UDC 575.21; 636.85
*Original scientific paper*

# INTERRELATIONSHIP OF POLLINATION CONDITIONS, FERTILIZATION AND SUNFLOWER SEED YIELD

Jovan JOKSIMOVIĆ, Jovanka ATLAGIĆ, Vladimir MIKLIČ, Nenad DUŠANIĆ, and Zvonimir SAKAČ

Institute of Field and Vegetable Crops, M. Gorkog 30, Novi Sad, Serbia and Montenegro

Joksimović J., J. Atlagić, V. Miklič, N. Dušanić, and Z. Sakač (2005): *Interrelationship of pollination conditions, fertilization and sunflower seed yield*. – Genetika, Vol. 37, No. 3, 209-215.

Four commercially important sunflower hybrids (NS-H-45, NS-H-111, NS-H-702 and Velja) and their parental components (Ha-74B, Ha-98B, CMS-3-8B, Ha-26B, RHA-583, RHA-R-Pl-2/1 and RHA-113N) were used over a period of two years to study the following traits: disk flower corolla length, nectar content, pollen viability, bee visitation, fertilization percentage and seed yield. Relations among the traits were determined by path coefficient analysis. The simple correlation coefficients showed that fertilization percentage and bee visitation had a highly significant influence on seed yield. The corolla length had a positive effect on nectar content, while nectar content had a significant negative influence on pollen viability. The highest significant direct influence on seed yield was that of fertilization percentage, while the effect on nectar content on seed yield was negative but not significant. The coefficient of determination was 0.8071.

*Key words*: sunflower, corolla length, nectar content, pollen viability, bee visitation, fertilization percentage, seed yield

*Corresponding author*: Jovan Joksimović, Institute of Field and Vegetable Crops, Maksima Gorkog 30, 21000 Novi Sad, Serbia and Montenegro
Tel: 381 021 4898 404; e-mail: jovanj@ifvcns.ns.ac.yu

## INTRODUCTION

The sunflower is an open-pollinated plant species. The development of sunflower inbred lines and hybrids is made possible by the fact that self pollination is present to a certain degree in the species. Many authors have studied the mechanism of sunflower self-incompatibility and determined that non-self pollen germinates much faster on the stigma than self pollen. Although self-incompatibility and self-compatibility are genetically determined, they are strongly influenced by environmental factors as well. These traits are highly important for fertilization and seed yield in sunflower.

Because of the introduction of sunflower hybrids into large-scale commercial production, especially the use of $F_1$ hybrids and parental lines in seed production (growing in spatial isolation), the presence of pollinators is necessary. In Serbia and Montenegro, the most important pollinator is the domestic bee, which accounts for 50-90% of all pollinators (MIKLIČ, 1996). The sunflower is a melliferous plant and hence attractive to pollinators. Sunflower attractiveness to pollinators is linked with floral traits of the plant, most importantly nectar content and disk flower corolla length (DFCL). The latter trait affects nectar accessibility and bee visitation, which, in turn, influence fertilization percentage. Pollen production and characteristics are important factors of attractiveness to pollinators. Pollen viability directly affects fertilization and seed yield.

The phenotypic variability and mode of inheritance of these factors affecting fertilization and seed yield have been studied previously in NS sunflower hybrids and their parental components (MIKLIČ *et al.*, 2002; JOKSIMOVIĆ *et al.*, 2003; ATLAGIĆ *et al.*, 2003; MIKLIČ *et al.*, 2004; ATLAGIĆ *et al.*, 2004).

The objective of this paper was to investigate the interrelationship of pollination conditions (disk flower corolla length, nectar content, pollen viability, bee visitation), fertilization percentage, and seed yield by determining simple correlation coefficients and separating the direct and indirect effects of the traits affecting seed yield.

## MATERIALS AND METHODS

The study materials were four commercially important sunflower hybrids (NS-H-45, NS-H-111, NS-H-702 and Velja) and their parental lines (Ha-74B, Ha-98B, CMS-3-8B, Ha-26B, RHA-583, RHA-R-Pl-2/1 and RHA-113N). They were sown as part of a stationary trial established in 1966 to study the effects of different fertilizer rates in maize, wheat, sunflower and sugar beet. The sunflower hybrids and their parental components were analyzed over a two-year period (2000 and 2001). The fertilizer rate was 50N:50P:50K and the following traits were analyzed: disk flower corolla length (DFCL), nectar content, pollen viability, bee visitation, fertilization percentage and seed yield.

