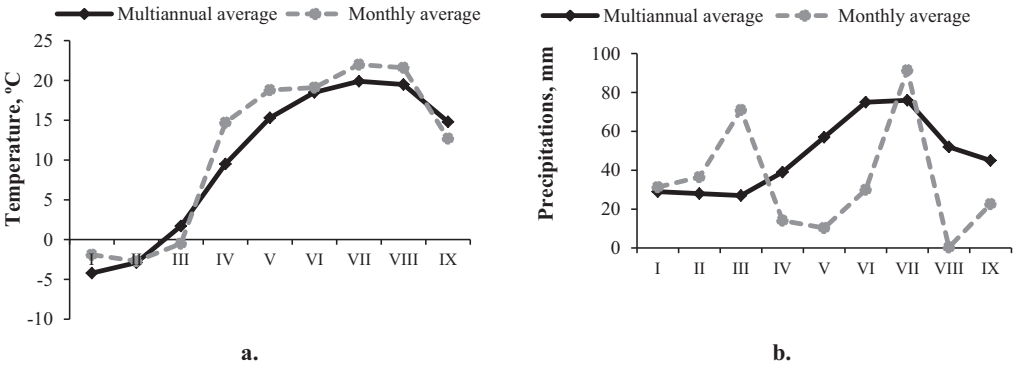


Figure 2. Average monthly temperatures (a) and amount of precipitations (b) for the growing season 2018 and multianual data

As shown in figures 3-9, for the majority of hybrids the values of yield and yield related traits were lower in 2018 compared to 2017. Considering that plants have been cultivated in relatively similar conditions, excepting the quantity of precipitation received, which was lower during 2018 vegetation period (146.1 mm) comparative to 2017 (270.6 mm), the decrease of analysed parameters could be mainly attributed to the inadequate water supply.

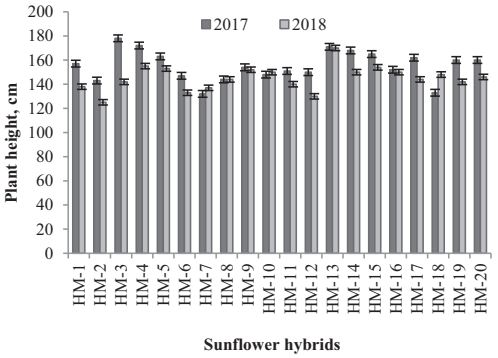


Figure 3. Plant height (cm) of twenty sunflower hybrids during two experimental periods (2017 and 2018)

The same findings were obtained by Yegappan et al. (1982) who reported that hydric stress significantly reduced number of leaf, head diameter, leaf area, weight of 1000 grains and grain yield. Đukić et al. (2011) stated that amount of precipitation and temperature conditions during the growing season are important limiting factors of yield levels and 1000 seeds weight.

Regarding the plant height, the values ranged between 132-178 cm in 2017 and 125-170 cm in 2018. The hybrids HM3, HM4 and HM13 were the tallest among tested genotypes, with the height of 171 to 178 cm in 2017, excepting HM3, the same hybrids were the tallest in 2018.

Compared to the tallest genotypes, the hybrids HM2, HM7 and HM18 were the lowest in 2017 with average height of 132 cm to 143 cm and HM2, HM6 and HM12 presented the minimal values (125-133 cm) in 2018. Plant height of a crop is the function of the combined effects of genetic makeup and the environment (Gvozdenović et al., 2005). Thus, different values in sunflower hybrids growing in identical field environments could be explained by their different genetic makeup. Marinkovic (1992) reported that plant height had a positive effect on seed yield. In our studies, no significant ($p<0.01$ or 0.05) correlations between plant height and seeds yield have been established (Table 1), the data being in accordance with those obtained by Papatheohari et al. (2016).

