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YIELD COMPONENTS AT SOME HYBRIDS OF SUNFLOWER (*Helianthus annuus* L.) UNDER DROUGHT CONDITIONS FROM SOUTH ROMANIA

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Abstract

Sunflower (Helianthus annuus L.) is the most important oil crop in Romania. The grain yield is determined by the yield components, respectively those elements participating to the yield formation, such as: plant population (number of plants per hectare), head diameter (cm), number of grains per head, grain weight per head (g), weight of thousand seeds (g). Water deficit is considered to be an important yield-limiting factor of sunflower. However, sunflower is considered to be a crop well adapted to drought conditions, better adapted than maize.
The aim of the paper was to present the results regarding yield components and grain yield obtained at an assortment of Romanian sunflower hybrids studied under drought conditions from South Romania. Also, it was aimed to evaluate the impact of drought on the sunflower yield components and grain yield compared to those values obtained under favourable conditions.
The study was realised under field conditions in the year 2012, which was characterised as being a drought year. Researches were performed at an assortment of ten sunflower hybrids created in Romania, respectively: PRO 112, PRO 111, PF 100, PRO 229, PRO 121, PRO 122, PRO 131, PRO 132, PRO 141, and PRO 142. The study was implemented in three different locations in South Romania.
Under drought conditions of 2012, the most affected yield component at the studied sunflower hybrids was head diameter. Compared to values obtained in favourable climatic conditions, in average for the studied sunflower hybrids the grain yield represented 70.0%. Under the same conditions, in average for ten maize hybrids, the grain yield represented only 37.8% from the values obtained under favourable climatic conditions. This is showing that sunflower is a better adapted crop to water stress than maize.

Key words*: sunflower, hybrids, yield, yield components, drought.*

INTRODUCTION

Water is the most important limiting factor for crop production (Barros et al., 2003; Farzad et al., 2013; Nazatiyan et al., 2009; Tabatabaei et al., 2012).
Shortage of water, the most important component of life, limits plant growth and crop productivity, particularly in arid regions more than any other abiotic environmental factor (Boyer, 1982, cited by Alahdadi et al., 2011).
Water deficit is considered to be the major yield-limiting factor of sunflower. Gholinezhad at al. (2009) showed that grain yield and yield components at sunflower decreased with increasing of water stress, this has been reported by many authors who have been cited, respectively: Ahmad et al. (2009); Ali Meo (2000); Anderia and Chiaranda (1995); Anwar et al. (1995); Daneshian et al. (2005); Erdem et al. (2006); Fereres et al. (1986); Jabary et al. (2007); Human et al. (1998); Kalamian et al. (2007); Karem et al. (2007); Nezami et al. (2008); Yegappan et al. (1982). Also, Nazatiyan et al. (2009) showed that grain yield and yield components at sunflower decreased with increasing of water stress, citing different authors, respectively Cox and Jolliffe (1986), Kamel and Khiyavi (2002), Mozzafari et al. (1996), Barros et al. (2004).
Sunflower (*Helianthus annuus* L.) is the most important oil crop in Romania. In the last decade, the annual harvested area with sunflower was between 0.75 and 1.15 million hectares. As harvested area of sunflower, Romania ranges the first place in European

Union. Romania has favourable conditions for growing sunflower and has a real potential for developing the sunflower crop by increasing first of all the yield. South Romania, the most important Romanian growing area for sunflower, is very often affected by drought which limits the yields.

Sunflower is considered to be a crop well adapted to drought conditions, especially because of its strong capacity to use water from the soil through a very well developed and very efficient root system (Vrânceanu, 2000), as well as through the leaves capacity to tolerate temporary water stress and the hairy stem and leaves (Ștefan et al., 2008). However, sunflower is not resistance to reduction of soil water until 40% FC, which decreases the plant growth and yield (Ardiarini et al., 2013).

Water stress in sunflower affects firstly the morphological characteristics of the plant, causing the reduction of plant height, above-ground biomass, and leaf area, and secondly the productive characteristics of the plant, namely the number of seeds head^{-1}, grain weight head^{-1} and weight of 1,000 seeds (Ion et al., 2004).

Ion et al. (2010) reported that in the specific conditions from South Romania, the less favourable climatic conditions from the years 2006 and 2007 affected the sunflower yield components and seed yield. In addition to previous works, the aim of the present paper was to present the results regarding yield components and grain yield obtained at an assortment of Romanian sunflower hybrids studied under drought conditions from South Romania. Also, it was aimed to evaluate the impact of drought on the sunflower yield components and grain yield compared to those values obtained under favourable conditions.

