ISSN 1330-7142
*UDK = 633.854.78:635.07*

# GRAIN AND OIL YIELD OF SINGLE-CROSS AND THREE-WAY CROSS OS SUNFLOWER HYBRIDS

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*Original scientific paper*
*Izvorni znanstveni članak*

## SUMMARY

***Sunflower breeding program at the Agricultural Institute Osijek is aimed at creating hybrids with high genetic potential for grain and oil yield and with improved agronomical traits. Achieved grain and oil yields of 30 new (single-cross and three-way cross) OS hybrids in comparison with standard hybrids (Apolon and Šokac), during 2006 and 2007 at location Osijek (Croatia) are presented in this paper. The experiments were set up in randomized complete block design (RCBD) and analyzed traits were grain and oil yield. The highest grain yield (for both years of the research) was achieved with hybrids OS-H-271 S and OS-H-35 T (above 5 t ha$^{-1}$), and oil yield with hybrids OS-H-35 T, OS-H-K3 T and OS-H-271 S (above 2 t ha$^{-1}$). On the average, three-way cross hybrids achieved higher grain and oil yield compared to single-cross hybrids. Experimental hybrids achieved higher grain and oil yield compared to registered OS sunflower hybrids, indicating a genetic advance in domestic sunflower hybrids breeding.***

***Key-words: sunflower, grain yield, oil yield, single-cross hybrids, three-way cross hybrids***

## INTRODUCTION

In Croatia sunflower (*Helianthus annuus* L.) began to be sown on larger areas in 1970 (Vratarić, 2004). In the period from 1970 to 2010, the production was characterized by large variations both in terms of areas 7006 - 49796 ha and in terms of grain yield 1.06 to 3.10 t ha$^{-1}$ (FAOSTAT Database, 2010). Generally, areas with sunflower in the Republic of Croatia are small (about 2% of the total area sown) and cannot cover the needs of the Croatian oil industry, which shows that there is certainly space for the expansion of this important oil crop in this country (Mijić et al., 2004).

Sunflower breeding in Croatia is realized only through programs and projects of the Agricultural Institute Osijek. As in most breeding centres of the world, the sunflower breeding is based on the application of the phenomenon of heterosis, or superiority of $F_1$ generation. Planned creation and use of genetic variability is the first step in this process. The following is the creation of high-quality inbred lines with good general and specific combining abilities, followed by their transfer into cytoplasmatic male sterile or restorer forms. New hybrids, created by breeding of self pollinating lines, are tested in many different environments. The best of them are introduced into the official registration procedure. The Croatian market demands, but also the presence of introduced hybrids, have imposed the need for continuous and intensive work based on modern breeding principles. The aim of this research was to evaluate the genetic improvement of OS sunflower germplasm through the analysis of grain and oil yield of 30 new OS sunflower hybrids (14 single-cross and 16 three-way cross) compared to the registered OS hybrids (Apolon and Šokac, single-cross hybrids), as standards.

## MATERIAL AND METHODS

This research was conducted during 2006 and 2007 at the experimental field of Agricultural Institute

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Osijek. Soil type was eutric cambisol, with 2 to 2.5% of humus, medium supplied with phosphorus and potassium. The pH value in KCl was 6.3.

At the Agricultural Institute Osijek, 32 sunflower hybrids created in the breeding program, were involved in trials, (2 standards (Apolon and Šokac), 14 single-crosses (SC) and 16 three-way cross (TWC) hybrids). Preceding crop in both researches was wheat, and the experiment was made according to randomized block design. Basic plot length was 5 m, and width 2.8 m. The number of plants on the basic plot was 96. The distance between rows was 70 cm and 21 cm within the rows. Rounding plot consisted of two middle rows. The sowing was done manually on a planned set of 68 027 plants per hectare. Properties of the grain and oil yield were analyzed and calculated on a t $ha^{-1}$. Common agricultural practice for sunflower production was applied, plowing to a depth of 30 cm with a basic fertilization with 300 kg $ha^{-1}$ NPK (7:20:30) and 100 kg $ha^{-1}$ UREA (46% N) was carried out in the second half of October. Sowing fertilization included 200 kg of NPK (7:20:30), and furrows are broken by a multitiller. Top dressing is made with 100 kg $ha^{-1}$ of KAN (27% N), together with the cultivation in the phase 4 pairs of permanent leaves. Weed control was carried out with (EPTC – "S-ethyl dipropyl karbamotioat" + dichlormid) + fluchloridon (4 + 2.5 l $ha^{-1}$) and chlorpyrifos (5 l $ha^{-1}$) for insects control. Disease control was done with vinclozoline + carbendazim (1.5 l $ha^{-1}$) at bud stage.