As shown in table 1, in both years a significant positive correlation, 0.5637 and 0.7074, in 2017 and 2018, respectively, were found between plant height and number of leaves. Divergent to the results of Hladni et al. (2010) and Khan et al. (2018), who reported a strong positive correlation of total leaf number per plant with the sunflower yield and seed oil content, in the present study, no significant correlations between the number of leaves and yield traits have been observed. According to the data, the highest leaves number (35 in 2017) was observed in HM4, one of the tallest hybrids and the least number of leaves (25 in

2017 and 18 in 2018) was sighted in HM18 and HM6, respectively, which were the smallest hybrids (Figure 4).

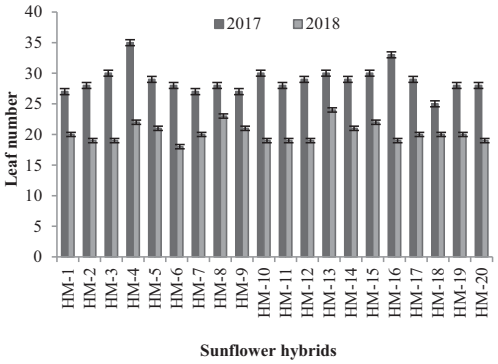


Figure 4. Number of leaves of twenty sunflower hybrids during two experimental periods (2017 and 2018)

The number of leaves per plant was significantly lower (by around 20-40%) in 2018 comparative to 2017 and may be due to a low quantity of rainfall during vegetation period. Obtained data are in agreement with the fact that plants under water deficit have reduced leaf growth, by the diminution of leaf number and/or reduction of area of individual leaves (Pereyra-Irujo et al., 2008).

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 (Balalic et al., 2016). Data shown in Figure 5 revealed significant differences among head diameter of various sunflower hybrids. In the first analysed year, the largest head 24 cm was recorded in HM7, followed by HM1, HM4 and HM10.

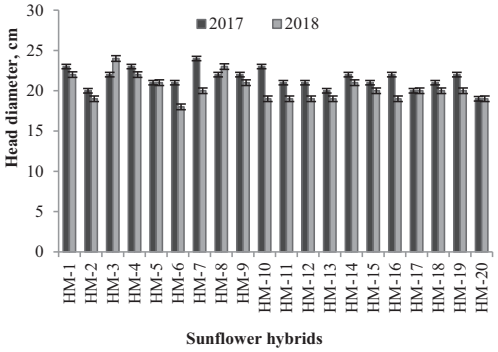


Figure 5. Head diameter (cm) of twenty sunflower hybrids during two experimental periods (2017 and 2018)

Table 1. Pearson correlation coefficients between some morpho-physiological traits and yield parameters in twenty sunflower hybrids

Traits	X2	X3	X4	X5	X6	X7	X8	X9
2017								
X1	0.5637*	-0.1539^{ns}	-0.1336^{ns}	-0.1055^{ns}	-0.3263^{ns}	-0.3414^{ns}	-0.1617^{ns}	-0.0762^{ns}
X2	-	0.1568^{ns}	-0.0147^{ns}	-0.0196^{ns}	-0.1963^{ns}	-0.2029^{ns}	-0.1112^{ns}	-0.1175^{ns}
X3	-	-	0.4871**	0.5415*	0.7290*	0.7188*	0.6350*	0.4546**
X4	-	-	-	0.9719*	0.5058**	0.5074**	0.3305^{ns}	0.5708*
X5	-	-	-	-	0.5905**	0.5532*	0.4180^{ns}	0.6145*
X6	-	-	-	-	-	0.9978*	0.6414*	0.5387**
X7	-	-	-	-	-	-	0.6340*	0.5285**
X8	-	-	-	-	-	-	-	0.7482*
2018								
X1	0.7074*	0.1287^{ns}	0.1513^{ns}	0.2748^{ns}	-0.0043^{ns}	-0.0276^{ns}	-0.0728^{ns}	-0.0498^{ns}
X2	-	0.3661^{ns}	0.3845^{ns}	0.3881^{ns}	0.1803^{ns}	0.1824^{ns}	0.0410^{ns}	0.3243^{ns}
X3	-	-	0.5135**	0.5620*	0.8338*	0.7931*	0.6473**	0.3822**
X4	-	-	-	0.8257*	0.4642**	0.4231**	-0.0467^{ns}	0.2262^{ns}
X5	-	-	-	-	0.6596*	0.6886*	0.1330^{ns}	0.5397*
X6	-	-	-	-	-	0.9884*	0.7915*	0.6117*
X7	-	-	-	-	-	-	0.7675*	0.6685*
X8	-	-	-	-	-	-	-	0.4997**

