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Original scientific paper

DIALLEL ANALYSIS FOR PLANT HEIGHT IN WINTER WHEAT

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The mode of inheritance and gene effect for plant height of 7x7 half diallel crosses of wheat varieties and lines was evaluated in F_1 and F_2 generation. The mode of inheritance, calculated for each combination separately, was different and depended on the cross combination. The absence of interallelic interaction between the genes determining the expression of plant height was concluded from the regression analysis. The regression line intercepts the Wr axis below the origin in F_1 indicating overdominance over an average of all arrays. In F_2 the regression line cuts the Wr axis above the origin indicating partial dominance.

Key words: diallel, plant height, winter wheat

INTRODUCTION

The present wheat breeding for plant height is based on the incorporation of growth semidwarf habit in commercial wheat cultivars. The semidwarf wheats reduced the yield loss due to lodging resistance. Replacing tall wheat types was responsible for increasing wheat yields from one tone per hectare in early 1960's to nearly 2.7 tonnes per ha in late 1990 (SINGH *et al*., 2001). The main sources of semidwarf *Rht* genes in wheat were Japanese varieties. These genes are incorporated into Yugoslavian and Macedonian varieties (PETROVIĆ and WORLAND,

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1992). The genetic control of height in wheat has been subject of numerous studies having in mind that inheritance of plant height has complex nature. To obtain efficient choice of parent material and promising hybrid progeny, information on genetic composition and trait inheritance are needed. This study was undertaken to explain the nature of gene effect and combining ability of different parents and cross combinations of wheat material. Based on the results of this experiment, breeding in future generations could be applied with more certain assumptions. The experiment was also aimed to select the best combining parents for future Macedonian wheat breeding program and to select positive lines in the later generations.

MATERIALS AND METHODS

The present experiment was conducted at the Agricultural research station "Butel" of the Agricultural Institute in Skopje. The materials selected for half diallel analyses for plant height were six varieties of winter wheat: Sava, Novosadska Rana 2, Novosadska Crvena, Agrounija – introduced from Yugoslavia, Radika and Milenka and line SK-136, created at the Institute in Skopje, their F_1 and F_2 generations. The parents, and both hybrid generations were examined in the same year (1996) to avoid the year interactions. The treatments were planted in randomised block design in three replications. The length of the row was 1m with 20cm space between and within rows. During the vegetation standard growing measures were applied. For F_1 and parents 30 plants and for F_2 120 plants were used for analyses. Simple analysis of variance was carried out. The inheritance of F_1 and F_2 progenies was evaluated with significant test of the mean values of the hybrid generations according their parents (BOROJEVIĆ, 1965). Combining ability analysis was performed according to GRIFFING (1956), method II, model I. Analysis of components of genetic variances and regression analysis were performed by using methods of JINKS (1954), HAYMAN (1954) and MATHER and JINKS (1971).

RESULTS AND DISCUSSION

The parents included in this examination were significantly different according their plant height (Table 1). The average values ranged from 58.50cm (variety Milenka) up to 77.00cm (Novosadska Crvena).

Table 1. Mean values and the inheritance of plant height in wheat (parents and F_1)

Parents	Radika	Milenka	Agrounija	N. Rana 2	Sava	SK-136	N. Crvena
Radika	**62.43**	62.53^{+d}	62.03	70.03^{+d}	64.30	61.93^{-d}	62.07^{-d}
Milenka		**58.50**	64.70^{+d}	62.23^{i}	60.17	66.40^{+d}	63.73^{pd}
Agrounija			**63.40**	57.90^{-h}	67.23^{+h}	62.63^{-d}	69.17^{i}
N. Rana 2				**68.07**	66.67^{+d}	67.70	76.17^{+d}
Sava					**61.77**	57.87^{-h}	64.73^{pd}
SK-136						**67.37**	74.37^{i}
N. Crvena							**76.97**

d – dominant; h – heterosis; i – intermediary; pd – partially dominant; LSD 0.05 = 3.28; 0.01 = 4.37

Among the hybrid combinations, Sava x SK-136 had the lowest average stem height (57.87cm) in F_1 generation, and Milenka x Sava (61.08) in F_2 (Table 2). The highest value in both hybrid generations had N. Rana 2 x N. Crvena (76.17cm and 76.50cm).