The study was realised under field conditions in the year 2012, which was characterised as being a drought year.

MATERIALS AND METHODS

Researches were performed in the year 2012 on an assortment of ten sunflower hybrids created in Romania, respectively: PRO 112, PRO 111, PF 100, PRO 229, PRO 121, PRO 122, PRO 131, PRO 132, PRO 141, and PRO 142.

The hybrids were studied in three different locations in South Romania, respectively:

- Fundulea, which is located in Călăraşi County, the area being characterised by: average altitude of 68 m; cambic chernozem soil; medium to heavy texture; pH between 6.4 and 6.8; humus content between 2.8 and 3.2%; average temperature of 10.4°C; sum of precipitation of about 550 mm.
- Vâlcelele, which is located in Călăraşi County, the area being characterised by: altitude between 40 and 45 m; chernozem soil; clay-loam texture; pH between 7.2 and 7.8; humus content between 2.2 and 2.8%; average temperature of 11.2^{o}C; sum of precipitation of about 514 mm.
- Vişani, which is located in Brăila County, the area being characterised by: average altitude of 43 m; cambic chernozem soil; loamy texture; soil reaction from slightly acid to slightly alkaline; humus content between 2.1 and 3.0%; average temperature of 11.0^{o}C; sum of precipitation of about 460 mm.

The year 2012 can be characterized as being warm and drought in early spring, summer and autumn. In all months till November except February, temperatures registered higher values than multiannual averages. In April and August, the monthly average temperature was higher by 3.1°C than multiannual average value, while in July, the monthly average temperature was higher by 4.7°C than multiannual average value.

March and April registered a rainfall deficit, but May was very wet, having a rain rate of 160 mm, which means more than double compared to the normal value. After May month, one followed a dry period which has been extended until autumn, period that culminated in July with only 2 mm precipitation (about 70 mm deficit). The lack of water affected the plant growth, respectively the yield components and grain yield.

The crop technology was the usual one for cultivating sunflower in South Romania.

For establishing the yield components and the grain yield, there were performed the following determinations: plant population (number of plants per hectare), head diameter (cm), number of grains per head, grain weight per head (g), weight of thousand seeds (g), grain yield at 9% humidity (kg per hectare).

In each location and for each hybrid, two plants in four replications (in total eight plants) were analysed for establishing the yield components. The analysed plants were representative (average plants) for the plant population in the crop. The heads and grains were detailed analysed in laboratory.
Analysis of variance (ANOVA) was performed for the data obtained in each location where the sunflower hybrids were studied.

RESULTS AND DISCUSSIONS

Under the drought conditions of 2012, head diameter for all the studied hybrids and locations was in average of 14.9 cm (Table 1). The highest average value, for all the three areas in which the hybrids were studied, was obtained for PRO 121 hybrid (16.5 cm), while the smallest average value was obtained for hybrid PRO 142 (13.6 cm). The values for the head diameter are different according to hybrid and location, they varying between 11.3 and 18.7 cm.

Table 1. Average head diameter (cm) at the studied sunflower hybrids, in different locations from South Romania and in 2012 climatic conditions

Sunflower hybrid	Location			*Average (hybrid)*
	Fundulea	Vâlcelele	Vişani	
PRO 112	16.0	14.4	14.3	*14.9*
PRO 111	18.7	15.5 *	14.5	*16.2*
PF 100	16.9	11.3 ^{o}	13.6	*13.9*
PRO 229	17.6	12.5	15.6	*15.2*
PRO 121	18.0	14.3	17.3	*16.5*
PRO 122	15.5	13.9	18.0	*15.8*
PRO 131	13.7	13.0	15.7	*14.1*
PRO 132	14.9	14.4	14.0	*14.4*
PRO 141	16.4	12.0	-	*14.2*
PRO 142	14.3	12.8	-	*13.6*
Average (control)	*16.2*	*13.4*	*15.4*	*14.9*
DL 5%	*2.9*	*1.60*	*2.8*	*6.1*
DL 1%	*3.9*	*2.18*	*3.8*	*8.3*
DL 0.1%	*5.2*	*2.95*	*5.1*	*11.2*

The number of grains per head, for all the studied hybrids and locations, was in average of 1,130 (Table 2). The highest average value for all the three areas in which the hybrids were studied was obtained for PRO 121 hybrid (1,291), which means this is well correlated with diameter of the head. The smallest average value for all the three areas in which the hybrids were studied was obtained for hybrid PRO 132 (954), which was the only hybrid with less than 1,000 seeds. The values for the number of grains per head are different according to hybrid and location, they varying between 615 and 1590.
As in the case of head diameter, the highest values for the number of grains per head were obtained in the location Fundulea, and for hybrid PRO 111.

