UDC 575:633,15
DOI: 10.2298/GENSR1001167B
Original scientific paper

MODE OF INHERITANCE AND COMBINING ABILITIES FOR KERNEL ROW NUMBER, KERNEL NUMBER PER ROW AND GRAIN YIELD IN MAIZE (*Zea mays* L.)

Jan BOĆANSKI[1], Zorana SREĆKOV[1], Aleksandra NASTASIĆ[2], Mile IVANOVIĆ[2], Ivica DJALOVIĆ[2],and Mirjana VUKOSAVLJEV[3]

[1] Faculty of Agriculture, Novi Sad, Serbia
[2] Institute of Field and Vegetable Crops, Novi Sad, Serbia
[3]WUR, Wageningen, Netherlands

Bočanski J., Z. Srečkov, A. Nastasić, M. Ivanović, I.Djalović and M. Vukosavljev (2010): *Mode of inheritance and combining abilities for kernel row number, kernel number per row and grain yield in maize (Zea mays L.)* - Genetika, Vol 42, No. 1, 169- 176.

Utilization of heterosis requires the study of combining abilities of potential parents. In view of this, the objective of this paper was to study combining abilities and determine the mode of inheritance and gene effects for the main agronomic character, grain yield, and its components, kernel row number and kernel number per row. Six inbred lines were used in the

Corresponding author: prof dr Jan Bocanski, Faculty of Agriculture, Novi Sad, Serbia, email: bocanski@polj.ns.ac.rs

study, three of which originated in the U.S., while the other three were developed at the Institute of Field and Vegetable Crops in Novi Sad. Kernel row number was inherited by superdominance, partial dominance, complete dominance and intermediacy. The mode of inheritance of kernel number per row and grain yield was superdominance. Additive gene action had the greatest influence on the expression of kernel row number, while the other two traits were influenced the most by nonadditive gene.

Key words: combining abilities,maize, mode of inheritance

INTRODUCTION

Maize is the number one field crop in the Pannonian region of Europe (BEKAVAC *et al*, 2007). Today, phenomenon of heterosis is considered one of the main reasons behind successful industrial production of maize (STUBER, 1997). However, crosses between lines do not always produce heterosis, which is why it is necessary to determine the combining abilities of lines in order to identify potential parents. Different methods exist for determining the combining abilities of parental lines. Diallel crossing is the most commonly used method in genetic studies for determining the mode of inheritance of major traits (YAN and HUNT, 2002).

The main objective of maize breeders is to obtain new inbred lines and hybrids that will outperform the existing hybrids with respect to a number of traits. In working towards this goal, particular attention is paid to grain yield as the most economically important trait in maize (VASIC *et al*., 2001). Grain yield is a complex quantitative trait that depends on a number of factors. It's within great influence of environmental conditions, has complex mode of inheritance and low heritability (BOCANSKI *et al.,* 2009). It is also depends on a number of components, including kernel row number and kernel number per row. The objective of this paper was to determine the mode of inheritance, gene effects and combining abilities for kernel row number and kernel number per row as grain yield components and grain yield in maize.

MATERIALS AND METHODS

To study the inheritance of kernel row number and kernel number per row, six inbred lines (N152, B73, Mo17, 358/II NS, 298/II NS and 1188/III NS) differing with respect to said traits were chosen. Lines N152, B73 and Mo17 originate from the U.S., while 358/II NS, 298/II NS and 1188/III NS are lines developed at the Institute of Field and Vegetable Crops in Novi Sad. During 2001, complete dialell crosses were made to produce the F_1 generation. In 2002, a trial was set up with the parents and F_1s using a randomized block design with four replications. Standard deviation (σ) and coefficient of variation (V) were used as indicators of variability of traits under study. To determine the mode of inheritance, the test of significance of generation means relative to parental ones was used. In order to obtain as complete a set of information as possible on the components of genetic variance and gene effects for traits under study, the dialell crosses were analyzed for combining abilities according to GRIFFING (1956), Method 2. Analysis of genetic variance components were done according to JINKS (1954), HAYMAN (1954) and MATHER and JINKS (1971).