Table 2. Mean values and the inheritance of plant height in wheat (parents and F_2)

Parents	Radika	Milenka	Agrounija	N. Rana 2	Sava	SK-136	N. Crvena
Radika	**62.43**	64.43 $^{+d}$	64.67	65.86 ^{i}	65.37 $^{+h}$	62.98 $^{-d}$	65.11 ^{pd}
Milenka		**58.50**	62.62 $^{+d}$	61.40 ^{pd}	61.08	63.08 ^{i}	64.18 ^{pd}
Agrounija			**63.40**	62.58 $^{-d}$	64.85	62.76 $^{-d}$	69.25 ^{i}
N. Rana 2				**68.07**	64.37 ^{i}	68.19	76.50 $^{+d}$
Sava					**61.77**	67.30	67.82 ^{pd}
SK-136						**67.37**	72.78 ^{i}
N. Crvena							**76.97**

d – dominant; h – heterosis; i – intermediary; pd – partially dominant

LSD 0.05 = 3.83; 0.01 = 5.09

The inheritance was different depending on the cross combination. In F_1 the plant height was mostly dominantly inherited, while intermediary was only in 3 combinations (Table 1). Significantly lower stem, compared to both parents, had only 1 combination (Agrounija x Sava). The inheritance in F_2 was dominant in 6 and partially dominant in 4 combinations. The trait is inherited intermediary in 6 combinations and, having in mind that additive gene effect could be fixed in the follow up generations, those combinations are of special interest for further breeding (Table 2).

The results from the analysis of the inheritance of plant height in the literature are different and depend, mostly, on the used material. The results from our investigation are in agreement with the findings of BEDE, 1980; KRALJEVIĆ–BALALIĆ and BOROJEVIĆ, 1985; СИЛИС *и др.*, 1988; BEDE *et al.*, 1990; PETROVIĆ *et al.*, 1995; KRALJEVIĆ–BALALIĆ *et al.*, 2001, where the plant height was mostly inherited dominantly, partially dominant and intermediary, with heterosis in very few combinations.

Combining ability analysis - Combining ability analysis was carried out using mean values of parents and their F_1 and F_2 hybrids. It was found to be highly significant in both generations, which means both additive and non-additive type of gene actions being responsible for the inheritance of the examined character (Table 3). However, additive component of genetic variance was 4.25 times higher in F_1 and 12.02 times in F_2. This ratio emphasized the importance of additive gene effect.

The obtained results of this analysis support the reports of BEDE, 1980; MIHALJEV and KRALJEVIĆ–BALALIĆ, 1981; SINGHAL *et al.* 1985; KRALJEVIĆ–BALALIĆ and BOROJEVIĆ, 1985, GUPTA *et al.* 1988; БЕБЯКИН и КОРОБОВА, 1989; BEDE *et al.*, 1990; MENON and SHARMA, 1994; MANN and SHARMA, 1995; LARIK et al., 1995; WAGOIRE *et al.*, 1998. Only in the findings of JAIN and RATHORE (1985) the SCA variance was higher than the GCA one, which indicates non-additive gene action (dominance and epistasis) of inheritance. Compared with the reports of the previous authors, our results do not agree with the ones of Силис и Шмакова (1986) where only GCA variances were significant for plant height.

Table 3. ANOVA for combining ability in the F_1 and F_2

Sources of variance	Degrees of freedom	Fe	
		F_1	F_2
GCA	6	45.06**	35.26**
SCA	21	10.61**	2.93**
E	54		
GCA/SCA		**4.25**	**12.02**

Range distribution of the best and worst combiners for this character was the same in both generations. Among the parents, the highest negative GCA value had the variety Milenka. Good combiners are also the varieties Sava, Radika and Agrounija as well, which GCA values are significant only in F_1 generation (Table 4).

Table 4. General combinig ability of the parents

Parents		GCA - F_1	Range	GCA - F_2	Range
Radika		-1.46**	3	-1.24	2
Milenka		-2.68**	1	-3.41**	1
Agrounija		-1.16*	4	-1.22	3
N. Rana 2		1.77	6	1.17	6
Sava		-1.82**	2	-1.13	4
SK-136		0.53	5	0.82	5
N. Crvena		4.81	7	5.01	7
SE		0.55		0.64	
LSD	0.05	1.09		1.28	
	0.01	1.46		1.70	

The estimated SCA effects of different crosses are shown in Table 5. Negative SCA values had 11 combinations in F_1 and 10 in F_2 generation, out of 21 combinations in total. However, only 6 of them in F_1 were significant and 2 in F_2. Three crossings with high SCA values were obtained from N. Crvena, as one of the parents, which variety was the worst combiner for this trait. The other parents of these crossings had good general combining ability. Only the combination N. Rana 2 x SK-136 with high SCA value was obtained as a result of crossing of parents that are both bad combiners. That proves that promising combinations could be also obtained from crossing of genotypes with bad GCA.

