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Productivity and quality of experimental sunflower hybrids in climatically different years

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Abstract. *The main purpose of sunflower breeding requires the developing of high-yielding hybrid varieties with broad ecological plasticity that would guarantee the stability of the yield and the quality of the production from them. This investigation involved 10 experimental F1 hybrid combinations developed with the participation of double haploid fertility restorer lines (DHR) obtained through the method of gamma-induced parthenogenesis in combination with embryo culture. The aim of the investigation was to study the productivity and quality of the seeds from the new experimental sunflower hybrid varieties with a view of their future use in practice. The experimental work included years 2014 and 2015, which were significantly different with regard to the climatic conditions. The experiments were carried out in the experimental field and the laboratory of the Technical University in Varna. The hybrid combinations were assessed according to the main parameters of sunflower productivity, namely seed yield (kg/ha) and oil yield (kg/ha), as well as according to the main quality parameter of sunflower seeds – oil percent in seed. Under the conditions of this investigation, the analysis of the results showed that the genotype potential of the hybrids was determining for the seed and oil yield; a relatively high effect of the year conditions was also established for the parameter oil yield. The percent of oil in seeds was determined on the basis of the genotype, and the effect of the year was considerably lower. Summing up the results from the testing of the experimental hybrids, it can be pointed out that three of the studied hybrid combinations (3607A x 112DHR, 3607A x 123DHR and 3607A x 167DHR) realized good production potential under variable agro-meteorological conditions and can find future realization in practice*.

Keywords: ecological plasticity, F1 hybrid combinations, oil content, oil yield, sunflower seeds, seed yield

Introduction

Sunflower *(Helianthus annuus* L.) is an important source of vegetable oil worldwide and a main oil seed crop in Bulgaria. Increasing the yield, the quality of seeds and the resistance to diseases and pests are some of the main aims of modern sunflower breeding, and heterosis plays a leading role for their achievement. Sunflower is a crop, which is grown on large areas due to its good ecological plasticity evident in its normal behaviour under drought and in its resistance to sharp variations of the climate. Due to its ability to grow under different agro ecological conditions and to its moderate tolerance to drought, sunflower can become a crop, which is preferred in the future, especially under the on-going ecological changes (Debaeke at al., 2017; Bhoite et al., 2018; Tariq et al., 2018; Miladinović et al., 2019). Sunflower is grown in a number of countries under conditions of almost annual occurrence of actual abiotic stress of different types, which are limiting factors for plant breeding. The main ecological stressors in the production of this crop are the insufficient moisture and the extreme high air temperatures, which cause soil and atmospheric drought during various stages of its ontogenetic development (Škorić, 1988). The amount and distribution of rainfalls and the air temperatures have the highest effect on the development and yield formation of sunflower; the response of the hybrid to these factors is largely dependent on its genotype (Monti, 1987). The genetic potential of the hybrid for seed yield, oil percent in seed, oil yield and resistance to economically important abiotic and biotic factors, are primary factors for sustainable sunflower production (Sarwar et al., 2013).

Sunflower is mainly grown for the oil obtained from the seeds. The oil content in the seeds is determined by the genotype and the agro ecological conditions, and their effect is especially strong at stage seed filling (Stanojević et al., 1992). Due to its specific anatomic and morphological structure, sunflower is more resistant to abiotic stress in comparison to other field crops (Škorić, 2016). Under the contemporary conditions of on-going climatic changes, it is a challenge to breeding to develop varieties with wide adaptability and ecological plasticity, which would guarantee the stability of yield and the quality of production of these varieties (Goksoy and Turan, 2000). As the variations of climatic variables have a substantial importance in determining yield, development of sustainable genotypes would be an important contribution to sunflower breeding (González et al., 2013).

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The aim of this investigation was to study the productivity and quality of the seeds from new experimental sunflower hybrid varieties with a view of their future use in practice.

Material and methods

The investigation was carried out in 2014 and 2015 in the experimental field and laboratory of the Technical University of Varna (TU - Varna). The hybrid combinations were tested according to the block design method, in two replications, the size of the harvest plot per replication being 7.35 m^2. Soil tillage, fertilization and weed control were done according to the traditional technology for growing of the crop in this region.