RESULTS AND DISCUSSION

The highest mean value of kernel row number was found in line B73 and the smallest in line Mo17. With the hybrids, the highest mean have combination N152 × B73 and the lowest Mo17 × 298/II NS. In the inheritance of kernel row number in the F_1 generation, it was complete dominance that was most often found (tab. 1). Partial dominance was found in the combinations N152 × Mo17, B73 × 358/II NS and Mo17 × 1188/III NS, while superdominance appeared in N152 × 1188/III NS and 358/II NS × 298/II NS. Intermediacy was present in B73 × Mo17. Similar to the results which we obtained SUJIPRIMATI (1996) found complete and partial dominance as the modes of inheritance of this trait, while VIVALDI-MARTINEZ *et al.* (2001) found superdominance.

Maximum mean value for kernel number per row was obtained for Mo17, and for grain yield for inbred line N152, while inbred line 358/II NS has the lowest mean value and for kernel number per row and for grain yield (tab. 1). Inbred line 1188/III NS in combination with lines 298/II NS and 358/II NS have maximum mean for kernel number per row and grain yield, respectively. The same line in combination with B73 and Mo17, also have and the minimum mean values for these two traits. The mode of inheritance of kernel number per row and grain yield per plant was superdominance in all of the combinations (tab. 1). These results are in agreement with results of SAEED *et al.* (2000), WOLF *et al.* (2000), VIVALDI-MARTINEZ *et al.* (2001), VALES *et al.* (2001), BOCANSKI *et al.* (2005, 2008), EDWARDS and LAMKEY (2002), MOHAMENADI *et al.* (2002), SOENGAS *et al.* (2003), TOLLENAAR *et al.* (2004), and UNAY *et al.* (2004).

Analysis of combining abilities using parental and progeny means showed there were highly significant differences in the F_1 generation with respect to the GCA and SCA for all three traits under study. For kernel row number the GCA/SCA ratio indicated the predominance of additive over nonadditive genes action (tab. 2), and these results are in accordance with the results of SAEED *et al.* (2000), SEČANSKI *et al.* (2005) and ŽIVANOVIĆ *et al.* (2007). For kernel number per row (GCA/SCA= 0.63) and grain yield (GCA/SCA= 0.20) nonadditive gene action have more important role in expression of these two traits. The more important role of nonadditive gene action in expression of kernel number per row and grain yield also was found by SAEED *et al.* (2000).

Table 1. Mean values, indicators of variability and mode of inheritance of kernel row number, kernel number per row and grain yield per plant

Parents and hybrids	x			σ			V		
	KRN	*NKR*	*GY*	*KRN*	*NKR*	*GY*	*KRN*	*NKR*	*GY*
N152	16.2	27.5	143.7	1.31	3.22	26.30	8.0	11.7	18.3
N152×B73	17.8^{d}	40.3^{sd}	262.5^{sd}	1.64	4.48	41.60	9.2	11.7	15.8
N152×Mo17	14.3^{pd}	42.2^{sd}	236.6^{sd}	1.26	4.22	32.40	8.8	10.0	13.6
N152×358/II NS	15.9^{d+}	35.1^{sd}	242.6^{sd}	1.61	4.52	37.60	10.1	12.9	15.5
N152×298/II NS	15.9^{d}	37.1^{sd}	218.0^{sd}	1.61	5.11	39.20	10.1	13.8	17.9
N152×1188/III NS	17.3^{sd}	36.6^{sd}	251.3^{sd}	1.53	3.92	35.80	8.8	10.7	14.2
B73	17.3	24.8	111.3	1.64	5.04	23.60	9.4	20.3	21.2
B73×Mo17	14.8^{i}	42.8^{sd}	226.0^{sd}	1.52	4.42	32.00	10.2	10.3	14.2
B73×358/II NS	16.5^{pd}	35.5^{sd}	218.3^{sd}	1.46	4.19	28.60	8.8	11.8	13.0
B73×298/II NS	17.3^{d+}	36.3^{sd}	200.6^{sd}	1.74	5.27	36.00	10.0	14.5	17.9
B73×1188/III NS	17.4^{d+}	34.3^{sd}	210.6^{sd}	1.75	3.41	26.80	10.0	9.9	12.7
Mo17	10.9	35.2	109.3	0.68	4.69	21.30	6.2	13.3	19.4
Mo17×358/II NS	13.4^{d+}	43.8^{sd}	207.3^{sd}	1.32	4.07	26.20	9.8	9.3	12.6
Mo17×298/II NS	13.2^{d+}	44.6^{sd}	260.0^{sd}	1.56	5.73	39.80	11.8	12.8	19.3
Mo17×1188/III NS	14.4^{pd}	40.0^{sd}	189.3^{sd}	1.33	3.92	26.80	9.2	9.8	14.2
358/II NS	13.0	19.8	91.3	1.39	3.34	12.60	10.7	16.9	13.8
358/II NS×298/II NS	15.9^{sd}	39.8^{sd}	211.3^{sd}	1.69	4.23	33.40	10.6	10.6	15.8
358/II NS×1188/III NS	15.9^{d+}	45.4^{sd}	270.0^{sd}	1.49	2.46	20.00	9.3	5.4	7.4
298/II NS	13.2	26.8	95.3	1.74	4.03	18.50	13.2	15.0	19.5
298/II NS×1188/III NS	16.1^{d+}	46.5^{sd}	255.3^{sd}	1.69	4.72	24.70	10.5	10.2	9.7
1188/III NS	16.1	24.1	101.7	1.50	4.49	24.60	9.3	18.6	24.2