DFCL was measured on 30 flowers taken from three plants per genotype. Nectar content in the flower was measured by the microcapillary method using 20 flowers from three plants per genotype. Pollen viability was determined by a

staining method (ALEXANDER, 1969) based on differential staining of viable and nonviable pollen grains. Pollen was taken from intact anthers of three inflorescences per genotype (from three segments per each inflorescence). Three microscopic preparations were made and viable and nonviable pollen grains were counted in ten fields of vision. Bee visitation was monitored throughout flowering (10-11) by counting the number of bees per inflorescence nine times during the day (at 07.00, 08.00, 09.00, 11.00, 13.00, 15.00, 16.00, 17.00 and 19.00 h). The number of bees was recorded on ten sunflower heads. Fertilization percentage was determined by counting the number of full and empty achenes on the head in a sample of five plants taken from each of the three replicates set up for each genotype. It was expressed as the ratio of the total number of disk flowers to the number of full achenes. Seed yield was determined by measuring the mass of full seeds per head in a sample of five heads per replicate for each genotype.

Data collected over the two study years were expressed as trait means, after which simple correlation coefficients were determined and path coefficient analysis was performed to separate the direct and indirect effects according to WRIGHT (1921), as applied by DEWEY and LU (1959).

## RESULTS AND DISCUSSION

The calculated simple coefficients of correlation showed that bee visitation and fertilization percentage had a highly significant positive effect on seed yield (0.7374** and 0.7645**). The DFCL had a significant positive effect on nectar content (0.6653*), while nectar content had a significant negative effect on pollen viability (-0.5909*) (Table 1).

*Table 1. Simple correlation coefficients among pollination conditions, fertilization and seed yield*

| Trait | Nectar content (X2) | Pollen viability (X3) | Pollinator visitation (X4) | Fertilization percentage (X5) | Seed yield (Y) |
|---|---|---|---|---|---|
| Corolla length (X1) | 0.6653* | -0.1938 | 0.1881 | -0.0553 | -0.0489 |
| Nectar content (X2) | | -0.5909* | -0.2748 | -0.0093 | -0.3584 |
| Pollen viability (X3) | | | -0.0155 | -0.1336 | 0.1478 |
| Pollinator visitation (X4) | | | | 0.5685 | 0.7374** |
| Fertilization percentage (X5) | | | | | 0.7645** |

*, ** significant at level for df=10 0.05=0.576; 0.01=0.708 respectively

The highly significant positive effects of fertilization percentage and pollinator visitation on seed yield we observed in our study support the findings of ŠPEHAR *et al.* (1986) and WAGHCHOURE *et al.* (1988), who found that seed yields

were lower in genotypes where no bees had been present at flowering, resulting in reduced fertilization. A significant positive correlation between fertilization percentage and seed yield was also reported by FICK (1983). The DFCL had a significant positive effect on nectar content and no significant influence on bee visitation. Earlier studies mostly reported that DFCL affected bee visitation via nectar accessibility (MIKLIČ *et al.*, 2004). The significant negative effect of nectar content on pollen viability observed in the present study makes no logical sense, but it was probably caused by some indirect effects of other characters on the two traits in question.

Because environmental factors have an extremely strong influence on the traits under study and seed yield is a highly complex trait, simple correlation coefficients very often do not show the real effects of independent variables (X) on the dependent one (Y), as they are masked by the effects of other traits. For this reason, we used path coefficient analysis in the present paper to try to obtain a more accurate explanation of the effects studied.

The highest significant positive direct effect on seed yield was that of fertilization percentage (0.6989*). The rest of the direct effects that we calculated were not significant. Nectar content had the greatest negative and DFCL the largest positive direct effect on seed yield (Table 2).

