10.7251/AGSY1203285B
UDK 633+631

DIFFERENT XENIA EFFECT ON STERILE AND FERTILE VERSIONS OF HYBRIDS IN MAIZE

Sofija BOZINOVIC[1*], Jelena VANCETOVIC[1], Slaven PRODANOVIC[2], Zoran CAMDZIJA[1], Milan STEVANOVIC[1], Nikola GRČIĆ[1], Milos CREVAR[1]

[1]Maize Research Institute ZemunPolje, Slobodana Bajica 1, 11185, Belgrade, Serbia,
[2]Faculty of Agriculture, University of Belgrade, Nemanjina 6, 11185, Belgrade, Serbia
(Corresponding author: sbozinovic@mrizp.rs)

Abstract

Cytoplasmic male sterility (*cms*) in maize is used to increase the quality of hybrid seed production and reduce its costs. Xenia is a direct cross fertilisation effect on the grain traits of the female component in the year of crossing. The combined and individual effects of cytoplasmic male sterility and xenia on two ZP maize hybrids were studied. This effect is called plus-hybrid effect and can be used for improving grain yield and grain quality in maize. The trials with crossess between two cms hybrids and their fertile counterparts and five unrelated hybrids were set up at one location during three consecutive years.

By examining the individual effects of *cms* and xenia we have observed that the xenia effect on some of the traits differs for sterile and fertile versions of the same hybrid This was obsered for 1000 kernel weigth, grain number per m^2 and relative oil and starch kernel content.

It seems like there is a kind of interaction between the cytoplasmic male sterility and xenia.

Key words: *cytoplasmic male sterility, xenia, pollination, maize*

Introduction

Cytoplasmic male sterility (*cms*) in maize is used to increase the quality of hybrid seed production and reduce its costs. While many researchers (Duvick, 1958; Everett, 1960; Josephson and Kincer, 1962) reported an inconsistent or even negative effect of *cms* on maize grain yield, Rogers and Edwardson (1952), Duvick (1965), Sanford (1965) and Pinter (1986) found higher yields of *cms* individuals due to more prolific plants. Two studies confirmed the female advantage of *cms* hybrids in more modern plant material (compared to hermaphrodite individuals) as well as the effect of environmental conditions (Kalman et al., 1985; Stamp et al., 2000). These facts encourage growers to grow hybrids with partially recovered fertility, that is a mixture of sterile and fertile variants of the same hybrid (Vidakovic and Vancetovic, 1994).

Xenia is a direct cross fertilisation effect on the grain traits of the female component in the year of crossing. Hoekstra et al., (1985), Weiland (1992), Westgate et al. (1999), Weingartner et al. (2002a, b) and Bozinovic et al. (2010a) found out a significant grain yield increase obtained by crossing with different pollinators. Weingartner et al. (2002a, b) and Bozinovic et al. (2010a) also found out great xenia impact on kernel number. These modifications result from the impact of xenia on several physiological traits, which play key roles in kernel development (e.g. the kernel growth rate (Seka and Cross, 1995) and/or enzyme activities and the duration of the grain-filling period (Bulant and Gallais, 1998; Bulant et al., 2000)). The change of the grain composition due to xenia was studied by

Lambert et al. (1998) Tsai and Tsai (1990) Weingartner et al. (2004) Vancetovic et al. (2009). The xenia effect on grain quality has been in practice since the 1990s. The system to improve qualitative kernel traits (TopCross system) was patented by DuPont Specialty Grains, Des Moines, Iowa, USA.

A new approach, dating from the end of the 20th century consists of mixing a sterile version of a yielding hybrid with a fertile version of unrelated hybrid with the aim to express a positive effect of *cms* and xenia. The combined effect of *cms* and xenia is referred to as the Plus-hybrid effect (Weingartner et al. 2002 a, b). This phenomenon was also investigated by Vancetovic et al. (2009) and Bozinovic et al. (2010 a, b).

The aim of this experiment was to examine the Plus-hybrid effect on the most important agronomic traits. By examining the individual effects of *cms* and xenia we have observed that the xenia effect on some of the traits differs for sterile and fertile versions of the same hybrid, and that reffers to some kind of sterile cytoplasm × pollinator interaction. We will present our results related to this phenomenon.