Table 2. Analysis of variance of combining abilities

Source of variation	df	MS			GCA/SCA		
		KRN	KNE	GY	KRN	KNE	GY
GCA	5	11.41**	37.77**	865.78**			
SCA	15	0.67**	60.31**	4198.62**	17.03	0.63	0.20
Error	60	0.07	0.38	56.56			

The highest GCA value for kernel row number and grain yield was found in line N152 (tab. 3 and 5), while inbred line Mo17 has the highest GCA value for kernel number per ear (tab. 4).

Table 3. GCA (diagonal) and SCA values for kernel row number

Parents	*N152*	*B73*	*Mo17*	*368/II NS*	*298/II NS*	*1188/III NS*
N152	**7.62****	0.32	0.08	0.23	0.16	0.52
B73		**1.35****	0.05	0.29	0.90	-0.01
Mo17			**-1.96**	0.48	0.09	0.28
368/II NS				**-0.48**	1.48**	0.29
298/II NS					**-0.36**	0.32
1188/III NS						**0.68****

For kernel row number, the highest SCA value was observed in the hybrid combination 358/II NS × 298/II NS, with the difference being highly significant relative to the other combinations (tab. 3). Almost all of the combinations had significant SCA values for kernel number per ear. This was most certainly influenced significantly by the higher values of nonadditive genetic variance we found for this trait (tab. 4). Highly significant SCA values for grain yield per plant were found in all of the combinations except B73 × 298/II NS, B73 × 1188/III NS and Mo17 × 1188/III NS (tab. 8).

Table 4. GCA (diagonal) and SCA values for kernel number per row

Parents	*N152*	*B73*	*Mo17*	*368/II NS*	*298/II NS*	*1188/III NS*
N152	**-0.69**	6.50**	2.82**	1.84**	1.10	1.77**
B73		**-1.64**	4.05**	3.39**	1.30	0.58
Mo17			**4.01****	5.87*	4.01**	0.60
368/II NS				**-1.85**	5.01**	8.69*
298/II NS					**0.75***	9.82**
1188/III NS						**-0.58**

Table 5. GCA (diagonal) and SCA values for grain yield

Parents	*N152*	*B73*	*Mo17*	*368/II NS*	*298/II NS*	*1188/III NS*
N152	**19.52****	52.05*	31.94**	32.92**	19.30**	37.20**
B73		**-0.54**	42.48**	40.38**	4.13	17.10
Mo17			**-7.23**	26.49**	30.69**	4.21
368/II NS				**-3.12**	31.08**	56.60**
298/II NS					**-9.92**	71.08**
1188/III NS						**1.37**