Table 2. Average number of grains per head at the studied sunflower hybrids, in different locations from South Romania and in 2012 climatic conditions

Sunflower hybrid	Location			*Average (hybrid)*
	Fundulea	Vâlcelele	Vişani	
PRO 112	1.265	964	933 ^{o}	*1.054*
PRO 111	1.590	996	1.245	*1.277*
PF 100	1.254	737	1.413	*1.135*
PRO 229	1.432	615 ^{o}	1.056	*1.034*
PRO 121	1.529	843	1.502	*1.291*
PRO 122	1.282	1.012	1.449	*1.248*
PRO 131	1.353	719	1.362	*1.145*
PRO 132	936 ^{o}	922	1.005	*954*
PRO 141	1.271	862	-	*1.067*
PRO 142	1.137	1.046	-	*1.092*
Average (control)	*1.305*	*872*	*1.246*	*1.130*
DL 5%	*360*	*246*	*303*	*564*
DL 1%	*485*	*335*	*413*	*767*
DL 0.1%	*643*	*454*	*552*	*1040*

The grain weight per head, for all the studied hybrids and locations, was in average of 41.93 g (Table 3). The highest average value for all the three areas in which the hybrids were studied was obtained for PRO 121 hybrid (48.75 g), which means this is well correlated with diameter of the head and the number of grains per head. The smallest average value for all the three areas in which the hybrids were studied was obtained for hybrids PRO 132 (34.62 g), which was the hybrid with the smallest value for number of grains per head, and PRO 141 (34.86 g), which was the hybrid with the smallest value for head diameter. It has to be underlined that for all the three areas in which the hybrids were studied, for the number of grains per head as average values, there were registered no values higher than 50 g.
The values for grain weight per head are different according to hybrid and location, they varying between 19.87 and 68.41 g.
The highest values of the grain weight per head were obtained in Vişani location.

The weight of thousand seeds, for all the studied hybrids and locations, was in average of 36.78 g (Table 4). The highest average value for all the three areas in which the hybrids were studied was obtained for PRO 112 hybrid (44.9 g), the only hybrid with a value higher than 40 g. The smallest average value for all the three areas was registered by PRO 141 hybrids (31.79 g).

The values for grain weight per head are different according to hybrid and location, they varying between 26.69 and 53.96 g.

As in the case of grain weight per head, the highest values for the weight of thousand seeds were obtained in Vişani location.

Table 3. Average grain weight per head (g) at the studied sunflower hybrids, in different locations from South Romania and in 2012 climatic conditions

Sunflower hybrid	Location			*Average (hybrid)*
	Fundulea	Vâlcelele	Vişani	
PRO 112	41.17	46.93 *	50.14	*46.08*
PRO 111	62.57	40.52	42.62	*48.57*
PF 100	48.96	21.02	52.38	*40.79*
PRO 229	45.39	19.87	44.20	*36.49*
PRO 121	56.77	30.27	59.22	*48.75*
PRO 122	44.93	31.79	68.41 **	*48.38*
PRO 131	47.89	22.64	48.05	*39.53*
PRO 132	30.98	29.18	43.69	*34.62*
PRO 141	46.71	23.01	-	*34.86*
PRO 142	45.55	36.97	-	*41.26*
Average (control)	*47.09*	*30.22*	*51.09*	*41.93*
DL 5%	*17.82*	*12.88*	*10.45*	*24.05*
DL 1%	*24.02*	*17.50*	*14.21*	*32.67*
DL 0.1%	*31.89*	*23.73*	*19.03*	*44.29*

Table 4. Average weight of thousand seeds (g) at the studied sunflower hybrids, in different locations from South Romania and in 2012 climatic conditions

Sunflower hybrid	Location			*Average (hybrid)*
	Fundulea	Vâlcelele	Vişani	
PRO 112	32.58	48.15 ***	53.96 **	*44.90*
PRO 111	38.10	40.50 *	34.44 ^{o}	*37.68*
PF 100	39.62	27.73 ^{o}	36.96	*34.77*
PRO 229	31.49	31.78	42.51	*35.26*
PRO 121	36.72	34.87	41.26	*37.62*
PRO 122	35.26	31.43	47.23	*37.97*
PRO 131	35.36	31.50	35.25	*34.04*
PRO 132	32.49	31.69	43.34	*35.84*
PRO 141	36.88	26.69 ^{o}	-	*31.79*
PRO 142	40.60	35.26	-	*37.93*
Average (control)	*35.91*	*33.96*	*41.87*	*36.78*
DL 5%	*6.63*	*5.56*	*7.03*	*18.62*
DL 1%	*8.93*	*7.56*	*9.55*	*25.30*
DL 0.1%	*11.86*	*10.25*	*12.80*	*34.29*