The investigation included ten F1 hybrid combinations (3607A x 112DHR, 217A x 112DHR, 3607A x 123DHR, 217A x 123DHR, 3607A x 153DHR, 217A x 153DHR, 3607A x 167DHR, 217A x 167DHR, 3607A x 172DHR and 217A x 172DHR). They were developed with the participation of fertility restorer double haploid lines (DHR) obtained through the method of gamma-induced parthenogenesis in combination with embryo culture. The CMS lines 3607A and 217A, developed at Dobrudzha Agricultural Institute – General Toshevo, were used as female parental forms of the F1 hybrid combinations. The crosses were made in 2013 in the experimental field of TU - Varna. Each DHR line was involved as a male component in two hybrid combinations with each of the used CMS lines. The hybrids Vokil and Veleka were used as standards in the study on the productivity and quality of the seeds from the experimental hybrids.

The parameters seed yield (kg/ha) and oil yield (kg/ha) were read on 30 plants from each of the two replications. Harvesting was manual at stage technical maturity. The seeds from each head, after being removed and cleaned from admixtures, were weighed to 0.01 g and the seed yield was calculated in kg/ha based on the mean seed yield per plant and the number of plants per ha.

Oil content in the seeds from the hybrid materials was determined by using nuclear magnetic resonance imaging (MRI) method for each of the two replications.

The statistical processing of the data was performed with the help of Microsoft Excel 2010 and BIOSTAT.

Results and discussion

Over the years of investigation, the monthly sum of rainfalls during the studied period was significantly lower in comparison to a fifty-nine-year period (1952-2010), and this was most evident in 2015 (Table 1). The precipitation sum in 2014 was higher by 42.7 mm than the sum for 2015, and by 53.6 mm lower than the mean long-term sum for the period May-September. In 2014, the rainfalls during the active vegetative growth of plants (May-July) significantly exceeded the monthly precipitation sum of 2015 thus ensuring the demands for moisture of sunflower during the critical stages bud formation and flowering. This explained the higher seed yield and the greater percent of oil in seeds in 2014 in comparison to 2015 (Figures 1 and 2).

Table 1. Monthly values of rainfalls and air temperature from April to September during 2014-2015

Year	V	VI	VII	VIII	IX	V-IX
Monthly precipitation sum, mm						
2014	42.0	53.0	38.0	36.0	28.0	197.0
2015	26.8	38.6	9.6	62.0	17.3	154.3
52-10	51.0	61.9	52.2	40.5	45.0	250.6
Mean monthly air temperatures, °C						
2014	15.4	20.1	22.6	22.4	19.0	19.50
2015	16.8	20.9	23.5	24.4	21.0	21.32
52-10	15.0	19.0	22.2	21.9	17.6	19.14

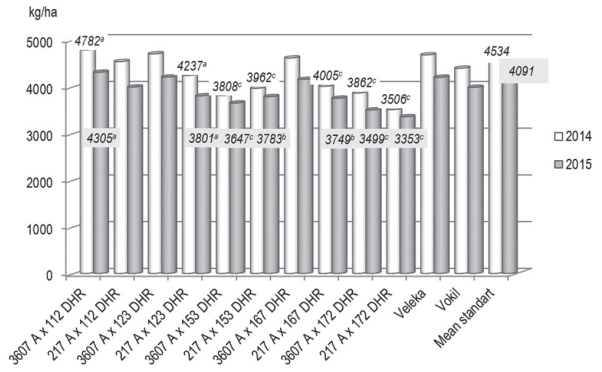

Figure 1. Productivity of sunflower hybrids for seed yield (kg/ha), harvest seasons 2014 and 2015
($^aLSD_{0.05}$ = 212.8; $^bLSD_{0.01}$ = 298.4; $^cLSD_{0.001}$ = 421.7)

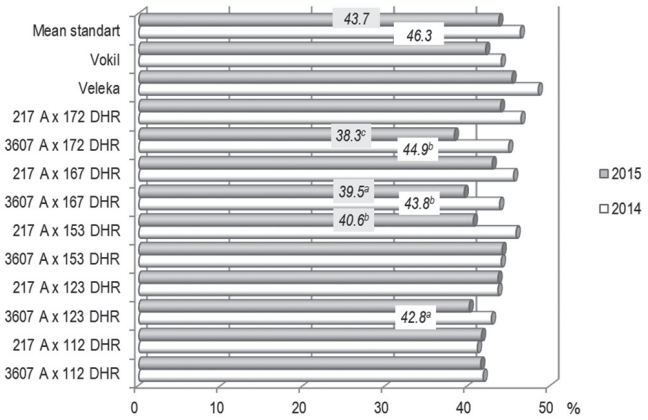

Figure 2. Oil content in seeds (%) of the tested sunflower hybrids ($^aLSD_{0.05}$ = 3.30; $^bLSD_{0.01}$ = 4.62; $^cLSD_{0.001}$ = 6.54)