X1 - Plant height (cm)
X2 - Total leaf number per plant
X3 - Head diameter (cm)
X4 - Total seed number per head (g)
X5 - Full seed number per head (g)
X6 - Weight of total seed per head (g)
X7 - Weight of full seed per head (g)
X8 - Weight of 1000 seeds (g)
X9 - Yield (kg/ha)

* F test for significance at level P<0.01; ** F test for significance at level P<0.05 ; ns - not significantly different

The shortest head diameter (19 cm) was observed in hybrid HM20. In second year the maximal value (24 cm) has been sighted at HM3, followed by HM8 and HM1 and the lowest at HM6 (18 cm). Obtained data confirms the findings that sunflower head diameter depend on genotype and environmental conditions, as well as interaction between these factors (Hladni et al., 2014; Moisa & Smit, 2014). Diameter values are higher comparative to those reported by other authors (Iqrasan et al., 2017; Khan et al., 2018; Balalic et al., 2016) and could be considered as intermediate (ranged between 20-25 cm).

Similar with the results reported by many authors (Hladni et al., 2004; 2008; 2010; Kaya et al., 2009; Killi & Tekeli, 2016; Gvozdenović, 2005), significant positive correlations between head diameter and seed yield related traits have been found (Table 1).

Thus, head diameter highly correlates with the number of total and full seeds per head (r = 0,4871** and 0,5415* in 2017, respectively, 0,5135** and 0,5620* in 2018), weight of total and full seeds per head (r = 0,7290* and 0,7188* in first analysed year and r = 0,8338*; r = 0,7931* in second year), as well as 1000-seed weight (r = 0,6350* in 2017 and r = 0,6473** in 2018).

The highest number of total and full seeds per head in both analysed years was showed by the hybrid HM14, followed by HM3, HM4, HM1, HM9 and HM18, the last three genotypes also indicating the higher value of weight of seeds per head. In 2018 growing season, the maximum was found in HM15 (Figure 6).

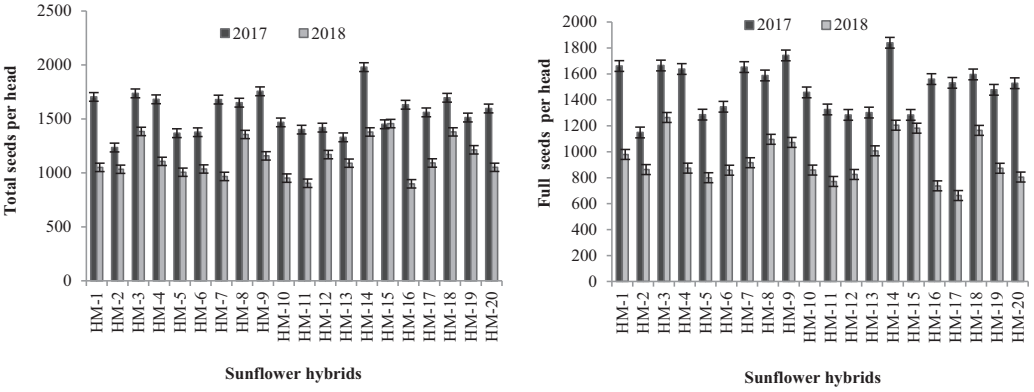


Figure 6. Number of total (a) and full (b) seeds per head of twenty sunflower hybrids during the two experimental periods (2017 and 2018)

The lowest number of achenes per head and one of the minimal values of seeds weight were characteristic for HM2 in 2017 and HM16 in 2018 (Figure 7).