Statistical analysis was performed using SAS statistical software (2003).

### Climate data

Mean monthly air temperature and rainfall in Osijek are shown in Table 1. During the vegetation in 2007, mean monthly temperatures were above perennial average, and especially in June and July, they were 2.7 and 2.6 °C above average. Year 2006 was characterized by temperatures within perennial average. In terms of rainfall, 2006 was characterized by surplus, while in 2007 there was a deficit of rainfall in comparison to perennial average. Only in August 2006 there was 122.6 mm of rainfall which is 60.7 mm more than perennial average.

**Table 1. Mean monthly air temperature (ºC) and rainfall (mm), Osijek**

*Tablica 1. Srednje mjesečne temperature zraka (ºC) i oborine (mm), Osijek*

| Month *Mjesec* | Mean monthly air temperature (ºC) *Srednje mjesečne temperature zraka (ºC)* | | | Rainfall (mm) *Oborine (mm)* | | |
|---|---|---|---|---|---|---|
| | 1970 - 2000 | 2006 | 2007 | 1970 – 2000 | 2006 | 2007 |
| I | -0.2 | -1.4 | 5.8 | 41.6 | 28.1 | 25.3 |
| II | 1.8 | 0.8 | 6.1 | 34.5 | 41.1 | 46.5 |
| III | 6.4 | 5.3 | 8.5 | 40.5 | 77.8 | 76.0 |
| IV | 11.2 | 12.9 | 13.3 | 51.0 | 95.5 | 2.9 |
| V | 16.7 | 16.4 | 18.2 | 59.2 | 79.3 | 56.1 |
| VI | 19.6 | 20.5 | 22.3 | 82.0 | 92.5 | 33.3 |
| VII | 21.3 | 24.0 | 23.9 | 66.3 | 15.3 | 27.4 |
| VIII | 20.8 | 19.6 | 22.2 | 61.9 | 122.6 | 45.0 |
| IX | 16.5 | 17.9 | 14.5 | 51.0 | 8.7 | 65.2 |
| IV-IX | | | | 371 | 414 | 230 |

Source: State Meteorological and Hydrological Service of The Republic of Croatia - Meteorological station Osijek

*(Izvor: Državni hidrometeorološki zavod RH - meteorološka postaja Osijek)*

## RESULTS AND DISCUSSION

The grain yield is of great importance for sunflower producers and therefore increasing grain yield is one of the main breeding goals (Fernandez Martinez et al., 2009). The highest average grain yield was achieved by OS-H-271 S (5.412 t $ha^{-1}$), and hybrids OS-H-2 S (4.753 t $ha^{-1}$), OS-H-K1 S (4.683 t $ha^{-1}$) are at the same level. With three-way cross hybrids the highest average grain yield was achieved by hybrid OS-H-35 T (5.409 t $ha^{-1}$), and hybrids OS-H T-K3 (4.984 t $ha^{-1}$), OS-H-14a T (4.878 t $ha^{-1}$), OS-H-282a T (4.785 t $ha^{-1}$), OS-H T-102 (4.658 t $ha^{-1}$) as well as OS-H-14 T (4.591 t $ha^{-1}$) are also at this level. Significantly higher grain yield achieved by new OS hybrids in comparison to the standard (Šokac and Apolon) shows their high genetic yielding potential, demonstrating an important genetic advance in the breeding process.

**Table 2. Mean grain yield (t ha-1) of single-cross and three-way cross sunflower hybrids in 2006 and 2007**
*Tablica 2. Prosječan prinos zrna (t ha-1) dvolinijskih i trolinijskih hibrida suncokreta u 2006. i 2007. godini*