The average plant population at the studied hybrids was in normal limits for sunflower cultivation in South Romania under rainfed conditions (no-irrigation), this varying between 60.8 thousand plants per hectare in Fundulea area from Călăraşi County and 62.3 thousand plants per hectare in Vişani area from Brăila County (Table 5).

Table 5. Average plant population (plants/ha) at the studied sunflower hybrids, in different locations from South Romania and in 2012 climatic conditions

Sunflower hybrid	Location			*Average (hybrid)*
	Fundulea	Vâlcelele	Vişani	
PRO 112	50,455 ^{oo}	61,791	57,778	*56,675*
PRO 111	58,249	62,022	59,948	*60,073*
PF 100	60,607	62,694	61,328	*61,543*
PRO 229	62,121	62,731	59,318	*61,390*
PRO 121	63,214	63,572	63,194	*63,327*
PRO 122	60,607	63,500	62,474	*62,194*
PRO 131	64,372	61,530	65,508	*63,803*
PRO 132	63,519	59,264	69,349 **	*64,044*
PRO 141	63,305	65,566	-	*64,436*
PRO 142	61,762	47,736 ^{ooo}	-	*54,749*
Average (control)	*60,821*	*61,041*	*62,362*	*61,408*

Under the drought conditions of 2012, the average grain yield, for all the studied hybrids and locations, was of 2,649 kg/ha (Table 6). The highest average value for all the three areas in which the hybrids were studied was obtained for PRO 121 hybrid (3,207 kg/ha), while the smallest average value was obtained for hybrids PRO 142 (2,160 kg/ha).

Table 6. Average grain yield at 9% humidity (kg/ha) at the studied sunflower hybrids, in different locations from South Romania and in 2012 climatic conditions

Sunflower hybrid	Location			*Average (hybrid)*
	Fundulea	Vâlcelele	Vişani	
PRO 112	2,175	3,017 *	3,012	*2,735*
PRO 111	3,845	2,615	2,652	*3,037*
PF 100	3,095	1,360	3,369	*2,608*
PRO 229	2,934	1,292	2,746	*2,324*
PRO 121	3,721	1,992	3,907	*3,207*
PRO 122	2,841	2,082	4,453 **	*3,125*
PRO 131	3,236	1,421	3,288	*2,648*
PRO 132	2,035	1,777	3,161	*2,324*
PRO 141	3,077	1,567	-	*2,322*
PRO 142	2,492	1,827	-	*2,160*
Average (control)	*2,945*	*1,895*	*3,323*	*2,649*
DL 5%	*1,181*	*880*	*725*	*1,544*
DL 1%	*1,591*	*1,196*	*986*	*2,099*
DL 0.1%	*2,112*	*1,621*	*1,320*	*2,845*

The grain yield higher than 3 tons/ha as average for all the three areas were registered by the hybrids PRO 121, PRO 122, PRO 111.
The values for grain yield are different according to hybrid and location, they varying between 1,292 and 4,453 kg/ha.
The specific climatic conditions from South Romania in the year 2012, characterised as being a drought year, affected the values of the yield components and the grain yield (Table 8) compared to the values obtained under favourable climatic conditions (Table 7).

Table 7. Values of the yield components and yield obtained in favourable climatic conditions, at the studied sunflower hybrids

Sunflower hybrid	Head diameter (cm)	Grain weight per head (g)	Weight of thousand seeds (g)	Grain yield at 9% humidity (kg/ha)
PRO 112	22	73	57	4,480
PRO 111	24	55	63	3,680
PF 100	22	64	68	3,910
PRO 229	21	90	65	4,460
PRO 121	26	72	60	4,250
PRO 122	21	50	68	3,380
PRO 131	22	59	69	3,370
PRO 132	22	46	49	3,650
PRO 141	21	51	57	3,380
PRO 142	21	58	56	3,660