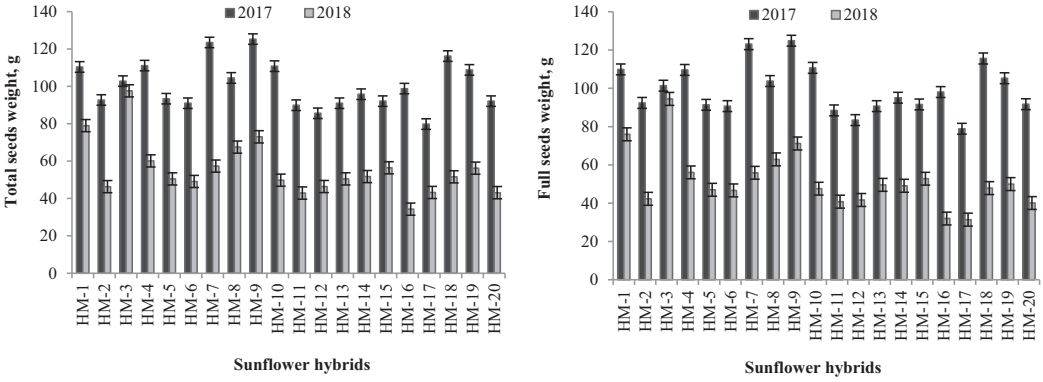
Number and weight of seeds per head were significantly lower in 2018 comparative to 2017. This fact may be due to lower water supply and correspond with the findings of Stanojević and Dragović (1988) which observed significant reductions in flower number and, respectively, seeds number in the presence of water deficit at budding or flowering stage.

In both experimental years, the analysis of the Pearson correlation coefficients has indicated very high positive correlations between these traits and seed yield (kg/ha). Thus, high correlations existed between the number of full seeds (0.6145* in 2017 and 0.5397* in 2018, respectively), as well as weight of total (0.5387** and 0.6117*) and full seeds (0.5285** and 0.6685*) and yield. Similarly, high positive correlations among mentioned traits and yield per plant have been reported by Hladni et al. (2010). Goksoy and Turan (2007) observed a very high positive correlation (r = 0.890**) between seed yield and number of seeds per head.

According to Škorić (1989) 1000-seed weight has an indirect effect on the quality of the seeds to be produced as well seed yield per unit area. Obtained data has shown that the average value of 1000 seeds weight of all hybrids was 69.12 g in 2017 and 52.4 g in 2018, being by 24%

lower. High number of 1000 seeds weight in both years was noticed in HM7 (84.9 g and 59.48 g, respectively), HM1 (83.7 g and 76.45 g, respectively), HM3 (78.5 g and 70.04 g, respectively) and HM4 (77.6 g and 63.21 g, respectively), while the lowest value of 1000 seeds weight (50.7 g) was noticed in HM11 in 2017 and HM18 (0.39 g) in 2018 (Figure 8).

The results are in agreement with those reported by Ibrahim (2012).



a. b.

Figure 7. Weight of total (a) and full (b) seeds per head of twenty sunflower hybrids during the two experimental periods (2017 and 2018)

The value of 1000 seeds weight varied significantly among the hybrids and years of study, being greatly influenced by the last factor. Thus, in the second year, this parameter decreased by 38-42% in the case of HM16 and HM18, significantly affecting the seed yields (by 46.4% and 21.5%, respectively). Data is in agreement with the findings of Radic et al. (2013), according to which 1000-seed weight depends first and foremost on the year of study and the hybrid.