In contrast to 2015, when mean monthly air temperatures of the period of investigation 2.18°C higher than the mean monthly temperature for the long-term period (1952-2010) were registered, year 2014 did not have statistical significance. The values of the mean monthly air temperatures are rather important for the formation of sunflower yield, especially during July-August, which is the period from flowering to seed maturation. A mean monthly temperature within the range of 22-25°C is considered the most favourable for this period (Pustovoyt, 1975).

In both years of study, the air temperature was within the range recommendable for sunflower; however, the better soil moisture reserves in 2014 during the period of active sunflower flowering in North-East Bulgaria were a prerequisite for the better development of the crop.

It can be summarized that the climatic conditions in 2014 were favorable for the realization of the sunflower's production potential, while in 2015, due to the higher mean monthly air temperatures, the insufficient available moisture in July and the heavy rainfalls in August, yields almost 11% lower were registered (Figure 1). The year conditions and the genotype of the hybrids, considered separately, had significant effect on the productivity parameters: seed and oil yield, while the combined effect of these two factors did not have statistically significant impact (Table 2). A probable reason for the absence of significant mutual effect of the two factors is the good plasticity of the sunflower plant, which manifests its adaptability according to the changeable vegetative growth conditions over years.

Table 2. Analysis of variance of seed yield, oil yield and oil percent

Indices	Source of variation	*df*	F	Sig
Oil percent, %	Factor A. Year	1	78.596	.000
	Factor B. Hybrid	11	13.833	.000
	$A_x B$	11	5.720	.000
Seed yield, kg/ha	Factor A. Year	1	8.431	.006
	Factor B. Hybrid	11	2.665	.009
	$A_x B$	11	.106	1.000
Oil yield, kg/ha	Factor A. Year	1	24.008	.000
	Factor B. Hybrid	11	2.887	.005
	$A_x B$	11	.305	.981

Under the conditions of this investigation, the results showed that the genotype potential of the hybrids was determining for the productivity parameters – seed yield (75.3%) and oil yield (53.7%); according to the parameter oil yield, a relatively high effect of the year conditions was also registered (40.6%). This can be explained by the fact that the oil content in the seeds is a varietal trait, which is strongly affected by the meteorological conditions as well. In contrast to the results reported by other authors (Popa et al., 2017), who pointed out that the meteorological conditions were determining for this trait, the analysis of the results from our investigation showed that the percent of oil in seeds was determined primarily by the genotype (51.8%), while the effect of the year was considerably lower (26.8%).

The combined effect of the factors had the highest relative significance according to the parameter oil content (21.4%), while the values for seed and oil yields were 3.0 и 5.7%, respectively.

In 2014, the registered yield (kg/ha) varied from 4782 kg/ha for hybrid 3607A x 112DHR to 3506 kg/ha for hybrid 217A x 172DHR, the mean yield of the standards being 4534 kg/ha. In 2015, the range of the realized production potential of the studied hybrids was from 4305 kg/ha for hybrid 3607A x 112DHR to 3353 kg/ha for hybrid 217A x 172DHR, in comparison to a mean yield from the standards 4091 kg/ha (Figure 1).

Three of the experimental hybrids (3607A x 112DHR, 3607A x 123DHR and 3607A x 167DHR) exceeded the mean standard by the parameter seed yield in both years of study, and hybrid 217A x 112DHR demonstrated values close to the mean standard in 2014. The exceeding in the three hybrids was from 1.2 to 5.2% in 2014, and in 2015 – from 1.5 to 5%.

It is noteworthy, that hybrids 3607A x 112DHR, 3607A x 123DHR and 3607A x 167DHR, which in 2014 exceeded the mean standard by the parameter seeds yield, in 2015 they also demonstrated such exceeding regardless of the considerably less favourable meteorological conditions. This makes these hybrid combinations potential hybrids with future significance for the practice, when more and more high-adaptability varieties will be in demand, which could realize relatively stable and high yields under conditions of coming climatic changes.