| Single-cross hybrids *Dvolinijski hibridi* | | | Three-way cross hybrids *Trolinijski hibridi* | | |
|---|---|---|---|---|---|
| Genotype *Genotip* | Grain yield *Prinos zrna* (t ha$^{-1}$) | Rank *Rang* | Genotype *Genotip* | Grain yield *Prinos zrna* (t ha$^{-1}$) | Rank *Rang* |
| OS-H-271 S | 5.412 | A | OS-H-35 T | 5.409 | A |
| OS-H- 2 S | 4.753 | ABCDE | OS-H-K3 T | 4.984 | AB |
| OS-H- K1 S | 4.683 | ABCDEF | OS-H-14a T | 4.878 | ABC |
| OS-H- 12 S | 4.334 | BCDEFGH | OS-H-282a T | 4.785 | ABCD |
| OS-H- 271a S | 4.212 | BCDEFGHI | OS-H-102 T | 4.658 | ABCDEF |
| OS-H- K2 S | 4.162 | BCDEFGHI | OS-H-14 T | 4.591 | ABCDEFG |
| ŠOKAC | 4.090 | BCDEFGHI | OS-H-70 T | 4.258 | BCDEFGHI |
| APOLON | 4.077 | BCDEFGHI | OS-H-282 T | 4.249 | BCDEFGHI |
| OS-H- 17 S | 3.964 | CDEFGHI | OS-H-302a T | 4.237 | BCDEFGHI |
| OS-H- 281 S | 3.888 | DEFGHI | OS-H-194 T | 4.234 | BCDEFGHI |
| OS-H- 116 S | 3.757 | FGHI | OS-H- 272 T | 4.154 | BCDEFGHI |
| OS-H- 123 S | 3.714 | GHI | OS-H-1 T | 4.118 | BCDEFGHI |
| OS-H-301 S | 3.635 | HI | OS-H-302 T | 4.090 | BCDEFGHI |
| OS-H- 60 S | 3.565 | HI | OS-H-190 T | 3.877 | DEFGHI |
| OS-H- 9 S | 3.548 | HI | OS-H-80 T | 3.870 | DEFGHI |
| OS-H- 301a S | 3.367 | I | OS-H-41 T | 3.840 | EFGHI |
| Mean/*Prosjek* | 4.073 | | Mean/*Prosjek* | 4.389 | |

$LSD_{0.05}$= 0.942

The main goal of every oil sunflower breeder is to create a hybrid that will, in different environmental conditions, achieve the highest oil yield (Mijić et al., 2007). The oil yield is an indicator of productivity of each hybrid (Škorić et al., 2005), but also, the most important sunflower selection criterium. The base of this trait is polygenic, which means that expression of oil yield is influenced by the genotype, the environment and the complex relations of genotype x environment. Firstly, oil yield is determined by oil content as well as grain yield per area unit. In this study, the highest average oil yield was recorded by an experimental hybrid OS-H-271 S (2.090 t ha$^{-1}$), six other hybrids (OS-H-2 S, OS-H-69 S, OS-H-17 S, Apolon, OS-H-K2 S, OS-H-K1 S) with oil yield above 1.8 t ha$^{-1}$ are also at this level. From three-way cross hybrids, the highest average oil yield was achieved by hybrid OS-H-35 T (2.234 t ha$^{-1}$), at the same level were hybrids OS-H-K3 T (2.138 t ha$^{-1}$), OS-H-282a T (1.974 t ha$^{-1}$), OS-H-14a T (1.968 t ha$^{-1}$) and OS-H T-102 (1.890 t ha$^{-1}$) (Table 3). Concerning grain yield, some experimental hybrids have achieved higher oil yield than standard hybrids, indicating genetic progress in breeding for this trait.

**Table 3. Average oil yield (t ha$^{-1}$) of single-cross and three-way cross sunflower hybrids in 2006 and 2007**
*Tablica 3. Prosječan prinos ulja (t ha$^{-1}$) dvolinijskih i trolinijskih hibrida suncokreta u 2006. i 2007. godini*

| Single-cross hybrids *Dvolinijski hibridi* | | | Three-way cross hybrids *Trolinijski hibridi* | | |
|---|---|---|---|---|---|
| Genotype *Genotip* | Oil yield *Prinos ulja* (t ha$^{-1}$) | Rank *Rang* | Genotype *Genotip* | Oil yield *Prinos ulja* (t ha$^{-1}$) | Rank *Rang* |
| OS-H-271 S | 2.090 | ABC | OS-H-35 T | 2.234 | A |
| OS-H-2 S | 1.942 | ABCD | OS-H-K3 T | 2.138 | AB |
| OS-H-69 S | 1.906 | ABCD | OS-H-282a T | 1.974 | ABCD |
| OS-H-17 S | 1.861 | ABCDE | OS-H-14a T | 1.968 | ABCD |
| APOLON | 1.846 | ABCDE | OS-H-102 T | 1.890 | ABCD |
| OS-H-K2 S | 1.829 | ABCDEF | OS-H-80 T | 1.808 | BCDEF |
| OS-H-K1 S | 1.816 | ABCDEF | OS-H-302 T | 1.800 | BCDEF |
| ŠOKAC | 1.784 | BCDEFG | OS-H-302a T | 1.751 | BCDEFG |
| OS-H-116 S | 1.782 | BCDEFG | OS-H-14 T | 1.745 | BCDEFG |
| OS-H-271a S | 1.782 | BCDEFG | OS-H-70 T | 1.741 | BCDEFG |
| OS-H-9 S | 1.677 | CDEFG | OS-H- 282 T | 1.731 | BCDEFG |
| OS-H-281 S | 1.644 | DEFG | OS-H- 194 T | 1.727 | BCDEFG |
| OS-H-60 S | 1.633 | DEFG | OS-H-272 T | 1.700 | CDEFG |
| OS-H-301 S | 1.459 | EFG | OS-H-190 T | 1.687 | CDEFG |
| OS-H-301a S | 1.424 | FG | OS-H-1 T | 1.619 | DEFG |
| OS-H-123 S | 1.368 | G | OS-H-41 T | 1.618 | DEFG |
| Mean/*Prosjek* | 1.740 | | Mean/*Prosjek* | 1.821 | |