Table 5. Specific combining ability of the hybrid combinations

Hybrid combinations		SCA F_1	SCA F_2
Radika x Milenka		1.56	3.52
Radika x Agrounija		-0.46	1.57
Radika x N. Rana 2		4.61	0.37
Radika x Sava		2.47	2.18
Radika x SK-136		-2.25	-2.16
Radika x N. Crvena		-6.40**	-4.22*
Milenka x Agrounija		3.43	1.69
Milenka x N. Rana 2		-1.97	-1.92
Milenka x Sava		-0.44	0.58
Milenka x SK-136		3.44	0.11
Milenka x N. Crvena		-3.51**	-2.98
Agrounija x N. Rana 2		-7.83**	-2.94
Agrounija x Sava		5.10	1.64
Agrounija x SK-136		-1.85	-2.40
Agrounija x N. Crvena		0.40	-0.10
N. Rana 2 x Sava		1.60	-1.24
N. Rana 2 x SK-136		-3.99**	-3.55*
N. Rana 2 x N. Crvena		4.47	4.76
Sava x SK-136		-5.95**	2.05
Sava x N. Crvena		-3.37*	-1.62
SK-136 x N. Crvena		3.92	1.40
SE		1.45	1.69
LSD	0.05	2.90	3.38
	0.01	3.85	4.49

Regression analysis (V_r/W_r) - The regression analysis graphs for F_1 and F_2 generations for plant height are presented in Fig. 1 and Fig. 2. The regression coefficients significantly differed from zero in both generations (b=0.921±0.119 in F_1 and b=0.990±0.096 in F_2), showing the absence of non-allelic interaction or epistasis in the crosses of this diallel set. In F_1 generation, the regression line cut the Wr axis below the point of origin, indicating overdominant inheritance for this character, considering all combinations, which corresponds with the results of BEDE, 1980; MIHALJEV and KRALJEVIĆ–BALALIĆ, 1981 and БЕБЯКИН и КОРОБОВА, 1989. In F_2 generation the cut is above the point of origin, which means partially dominant inheritance, and supports the findings of СИЛИС *и др.*, 1988; GUPTA *et al.*, 1988 and others.

The arrays that correspond to parents were similarly distributed along the regression line, in both hybrid generations, and they indicate that the parents were genetically divergent for the analysed trait. The varieties Radika, Milenka, Sava and Agrounija possessed an excess of dominant genes over recessive, while the variety N. Crvena, according to its array, which is far away from the origin had the highest quantity of recessive genes.