Material and methods

The three-replicate trial was carried out in the experimental field of the Maize Research Institute, Zemun Polje, Beograd-Zemun, in 2008, 2009 and 2010 according to the randomised complete block (RCB) split-plot experimental design. Two sterile (*cms-S*) hybrids (ZP-1 st and ZP-2 st) and their fertile counterparts (with normal - N cytoplasm) were used in the experiment as females, while five fertile hybrids (ZP-1, ZP-2, ZP-3, ZP-4 and ZP-5) were selected as pollinators.

The observed female components represented the main plots (sterile and fertile versions of the hybrids ZP-1 and ZP-2). Fertile female component plants were detasseled prior to pollination. The fertile hybrid pollinator blocks (subplots) consisted of 14 rows, each 18 m long. The rows were 0.75 m apart and the plant density was 77,220 plants ha^{-1}. The trial was planted mechanically and harvested by hand.

A combined effect of *cms* and xenia was observed as a difference between effect of xenia on the fertile and sterile version of the same hybrid. The xenia effect was calculated on the basis of differences between average values of the traits of the non-isogenically and isogenically pollinated hybrid.

These traits were studied: grain yield (tha^{-1}), 1000 kernel weigth, kernel number per m^2, oil, protein and starch percentage in kernel.

To correct for non-normality all statistical analyses for percentage traits were done on arcsine transformed values. A *t*-test was performed to test the significance of differences between the appropriate means.

Results and discussion

Sterile and fertile versions of ZP 1 and ZP 2 showed different reaction to xenia (Table 1). Although xenia of ZP 4 influenced differently on ZP 1st and ZP 1ft and xenia of ZP 4 and ZP 5 influenced differently on ZP 2st and ZP 2ft for grain yield, it was not significant. ZP 5 xenia had negative impact at the same level of significance on both versions of ZP 1 for this trait. Xenia influenced differently on 1000 kernel weight for second hybrid. ZP 1 and ZP 3 had significant impact on ZP 2ft, but not on its sterile version ZP 2st. It is interesting that ZP 2st under the influence of ZP 1 had lower value for this trait, whereas ZP 2ft had significantly higher value for this trait in accordance to its sterile i.e. fertile version isogenically pollinated. Considering number of kernels per m^2 it can be concluded that fertile versions of both hybrids statistically significantly reacted on ZP 5 xenia, while their sterile versions didn't react so significant.

Table 1. Xenia effect on sterile and fertile hybrids for grain yield, 1000 kernel weight and kernel number per m^2 for all three years.

Hybrid[a]	Pollinator	GY (tha^{-1})		1000KW		KN/m^2	
		St	Ft	St	Ft	St	Ft
ZP 1	ZP 2	0.32ns	0.20ns	-3.85ns	8.64ns	58.07ns	-65.41ns
	ZP 3	-0.27ns	-0.31ns	8.48ns	6.38ns	-58.88ns	-9.16ns
	ZP 4	-0.21ns	0.05ns	3.54ns	-4.99ns	-13.53ns	11.92ns
	ZP 5	-0.76†	-0.71†	-6.38ns	-13.99	48.57ns	221.72†
ZP 2	ZP 1	-0.15ns	-0.33ns	-7.68ns	18.82*	2.31ns	105.45ns
	ZP 3	0.17ns	0.42ns	4.19ns	22.99*	-110.21	-34.77ns
	ZP 4	-0.02ns	0.33ns	-1.32ns	5.05ns	-43.07ns	28.57ns
	ZP 5	-0.71ns	0.20ns	-5.99ns	-1.98ns	127.95†	322.78**

GY - grain yield, 1000KW - 1000 kernel weight, KN/m^2 - kernel number per m^2. ns- statistically not significant, †- significant at the 0,1 probability level, * - significant at the 0,05 probability level, ** - significant at the 0.01 probability level.

[a] The values in all tables indicate differences of shown ZP 1 × pollinator combinations with regard to ZP 1 × ZP 1 for the first hybrid and ZP 2 × pollinator combinations with regard to ZP 2 × ZP 2 for the second hybrid, for both sterile an fertile versions.