Oil content in seeds is a main qualitative trait of the cultivated sunflower, which determines its use. The results for the studied experimental hybrids by the end of each year of investigation showed higher values of this parameter in 2014 (Figure 2). The difference in the mean standards was 2.6%, at values 46.3% in 2014 and 43.7% in 2015, respectively.

Although the oil content in seeds is determined by the genotype, it is also influenced by the agro ecological conditions, and this influence is especially strong at stage seed filling. According to Stanojević et al. (1992), high temperatures, especially in combination with insufficient moisture during seed filling, as was observed in June of 2015, have negative effect on the accumulation of oil in the seeds. The differences in the climatic characteristics of the above two years explain the higher values of the oil percent in seed during the first year of the investigation. In 2014, this parameter varied from 41.1% in hybrid 217A x 112DHR to 46.4% in hybrid 217A x 172DHR. In 2015, the range of manifestation of this trait in the investigated hybrids was from 38.5% (3607A x 172DHR) to 44.1% (3607A x 153DHR).

In seven of the studied hybrid combinations, the differences in the oil percent of seed during the two years of the investigation were not significant, which was indicative for the ability of the hybrid genotype to respond adaptively to the changeable conditions of the environment. Only in crosses 217A x 153DHR, 3607A x 167DHR and 3607A x 172DHR, the lower oil content in seeds during 2015 was statistically significant.

For the final evaluation of the hybrids' profitability in sunflower production, the oil yield is very important (Škorić, 1988). The hybrids with high productivity potential in combination with high oil percent in seeds realize high oil yield as well. The results for each of the investigated experimental hybrids during each year of study showed higher values of oil yield in 2014 (Figure 3).

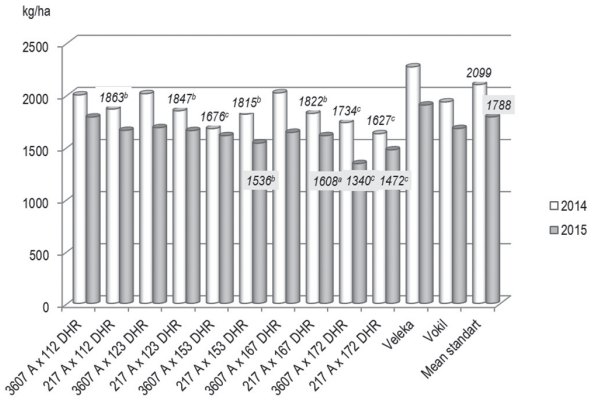

Figure 3. Oil yield (kg/ha) of tested sunflower hybrids, harvest seasons 2014 and 2015
($^{a}LSD_{0.05}$ = 148.2; $^{b}LSD_{0.01}$ = 207.8; $^{c}LSD_{0.001}$ = 293.7)

The difference in the values of the mean standards was 15% at yields 2099 kg/ha in 2014 and 1788 kg/ha in 2015. Among the experimental materials, hybrids 3607A x 112DHR, 3607A x 123DHR and 3607A x 167DHR are noteworthy due to their relatively high values for oil yield in both years of investigations.

The lowest values of oil yield were read in hybrid combination 217A x 172DHR in 2014, and very low were the values in 2015, although the hybrid had high oil content in seeds. The reason for this was the low seed yield the hybrid realized during the investigation. On the other hand, hybrid 3607A x 112DHR, which exceeded the mean standard by seed yield by 5.2%, demonstrated oil content in seeds (41.8%) below the mean standard, which significantly reduced the value of the end parameter – oil yield (Figure 3). The high-yielding hybrid 3607A x 123DHR was also with relatively low oil content. The lower oil percent in these two hybrids was partially compensated for by the higher seed yield.

Conclusion

It was found that the genotype potential of the experimental hybrids included in the study was determined with regard to the productivity parameters *seed yield* and *oil yield*, as well as with regard to the qualitative parameter oil content in seeds. The effect of the year conditions was lower in comparison to the effect of the genotype, which was an indication for the adaptability of the investigated hybrids to the changeable climatic conditions during the investigation. Summing up the results from the study, it can be pointed out that hybrid combinations 3607A x 112DHR, 3607A x 123DHR and 3607A x 167DHR possess good productivity potential and adaptability to the changeable agro-meteorological conditions and can be used in practice in the future.

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