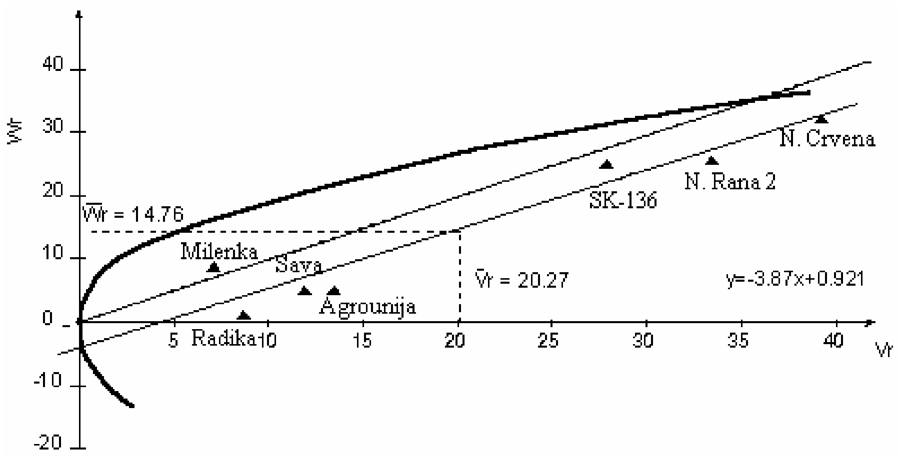

Fig.1. V_r/W_r regression for plant height in wheat in the F_1 generation

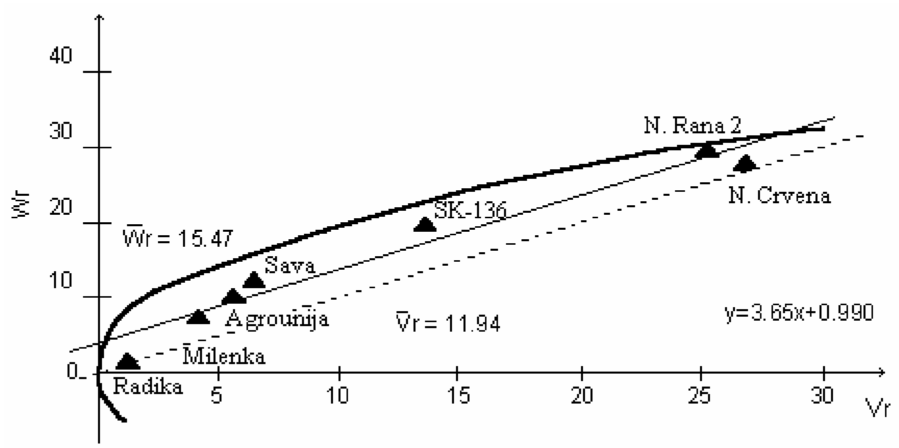

Fig.2. V_r/W_r regression for plant height in wheat in the F_2 generation

CONCLUSION

The genotypes included in this analysis were significantly different according their plant height. The variety Milenka had lowest plant height (58.50cm) and Novosadska Crvena had highest (77.00cm).

The mode of inheritance of plant height in F_1 and F_2 depended on the combination (dominant, partially dominant, intermediary and overdominant).

Regression analysis (Vr/Wr) showed that regression coefficient (b±sb) in F_1 and F_2 generation was not significantly different from unity, which indicates absence of interallelic interaction for plant height.

Both additive and non-additive gene effect was responsible for the inheritance of plant height according to the analysis of variance for combining ability where it was found that GCA and SCA were highly significant in both generations. GCA was few times higher than SCA, which points to the higher importance of additive component of genetic variance.

Best combiners for this character are Milenka, which had the highest negative GCA value in both generations, and Sava, Radika and Agrounija.

Almost half of the hybrid combinations had negative SCA, but only few of them were significant. They were obtained by crossing of one parent with good GCA and one with poor, or by crossing of two poor combiners.

Regression line intercepts Wr axis below the origin in F_1 indicating overdominant inheritance, while in F_2 the cut was above the origin, i.e. the inheritance of plant height was partially dominant.

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REFERENCES

БЕБЯКИН З.М. и Н.И. КОРОБОВА (1989): Генные взаимодеиствия и эффекты комбинационной способности сортов озимой пшеницы по компонентам урожая. Цитология и генетика *23* (1), 23-26.

BEDE M. (1980): Efekat gena i kombinatorni sposobnosti mutanata ozime pšenice u dijalelnom križanju. Doktorska disertacija. Zbornik radova, God. XI, Sv. 1. Osijek.

BEDE M., G. DREZNER i J. MARTINČIĆ (1990): Genetska osnova stvaranja novih sorti ozime pšenice. Savremena Poljoprivreda, *38* (1-2), 131-137.

BOROJEVIĆ S. (1965): Način nasleđivanja i heritabilnost kvantitativnih svojstava u ukrštanjima raznih sorti pšenice. Savremena poljoprivreda *7-8*, 587-607.

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

GUPTA S., Z. AHMAD, and R.B. GUPTA (1988). A Study of Gene Effects for Some Quantitative Traits by Different Diallel Models in Wheat (*Triticum aestivum* L.). Genetika, *20* (1), 40-52.

HAYMAN B.I. (1954): The theory and analysis of diallel crosses. Genetics, *39*, 789-809.

JAIN A.K. and R.K.S. RATHORE (1985): Evaluation of Combining Ability in Exotic Restorers and Indian Cultivars of Wheat (*Triticum aestivum* L.). Genetika *17* (3), 245-251.

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

KRALJEVIĆ–BALALIĆ M. i S. BOROJEVIĆ (1985): Nasleđivanje visine stabljike i žetvenog indeksa pšenice. Arhiv za poljoprivredne nauke *46* (163), 201-290.