$LSD_{0.05}$= 0.419

After analyzing the grain yields of single-cross and three-way cross hybrids it is evident that the average three-way cross hybrids had better yield in both years (Table 4). Also, higher oil yield was achieved in 2007 with three-way cross hybrids, while in 2006 it was at the same level with single-cross hybrids. In the two-year average, three-way cross hybrids have achieved higher grain yield (Table 2) and oils (Table 3), compared to the single-crosses. These results are not in agreement with Fick and Zimmer (1976), while Shuster and Friedt (1988), Giriraj et al. (1988) emphasize the lower yield, but greater stability of three-way cross hybrids. The reason for this lies in the fact that because of their genetic constitution three-way cross hybrids manage to offset the unwanted effects of stress, to achieve optimum agronomic traits, and to achieve better yields in different environments in comparison to single-cross hybrids.

The importance of the year, as a significant factor in high grain and oil yield, was stressed by a number of researchers (Škorić, 1988, Krizmanić et al., 2003, Schoeman, 2003). In 2007 a higher grain and oil yield was achieved in comparison to 2006 (Table 3). From the meteorological data it is evident that during the growing period of 2006 there was 184 mm of rainfall higher in comparison to 2007. This especially applies to August and an intensive phase of grain filling when 122.6 mm of precipitation was measured, which was 60.7 mm more than perennial average. It is known that the sunflower plant responds extremely well to the supply of winter moisture, but not the higher rainfall in the vegetation. More intense rainfall during the growing season influence the development of root systems in the surface layer of soil resulting in reduced absorbent power, but also easier lodging of plants. It also creates a favorable microclimate for disease development. Since sunflower is a crop susceptible to pathogen attacks (Vratarić and Sudarić, 2004; Duvnjak et al., 2008), intense rainfall during the growing season during 2006 resulted in lower grain and oil yield. Grain and oil yield can also be reduced by precipitation during flowering. Given the nature of the sunflower blossom, and entomofility, intense rainfall during the flowering interferes with the flight of insects, thereby reducing the reproductive success (Puškadija et al., 2009). This is even more so if the rainfall is followed by wind. Reduction of oil content, and subsequently the oil yield can be caused by high temperatures ($>$ 25°C) during flowering (Miklič et al., 2009).

**Table 4. Grain and oil yield (t ha$^{-1}$) of sunflower hybrids in research years**

*Tablica 4. Prinos zrna i prinos ulja (t ha$^{-1}$) hibrida suncokreta po godinama istraživanja*

| Traits<br>*Svojstva* | Year<br>*Godina* | Hybrid<br>*Hibrid* | Range<br>*Raspon*<br>(t ha$^{-1}$) | Mean<br>*Prosjek* |
|---|---|---|---|---|
| Grain yield<br>*Prinos zrna* | 2006 | Single-cross hybrids<br>*Dvolinijski hibridi* | 3.022 – 4.964 | 3.747 |
| | | Three-way cross hybrids<br>*Trolinijski hibridi* | 3.023 – 5.187 | 3.803 |
| | | Mean<br>*Prosjek* | | 3.775 |
| | 2007 | Single-cross hybrids<br>*Dvolinijski hibridi* | 3.537 – 5.860 | 4.495 |
| | | Three-way cross hybrids<br>*Trolinijski hibridi* | 4.216 – 5.630 | 4.878 |
| | | Mean<br>*Prosjek* | | 4.687 |
| | $LSD_{0.05}$ = 0.163* | | | |
| Oil yield<br>*Prinos ulja* | 2006 | Single-cross hybrids<br>*Dvolinijski hibridi* | 1.347 – 1.974 | 1.573 |
| | | Three-way cross hybrids<br>*Trolinijski hibridi* | 1.355 – 2.222 | 1.590 |
| | | Mean<br>*Prosjek* | | 1.582 |
| | 2007 | Single-cross hybrids<br>*Dvolinijski hibridi* | 1.347 – 2.323 | 1.892 |
| | | Three-way cross hybrids<br>*Trolinijski hibridi* | 1.694 – 2.285 | 2.066 |
| | | Mean<br>*Prosjek* | | 1.979 |
| | $LSD_{0.05}$ = 0.072* | | | |