For kernel row number, data in table 6 show, the additive component of variance (D = 5.92) was greater than the dominant one (H_1=1.86), indicating that the additive component accounted for the larger part of genetic variance in the inheritance of this trait when looking at the combinations as a whole. When considering the combinations individually, however, then this fits in with the overall results, as the F_1 generations of some of the combinations were intermediate, dominant or partially dominant (tab. 1). For the other two traits, kernel number per row and grain yield, the dominant component of variance was larger than the additive one, indicating that the dominant component of variance had more influence in the inheritance of these traits (tab. 6) The F value was positive for kernel row number and kernel number per row, meaning there were more dominant than recessive genes in the expression of these traits. With grain yield, it was the opposite, i.e. the F value was negative, indicating the preponderance of recessive genes in the expression of the trait. Looking at the $H_2/4H_1$ ratio, we can see that the distribution of dominant and recessive genes was not symmetrical for any of the three traits. In the inheritance of kernel row number, the value of the average degree of dominance was less than one, which indicates the partial mode of inheritance when all the combinations are considered together. With the other two traits, the average degree of dominance was larger than one, indicating that superdominance was present in their inheritance, which is in agreement with the results we obtained by the t-test concerning the significance of differences between parental means and those of the F_1 hybrids. For kernel row number and kernel number per row, the ratio of the total number of dominant alleles to that of recessive ones was above the value of one in all of the parents, showing that dominant alleles predominated over recessive ones. For grain yield per plant, the ratio was less than one; hence recessive alleles were more numerous than dominant ones.

Table 6. Components of variance

Components	Values		
	Kernel row number	Kernel number per row	Grain yield per plant
D	5.92	26.01	307.74
H_1	1.86	158.60	10313.04
H_2	1.59	151.54	10170.60
F	0.52	14.99	-31.75
E	0.07	0.38	56.56
$H_2/4H_1$	0.22	0.24	0.247
$\sqrt{\frac{H_1}{D}}$	0.56	2.47	5.79
K_D/K_R	1.17	1.26	0.98

Received Febuary 25th, 2010
Accepted April 12th, 2010

REFERENCES

BEKAVAC, G., B. PURAR, M.STOJAKOVIĆ, Đ.JOCKOVIĆ, M.IVANOVIĆ, A.NASTASIĆ (2007): Genetic analysis of stay–green trait in broad-based maize populations. Cereal Researh Communications, *35* (1), 31–41

BOĆANSKI, J., Z.SREĆKOV, A.NASTASIĆ (2009): Genetic and phenotypic relationship between grain yield and components of grain yield of maize (*Zea mays* L.). Genetika, *41*(2), 145-154.

BOĆANSKI, J., Z. SREĆKOV, A. NASTASIĆ (2005): Genetic analysis of cob weight and grain yield (*Zea mays* L.). Annals of Scientific Work, *29* (1), 113-121

BOĆANSKI, J., Z. SREĆKOV, A. NASTASIĆ (2008): Mode of inheritance of cob weight and grain yield in maize. A Periodical of Scientific Research on Field and Vegetable Crops, *45*(2): 47-53

EDWARDS, J. W., K. R. LAMKEY (2002): Quantitative genetics of inbreeding in a synthetic maize population. Crop Sci., *42,* 1094-1104

GRIFFING, B. (1956): Concept of general and specific combining ability in relation to diallel crossing systems. Aust. J. Biol. Sci., *9*, 463-493

HAYMAN, B. J. (1954): The theory and analysis of diallel crosses. Genetics, *39*, 787-809

JINKS, J. L. (1954): The analysis of continuous variation in a diallel cross of Nicotiana rustica varieties. Genetics, 39, 767-789

MATHER, K., J. L. JINKS (1971): Biometrical genetics. Second Ed., Chapman and Hall, London, 249-271

MOHAMEDANI, S. A., B. M. PRASANNA, C. SUDAN, N. N. SINGH (2002): A microsatellite marker based study of chromosomal regions and gene effects on yield and yield components in maize. Cell. Mol. Biol. Lett., *7*(2A), 599-606

SAEED, M. T., M. SALEEM, M. AZFAL (2000): Genetic analysis of yield and its components in maize diallel crosses (Zea mays L). Int. J. Agri. Biol., *2*(4), 376-378

SEČANSKI M., T. ŽIVANOVIĆ, G. TODOROVIĆ (2005): Components of genetic variability and heritability of the number of rows per ear in silage maize. Biotechnology in Animal Husbandry, *21 (*1-2), 109-121