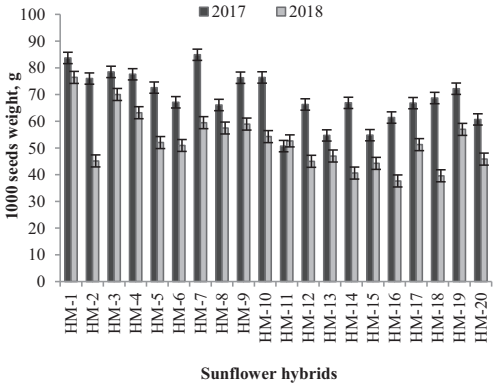


Figure 8. 1000 seeds weight (g) of twenty sunflower hybrids during two experimental periods (2017 and 2018)

Similar with the results reported by numerous authors (Hladni et al., 2004; 2010; Behradfar et al., 2009; Kaya, 2015) this parameter highly correlates with seed yield. Thus, the Pearson correlation analysis showed significant ($p<0.01$ or 0.05) positive correlation (r=0.7482* in 2017 and 0.4997* in 2018) of 1000 seeds weight with seeds yield.

The seed yield in 2017 growing season varied between 2139.1-3152.9 kg/ha, with an average value of 2743.5 kg/ha (Figure 9).

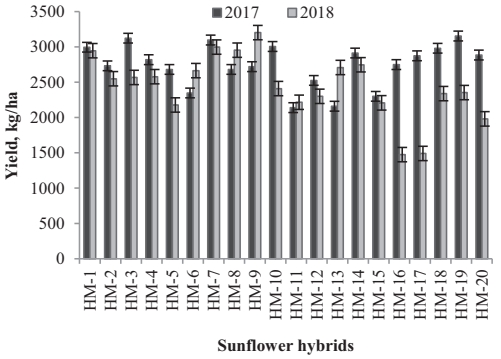


Figure 9. Seeds yield (kg/ha) of twenty sunflower hybrids during two experimental periods (2017 and 2018)

The highest value for seed yield was established in HM19 (3152.9 kg/ha) followed by HM3 (3122.7 kg/ha) and other hybrids,

such as HM7, HM10, HM14 and HM1 with the value ranged among 2912.5-3096.9 kg/ha. The minimal yield observed at hybrid HM11 (2139.1 kg/ha).

In 2018 seed yield was lower for the majority of hybrids, with values between 1474-3202 kg/ha, with average value of 2442.5 kg/ha. The sunflower hybrid HM9 showed the maximum yield, even 17% higher than in previous year. The most affected hybrids were HM16 and HM1, which produced the minimal yield values, by around 50% lower than in 2017 growing season. In the majority of cases the diminution of seeds yield was insignificant. Thus, the hybrid combinations HM1, HM2, HM4, HM6-HM9 and HM11-HM15 showed stable yield values.

CONCLUSIONS

The results of the study of twenty sunflower hybrids grown under Moldovan environmental conditions, during two years, indicated that the growth and productivity of combinations depended both on the year of observation and the genotype. A stable seeds yield was obtained in HM1, HM2, HM4, HM6-HM9 and HM11-HM15 sunflower hybrids. Mentioned hybrids shown similar values in both years, even the 2018 growing season is characterized by a significant lower rainfall quantity. The number of leaves per plant was the most affected by environmental conditions trait, this finding being in agreement with the fact that plants under water deficit reduce leaf growth. Also, yield related traits, such as number and weight of seeds per head and 1000 seeds weight, were significantly influenced by the unfavourable environmental conditions. Thus, in the second year, these parameters have been decreased by 21-45% for all analysed hybrids.

Determination of relationships between seed yield and some morpho-physiological parameters, such as plant height, head diameter, leaf number, number and weight of total and full seeds per head and 1000 seeds showed high positive correlations between some of traits. Analyses of Pearson correlation coefficients indicated that the number and weight of total and full seeds per head and the weight of 1000 seeds had a high positive correlation with seed yield per surface unite. Also, a positive but low correlation with seed yield was found related the head diameter. In both years a significant positive correlation were established between plant height and number of leaves.

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