It is observable (Table 2) that xenia effect on proportion of oil were statistically more significant in grain of ZP 1st than of ZP 1ft. Moreover, apart from ZP 4, xenia effects of remaining pollinators of both versions of the hybrid ZP1 were negative for this trait. Xenia effects of ZP 1, ZP 3 and ZP 4 for this trait were significantly positive on fertile ZP 2 and poor on ZP 2st. These effects on the grain protein content of both studied hybrids were not significant, although were different on their sterile and fertile versions. Xenia effects on the grain starch content were not statistically different in both versions of the hybrid ZP 1. It may be noted that the fertile hybrid ZP 2 responded more poorly to isogenic pollination for the starch proportion in grain. Two pollinators statistically negatively affected ZP 2, while ZP 5 positively affected both versions, but effects for this trait were significant only in the sterile version.

Table 2. Xenia effect on sterile and fertile hybrids for oil, protein and starch percentage for all three years.

Hybrid	Pollinator 2	Oil		Protein		Starch	
		St	Ft	St	Ft	St	Ft
ZP 1	ZP 2	-0.18*	-0.12ns	0.13ns	-0.12ns	0.29ns	0.03ns
	ZP 3	-0.31**	-0.19†	-0.14ns	-0.25ns	0.48†	0.27ns
	ZP 4	0.03ns	0.03ns	0.31ns	-0.11ns	0.02ns	-0.02ns
	ZP 5	-0.23 *	-0.12ns	0.30ns	0.15ns	0.34ns	0.12ns
ZP 2	ZP 1	0.07ns	0.25 **	-0.21ns	0.26ns	-0.30ns	-0.47†
	ZP 3	-0.08ns	0.14†	0.09ns	-0.10ns	0.18ns	-0.01ns
	ZP 4	0.04ns	0.23*	-0.23ns	-0.05ns	0.12ns	-0.48†
	ZP 5	-0.25*	-0.06ns	-0.36ns	-0.27ns	0.48**	0.13ns

ns- statistically not significant, †- significant at the 0,1 probability level, * - significant at the 0,05 probability level, ** - significant at the 0.01 probability level.

Although the effect of the phenomenon of xenia on the chemical composition of grain has been proved and explained, the xenia effects on the grain yield and the number of kernels in maize are not biologically quite clear. Bulant *et al.* (2000) investigated the enzyme activity in cross-fertilised kernels and found that differences in this activity were expressed soon after fertilisation but were insufficient to explain the xenia effects on kernel weight. Given data on existence of xenia effects on grain yield and the number of kernels per m^2 are in accordance with those obtained by Weingartner et al. (2002 a, b). Furthermore, Weingartner et al. (2004), as well as, Tsai and Tsai (1990) have recorded a significant oil and protein increase in maize grain under effects of xenia, but results obtained in our studies show that effects of xenia on oil differed between hybrid versions, while the protein contents were not significantly affected by xenia. Studying xenia effects on selected traits, Weingartner et al. (2002 a, b) and Weingartner et al. (2004) have estimated this effect as sterile hybrid nonisogenically pollinated with regard to sterile hybrid isogenically pollinated. In their experiment the effects of cms and xenia on the tested hybrids were not separately observed, while we did it, additionally evaluating xenia effects even on fertile versions of our hybrids. Theoretically, xenia effect on sterile and fertile versions of the same hybrid should be equal or at least should be positive or negative for the same hybrid. This study shows that this is not so, and that maybe cytoplasm in certain way modifies xenia effects on a hybrid. Even though such studies on the phenomenon of xenia have not been conducted in such a way, it is our opinion that it would be interesting and useful to determine the nature of this phenomenon.

Conclusion

The xenia mechanism of action on a certain traits has not been explored enough. By examining xenia effect through Plus-hybrid effect we concluded that it has different impact for some traits on sterile and fertile versions of one hybrid, but some kind of regularity could not be observed and confirmed. Besides the influence of the nuclear genome of a female component on this phenomenon, it is also necessary to study effects of sterility, because it is obvious that a certain modification occurs.

Acknowledgments

This research was supported by the Ministry of science and technology of Serbia through project TR 31068

References

Bozinovic S., Vancetovic J., Babic M., Filipovic M and Delic N. (2010a). The plus-hybrid effect on the grain yield of two ZP maize hybrids, Genetika, 42, (No. 3),475 -484.