KRALJEVIĆ-BALALIĆ M., A.J. WORLAND, E. PORCEDDU, and M. KUBUROVIĆ (2001): Variability and gene effects in wheat. In: genetics and breeding of small grains, Belgrade (Eds. Quarrie S.A. *et al*.,), 9-49.

LARIK A.S., A.R. MAHAR, and H.M.I. HAFIZ (1995): Heterosis and Combining Ability Estimates in Diallel Crosses of Six Cultivars of Spring wheat. Wheat Information Service, *80*, 12-19.

MANN M.S. and S.N. SHARMA (1995): Combining Ability in the F_1 and F_2 generations of diallel cross in macaroni wheat (*Triticum durum* Desf.). Indian Journal of Genetics *55* (2), 160-165.

MATHER K. and J.L. JINKS (1971): Biometrical genetics. Sec. Ed., Chapman and Hall, London.

MENON Uma and S.N. SHARMA (1994): Combining Ability Analysis for Yield and its Components in Bread Wheat Over Environments. Wheat Information Service, *79*, 18-23.

MIHALJEV I. i M. KRALJEVIĆ–BALALIĆ (1981): Genetska analiza kvantitativnih svojstava pšenice. Genetika, *13* (3), 265-280.

PETROVIĆ S. i A.J. WORLAND (1992). Geni reduktori visine stabljike. I. Determinacija prisustva u Jugoslovenskim sortama pšenice. Savremena poljoprivreda , *40* (6), 81-85.

PETROVIĆ S., M. KRALJEVIĆ–BALALIĆ i P. RONĆEVIĆ (1995): Nasledjivanje glavnih komponenti prinosa kod jare pšenice. Abstrakti. Prvi Simpozijum oplemenjivanje organizama sa medjunarodnim učešćem. Vrnjačka Banja.

СИЛИС Д.Я., А.Г. КАНЕВСКАЯ, Т.В. ШМАКОВА и Е.Н. Миронов (1988): Влияние экологичњеских факторов на генетический контроль количестенных признаков озимой мягкой пшеницы. Высота растения. Генетика *24* (10), 1857-1866.

СИЛИС Д.Я. и Т.В. ШМАКОВА (1986): Влияние зкологических факторов на комбинационую способность сортов озимой мягкой пшеницы. Вестник сельскохазяиственой науки, Москва, *12*, 57-62.

SINGH S.S., J.B. SHARMA, NANAK CHAND and D.N. SHARMA (2001). Breaking yield barriers in wheat – new plant type designed. Wheat Information Service , *93*, 22-26.

SINGHAL N.C., M.P. SINGH, and R.B. MEHRA (1985). Genetic Analysis of Components of Plant Height in Bread Wheat. Genetika, *17*, 153-63.

WAGOIRE W.W., O. STOLEN, and R. ORTIZ (1998). Combining ability analysis in bread wheat adapted to the East African highlands. Wheat Information Service, *87*, 39-41.

DIALELNA ANALIZA ZA VISINU STABLJIKE OZIME PŠENICE

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Izvod

Ispitivan je efekat gena i kombinirajuće sposobnosti za visinu stabljike kod pšenice u seriji dialelnih F_1 i F_2 hibrida šest sorti i jedne linije. Roditelji su se značajno razlikovali u srednjim vrednostima za ispitivano svojstvo. Najmanju prosečnu vrednost za visinu je imala sorta Milenka (58,5cm), a najveću Novosadska Crvena (77,0cm). Način nasleđivanja zavisio je od kombinacije ukrštenja (intermedijaran, parcijalno dominantan, dominantan i superdominantan). Kako opšte, tako i specifične kombinirajuće sposobnosti imale su visoko signifikantne varijanse u obe generacije. U većini slučajeva kombinacije sa visokom SKS imale su bar jednog roditelja sa visokim vrednostima OKS. Roditelj Milenka se pokazao kao najbolji opšti kombinator za visinu stabljike. Regresiona analiza (Vr/Wr) je pokazala odsustvo interalelne interakcije u obe generacije. Nasleđivanje je bilo superdominantno u F_1 i parcijalno dominantno u F_2. Milenka je posedovala najviše dominantnih gena za visinu biljke, dok je Novosadska crvena imala najviše recesivnih gena za visinu stabljike pšenice.

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