* LSD values for year of investigation/*LSD vrijednosti odnose se na godine istraživanja*

The results of ANOVA indicate that in the specific year, hybrids and their interactions, had significant or highly significant impact on the grain and oil yield (Table 5). Hybrid x year interaction increases the complexity of grain and oil yield (Vratarić and Sudarić, 2004).

**Table 5. Analysis of variance for grain and oil yield traits**

*Tablica 5. Analiza varijance za svojstva prinos zrna i prinos ulja*

| Source of variation<br>*Izvori variranja* | Grain yield / *Prinos zrna* | Oil yield / *Prinos ulja* |
|---|---|---|
| | MS (mean squares)<br>*Sredina kvadrata* | MS (mean squares)<br>*Sredina kvadrata* |
| Hybrid / *Hibrid* | 39935** | 7615** |
| Year / *Godina* | 1776** | 242** |
| Hybrid x Year / *Hibrid x godina* | 479* | 120** |

* F test significant on level P<0.05 */F test značajan na razini P<0.05*

** F test significant on level P<0.01/*F test značajan na razini P<0.01*

## CONCLUSION

Based on studies of grain and oil yield, of 16 single-crosses and 16 three-way cross sunflower hybrids created at the Agricultural Institute Osijek the following conclusions can be drawn:

- Grain yield above 5 t $ha^{-1}$ and oil yield over 2 t $ha^{-1}$ were found with hybrids OS-H-271 S and OS-H-35 T. Oil yield over 2 t $ha^{-1}$ was also achieved by OS-H-K3 T hybrid.

- Three-way cross hybrids in both years achieved higher grain yield. Oil yield of three-way cross hybrids in 2007 was also higher, while in 2006 it was approximately on the same level as with single-cross hybrids.

- In 2007 higher grain (for 0.912 t $ha^{-1}$) and oil (for 0.397 t $ha^{-1}$) yield was achieved in comparison to 2006.

- Experimental hybrids have achieved higher grain and oil yield in comparison to the registered OS sunflower hybrids which indicates progress in the breeding program at the Agricultural Institute Osijek.

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# PRINOS ZRNA I ULJA DVOLINIJSKIH I TROLINIJSKIH OS HIBRIDA SUNCOKRETA

***SAŽETAK***

***Oplemenjivački rad na suncokretu u Poljoprivrednom institutu Osijek ima za cilj stvaranje hibrida suncokreta visokoga genetskoga potencijala za prinos zrna i ulja uz poboljšanje agronomskih svojstava. U ovome radu prezentirani su ostvareni prinosi zrna i ulja 30 novih (dvolinijski i trolinijski) OS hibrida suncokreta u usporedbi sa standardnim OS hibridima suncokreta (Apolon, Šokac) tijekom 2006. i 2007. godine na lokalitetu Osijek (Hrvatska). Pokusi su postavljeni prema slučajnome bloknome rasporedu, a analizirana su svojstva prinos zrna i prinos ulja. Najveće prinose zrna, za obje godine istraživanja, ostvarili su hibridi OS-H-271 S i OS-H-35 T (preko 5 t ha$^{-1}$), a prinose ulja OS-H-35 T, OS-H-K3 T i OS-H-271 S (preko 2 t ha$^{-1}$). U prosjeku, trolinijski hibridi ostvarili su veće prinose zrna i ulja u odnosu na dvolinijske hibride. Novi hibridi postigli su veće prinose zrna i ulja od standardnih OS hibrida suncokreta, što ukazuje na genetski napredak u oplemenjivanju domaćih hibrida suncokreta.***

***Ključne riječi: suncokret, prinos zrna, prinos ulja, dvolinijski hibridi, trolinijski hibridi***

(Received on 11 January 2011; accepted on 9 March 2011 - *Primljeno 11. siječnja 2011.; prihvaćeno 09. ožujka 2011.*)