Bozinovic, S., Vancetovic J., Levic J. and Stankovic S. (2010). The effects of cytoplasmic male sterility and xenia on maize kernel infection with *Fusarium verticillioides.* Book of papers of 45th Croatian and 5th International Symposium on Agriculture. Opatija, Croatia, pp. 380-384.

Bulant C., Gallais A. (1998). Xenia effects in maize with normal endosperm: i. importance and stability, Crop Sci, 38, 1517-1525.

Bulant C., Gallais A., Matthys-Rochon E., Prioul J.L. (2000). Xenia effects in maize with normal endosperm: II. kernel growth and enzyme activities during grain filling, Crop Sci, 40, 182-189.

Duvick D.N. (1958). Yields and other agronomic characteristics of cytoplasmically pollen sterile corn hybrids, compared to their normal counterparts. Agron J, 50, 121-125.

Duvick D.N. (1965). Cytoplasmic pollen sterility in corn. Adv. Genet., 13, 1-56.

Everett H.L. (1960) Effect of cytoplasms and an Rf gene in maize. Agron. J., 52, 215-216.

Josephson L.M., Kincer H.C. (1962). Effects of male-sterile cytoplasm on yields and other agronomic characteristics of corn inbreds and hybrids. Crop Sci, 2, 41-43.

Kalman L., Pinter L., Pinter Z. (1985). Comparative study on major agronomic charachteristics of male fertile (normal) and cytoplasmic male sterile analogues in maize (Zea mays L.) Acta Agron Hung, 34, 128-134.

Lambert R.J., Alexander D.E., Han Z.J. (1998). A high oil pollinator enhancement of kernel oil and effects on grain yields of maize hybrids. Agron. J., 90, 211-215.

Pinter L. (1986) Effect of rough detasseling on some agronomic traits of maize (*Zea mays* L.) progenies. Acta Agron. Hung., 35, 279–285.

Rogers J.S., Edwardson J.R. (1952). The utilization of cytoplasmic male-sterile inbreds in the production of corn hybrids. Agron. J., 44, 8-13.

Sanford J.O., Grogan C.O., Jordan H.V., Sarvella P.A. (1965). Influence of male-sterility on nitrogen utilization in corn, *Zea mays* L. Agron. J., 57, 580–583.

Stamp P., Chowchong S., Menzi M., Weingartner U., Käser O. (2000) Increase in the yield of cytoplasmic male sterile maize revisited. Crop Sci, 40, 1586-1587.

Seka D., Cross H.Z. (1995). Xenia and maternal effects on maize kernel development. Crop Sci, 35, 80-85.

Tsai C.L., Tsai C.Y. (1990). Endosperm modified by cross-pollinating maize to induce changes in dry-matter and nitrogen accumulation. Crop Sci, 30:804-808.

Vancetovic J., Lj., Jankuloski, S., Bozinovic and D. Dodig (2009). The effects of cytoplasmic male sterility and xenia on the chemical composition of maize grain. Genetika, 41, (1), 95-106.

Vidakovic, M. and Vancetovic, J. (1994). Male sterility in the hybrid seed production. Kukuruza i sorgo, 1, 12-13. (In Russian).

Weiland R.T. (1992). Cross-pollination effects on maize (*Zea Mays* L) hybrid yields. Can J Plant Sci, 72, 27-33.

Weingartner, U., Kaeser, O., Long, M., and Stamp, P. (2002a). Combining male sterility and xenia increases grain yield of maize hybrids. Crop Sci, 42, 127-134.

Weingartner, U., Prest, T.J., Camp, K.-H. and Stamp, P. (2002b). The plus-hybrid system a method to increase grain yield by combined cytoplasmic male sterility and xenia. Maydica, 47, 127-134.

Weingartner, U., Camp, K.-H and Stamp, P. (2004). Impact of male sterility and xenia on grain quality traits of maize. Europ. J. Agronomy, 21, 239-247.

Westgate, M.E., Wicks, Z. and Barbour, N. (1999). Selecting maize hybrids for increased yield in mixed stands. In: Proceedings of the ASA-CSSA SSSA Annual Meeting, Salt Lake City, Utah, Div. C-4, pp.119.