*Table 2. Analysis of direct and indirect effects of pollination conditions, fertilization and seed yield*

| Trait | Direct effect | Indirect effects | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | Corolla length (X1) | Nectar content (X2) | Pollen viability (X3) | Pollinator visitation (X4) | Fertilization percentage (X5) | |
| Corolla length (X1) | 0.3144 | 1 | -0.3517 | 0.0016 | 0.0255 | -0.0387 | -0.0489 |
| Nectar content (X2) | -0.5287 | 0.2092 | 1 | 0.0048 | -0.0372 | -0.0065 | -0.3584 |
| Pollen viability (X3) | -0.0082 | -0.0609 | 0.3124 | 1 | -0.0021 | -0.0933 | 0.1478 |
| Pollinator visitation (X4) | 0.1355 | 0.0592 | 0.1453 | 0.0001 | 1 | 0.3973 | 0.7374 |
| Fertilization percentage (X5) | 0.6989* | -0.0174 | 0.0049 | 0.0011 | 0.0770 | 1 | 0.7645 |

Residual effect = 0.4392; Coefficient of determination = 0.8071

The significant positive direct effect of fertilization percentage on seed yield was expected, as it had already been detected earlier using the simple correlation coefficients. It was also confirmed by the positive values of indirect effects of the other traits (pollinator visitation, pollen viability, nectar content) and reduced by the negative indirect effect of DFCL. The other direct effects were not significant, but it is interesting to note the high direct effect of nectar content, especially in view of it being negative. These findings are not supported by the

previous studies of some authors, in which nectar content had direct influence on bee visitation (GOLUBOVIĆ *et al.*, 1992; KAMLER, 1997) and hence fertilization percentage and seed yield. Probably contributing to the negative sign of this direct effect were the negative indirect effects of fertilization percentage and bee visitation. Other possible contributions to the positive direct DFCL effects on seed yield included the large negative indirect effects of nectar content and fertilization percentage and the positive but small indirect effects of pollen viability and pollinator visitation. The small positive indirect effects of the rest of the traits contributed to the positive but small and insignificant direct effect of pollinator visitation on seed yield.

The interrelations of the traits under study and their effects on seed yield are complex. Their study is justified by the high value of the determination coefficient (0.8071) (only 20% are attributable to the influence of other traits).

## CONCLUSION

The determination of the relations among the traits regarded as pollination conditions (disk flower corolla length, nectar content, pollen viability and pollinator visitation), fertilization percentage and seed yield using simple correlation coefficients and separation of direct and indirect trait effects represents a highly important contribution to the development of new sunflower inbreds and hybrids.

Received March 23rd, 2005
Accepted June 1st, 2005

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# MEĐUZAVISNOST USLOVA OPRAŠIVANJA, OPLODNJE I PRINOSA SEMENA SUNCOKRETA

Jovan JOKSIMOVIĆ, Jovanka ATLAGIĆ, Vladimir MIKLIČ, Nenad DUŠANIĆ i Zvonimir SAKAČ

Naučni institut za ratarstvo i povrtarstvo, M. Gorkog 30, Novi Sad, Srbija i Crna Gora

I z v o d

Kod četiri komercijalno važna hibrida suncokreta (NS-H-45, NS-H-111, NS-H-702 i Velja) i njihovih roditeljskih komponenti (Ha-74B, Ha-98B, CMS-3-8B, Ha-26B, RHA-583, RHA-R-Pl-2/1 i RHA-113N) u dve godine su ispitivana sledeća svojstva: dužina krunice cevastog cveta, sadržaj nektara, vitalnost polena, poseta pčela, % oplodnje i prinos semena. Međuzavisnost ispitivanih svojstava je utvrđena Path coefficient analizom. Prosti koeficijenti korelacije su pokazali da su % oplodnje i poseta oprašivača imali visoko značajan pozitivan uticaj na prinos semena. Značajan pozitivan efekat je imala dužina krunice na sadržaj nektara, a značajan negativan efekat je imao sadržaj nektara na vitalnost polena. Najveći značajan direktan efekat na prinos semena je imao procenat oplodnje, dok je negativan, ali ne i značajan efekat imao sadržaj nektara na prinos semena. Koeficijent determinacije je iznosio 0,8071.

Primljeno 23. III 2005.
Odobreno 1. VI 2005.