Compared to values obtained in favourable climatic conditions, under drought conditions of 2012, as average value for all the three studied locations (Table 9), the head diameter represented between 63.2% (PF 100 hybrid) and 75.2% (PRO 122 hybrid), the grain weight per head represented between 40.5% (PRO 229 hybrid) and 96.8% (PRO 122 hybrid), and the weight of thousand seeds represented between 49.3% (PRO 131 hybrid) and 78.8% (PRO 112 hybrid).
The grain yield obtained under drought conditions of 2012, as average value for all the three studied locations from South Romania, compared to values obtained in favourable climatic conditions, it represented between 52.1% at PRO 229 hybrid and 92.5% at PRO 122 hybrid (Table 9).
Hybrids PRO 122, PRO 111, and PRO 131 which registered the smallest reduction of grain yield in 2012 compared to favourable conditions, they have a smaller yielding capacity under favourable conditions, but their yield is more stable from year to year, this being less affected by the climatic fluctuations.
Hybrids PRO 229 and PRO 112 which registered the largest reduction of grain yield in 2012 compared to favourable conditions, they have a high yielding capacity under favourable conditions, but they are less stable from year to year, which means these hybrids are not well adapted to water stress.

Table 8. Percentages of yield components and yield obtained in 2012 from values obtained in favourable climatic conditions, at the studied sunflower hybrids

Sunflower hybrid	Head diameter	Grain weight per head	Weight of thousand seeds	Grain yield at 9% humidity
PRO 112	67.7	63.1	78.8	61.0
PRO 111	67.5	88.3	59.8	82.5
PF 100	63.2	63.7	51.1	66.7
PRO 229	72.4	40.5	54.2	52.1
PRO 121	63.5	67.7	62.7	75.5
PRO 122	75.2	96.8	55.8	92.5
PRO 131	64.1	67.0	49.3	78.6
PRO 132	65.5	75.3	73.1	63.7
PRO 141	67.6	68.4	55.8	68.7
PRO 142	64.8	71.1	67.7	59.0

Compared to values obtained in favourable climatic conditions, under drought conditions of 2012, as average value for all the ten studied hybrids and in all the three studied locations, the head diameter represented 67.1%, the grain weight per head represented 70.2%, the weight of thousand seeds represented 60.8%, and the grain yield represented 70.0%. So, under drought conditions of 2012 the most affected yield component was head diameter (Figure 1).

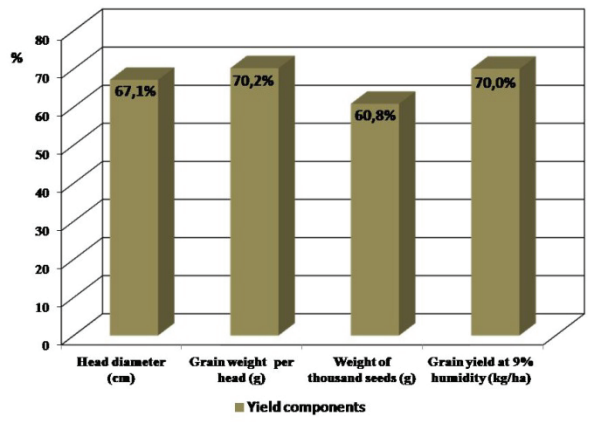

Figure 1. Yield components and yield obtained in 2012 as average percentage from values obtained in favourable climatic conditions

It has to be underlined the fact that in the same locations and under the same drought conditions of 2012, in average for ten maize

hybrids, the grain yield was only of 37.8% from the yield obtained in favourable climatic conditions (Ion et al., 2013). Compared to maize, sunflower realised in average for the ten studied hybrids 70.0% of the yield obtained in favourable climatic conditions, which is showing the much better drought adaptability of sunflower compared to maize. So, for South Romania sunflower is a crop better adapted to water stress than maize, the grain yield at sunflower being more stable from one year to another.

CONCLUSIONS

The drought from the year 2012 affected the values of the yield components and the grain yield at the studied sunflower hybrids.

Hybrids PRO 122, PRO 111, and PRO 131, with smaller yielding capacity under favourable climatic conditions, have a more stable grain yield from one year to another, they being less affected by the climatic fluctuations.

Hybrids PRO 229 and PRO 112, with high yielding capacity under favourable climatic conditions, have a less stable grain yield from one year to another, which means these hybrids are not well adapted to water stress.

Under drought conditions of 2012, head diameter was the most affected yield component at the studied sunflower hybrids.

Compared to values obtained in favourable climatic conditions, under drought conditions of 2012, in average for the ten studied sunflower hybrids the grain yield represented 70.0%.

For South Romania, sunflower is a better adapted crop to water stress than maize.

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