SOENGAS, P., B. ODRAS, R. A. MALVAR, P. REVILLA, A. ORDAS (2003): Heterotic patterns among flint maize populations. Crop Sci., *43*: 844-849

STUBER, C. W. (1997): The biology and physiology of heterosis. Book of Abstracts. The genetics and Exploitation of Heterosis in Crops; An International Symposium. CIMMYT, D. F., Mexico, 108–109

SUJIPRIMATI, S. (1996): Heterosis, combining ability and yield prediction in Hybrids from local maize inbred lines. Ph. Thesis, University Putra, Malaysia

TOLLENAAR, M., A. AHMADZADEH, E. A. LEE (2004): Physiological basis of heterosis for grain yield in maize. Crop Sci., *44,* 2086-2094

ÜNAY, A., H. BASEL, C. KONAK (2004): Inheritance of grain yield in a half-diallel maize population. Turk. J. Agric. For., 28, 239-244

VALES, M. I., R. A. MALVAR, P. REVILLA, A. ODRAS (2001): Recurrent selection for grain yield in two Spanish maize synthetic populations. Crop Sci., *41,* 15-19

VASIC, N., M. IVANOVIC, L. PETERNELLI, Đ.JOCKOVIC, M.STOJAKOVIC, J. BOCANSKI (2001): Genetic relationships between grain yield and yield components in a synthetic population and their implications in selection. Acta Agronomica Hungarica, *49* (4), 337–342

VIVALDI-MARTINEZ, V. A., M. CLEGG, B. JOHNSON, R. VALDIVIA-BERNAL (2001): Phenotypic and genotypic relationships between pollen and grain yield components in maize. Agrosciencia, 35(5), 503-511

WOLF, D. P., L. A. PETERNELLI, A. R. HALLAUER (2000): Estimates of genetic variance in a F_2 maize population. J. Hered., *91* (5), 384-391

YAN, W., L. A. HUNT (2002): Biplot analysis of diallel data. Crop Sci., *42*, 21-30.

ŽIVANOVIĆ T., M. SEČANSKI, M. FILIPOVIĆ (2007): Combining abilities for the number of kernel rows per ear in silage maize. Plant breeding and seed production, XIII (3-4): 13-19

NAČIN NASLEĐIVANJA I KOMBINACIONE SPOSOBNOSTI BROJA REDOVA ZRNA NA KLIPU, BROJA ZRNA U REDU I PRINOSA ZRNA KUKURUZA (*Zea mays* L.)

Jan BOĆANSKI[1], Zorana SREĆKOV[1], Aleksandra NASTASIĆ[2], Mile IVANOVIĆ[2], Ivica DJALOVIĆ[2], Mirjana VUKOSAVLJEV[3]

[1] Poljoprivredni fakultet, Novi Sad, Srbija
[2] Institut za ratarstvo i povrtarstvo, Novi Sad, Srbija
[3]WUR, Wageningen, Holandija

I z v o d

Iskorištavanje heterozisa zahteva poznavanje kombinacionih sposobnosti potencijalnih roditelja. Imajući ovo u vidu cilj ovog rada je bio proučavanje kombinacionih sposobnosti i utvrđivanje načina nasleđivanja prinosa zrna, kao glavne agronomske osobine, i komponenti prinosa zrna, broj redova zrna na klipu i broj zrna na klipu. U radu je korišteno 6 inbred linija, od kojih su 3 poreklom iz SAD, a 3 su razvijene u Institutu za ratarstvo i povrtarstvo u Novom Sadu. Način nasleđivanja broja redova zrna na klipu bila je superdominacija, parcijalna dominacija, puna dominacija i intermedijarnost, a kod broja zrna na klipu i prinosa zrna po biljci u svim hibridnim kombinacijama pojavila se superdominacija. Aditivni efekat gena imao je najveći uticaj na ekspresiju broja redova zrna na klipu, dok je za druge dve proučavane osobine ustanovljeno da je neaditivan efekat gena imao najveći uticaj.

Primljeno 25. II. 2010.
Odobreno 12. IV. 2010.