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Combining Abilities for Grain Weight per Plant in Two-Rowed Barley Hybrids

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Abstract: 10 F_1 and F_2 hybrids were obtained through diallel crossing of five divergent two-rowed barley cultivars (Vada, Djerdap, NS-293, Jagodinac and Sladoran) for exami-nation of the mode of inheritance and combining abilities for grain weight per barley plant.

The inheritance mode was evaluated using the test of the significance of mean values of generations with respect to the parental average. The analysis of variance of combining abilities was made following the method 2, mathematical model I, for the incomplete diallel.

Different modes of inheritance of grain weight per plant in the F_1 and F_2 generations were determined, being intermediary partial dominance, dominance or superdominance.

Highly significant differences for the general (GCA) and special (SCA) combining abilities in the F_1 and F_2 generations showed that the grain weight per plant in these investigations was dependent on genes with additive and non-additive or dominant effects. The GCA variance was higher in both the F_1 and F_2 generation than the SCA variance. Positive GCA values were also determined with the Vada and Djerdap cultivars, the cultivar Jagodinac in the F_1 and F_2 generations being the best general combiner for grain weight per plant.

Key words: barley, grain weight per plant, combining abilities.

Introduction

Barley yield is a highly complex trait resulting from the genotype and environmental effects throughout the life cycle of the plant. As yield increase is based also on higher grain dry matter productivity, breeding for higher biomass and higher grain weight per plant is a way to increase barley yield (Pržulj and Momcilovic 2000). Analysing the 1920-1985 period, Bekerrouy (1987) established the biological yield increase and grain yield increase to be 22.5 kg/ha and 15.7 kg/ha, respectively.

Biological yield includes grain weight and weight of the remaining vegetative part of the stalk. Grain weight per plant is a complex trait controlled by a number of genes the expression thereof being also highly dependent on the cultivar adaptation to environmental conditions (Paunovic et al., 2007). In their two- and multiple-rowed barley population studies, Tseng and Poelhman (1974) reported the greater biomass and higher grain weight per plant in multiple-rowed barley, as opposed to Lalic (1988) who underlined the increasingly more equalised yield of two- and multiple-rowed barley.

The information on the genetic determination of grain weight per plant and combining abilities of parents for the trait concerned should help breeders develop genotypes with a higher genetic yield potential.

Material and Method

Five parental cultivars and their F_1 and F_2 hybrids obtained by diallel crossing were analysed in the research. The parents selected were divergent in terms of the trait investigated.

Genotypes developed in different breeding centres, being Vada, Djerdap, NS-293, Jagodinac and Sladoran, were selected for the crossings.

The crossings were made in the spring of 1997 using diallel crossing method (without reciprocal) with ten hybrid combinations in the F_1 generation being obtained. The hybrid seed was sown that year in October following a thin sowing principle (in 1m long rows at an intra- and inter-row spacings of 10 cm and 20 cm, respectively) resulting in the obtainment of the F_2 generation seed. A simultaneous crossing between the parental cultivars was performed and the F_1 generation hybrid seed was obtained. The whole of the generation material was sown in the autumn of 1999 in order to ensure an equal effect of environmental factors. The trial was set up at an experimental field of the Small Grains Research Centre in Kragujevac according to a randomised block design in three replications. The material was sown following the thin sowing principle in 1m long rows with inter- and intra-row spacings of 20 cm and 10 cm, respectively, thereby ensuring equal growing conditions for all the generations being monitored.

Standard mean parameters ($\bar{x}$), standard error of the mean ($S\bar{x}$) and coefficient of variability (V%) were calculated in order to examine the variability and mode of inheritance of traits for the F_1 and F_2 generation parents.

The LSD test was used to test the significance of differences in mean values of the trait examined. Since the F_1 and F_2 generation parents were cultivated in the same year, the heritability values (h^2) were calculated following the formula.

$$h^2 = \frac{\sigma F2 - \frac{\sigma^2 P_1 + \sigma^2 P_2 + \sigma^2 F_1}{3}}{\sigma^2 F_2}$$

The analysis of variance of combining abilities was made after the method 2, mathematical model I, for the incomplete diallel (Griffing 1956).

Research Results

Means and variability of grain weight per barley plant

The parents used for the crossings significantly differed in grain weight per barley plant. The highest value of the trait was determined in the Vada cultivar (13 g) and the lowest one with the Sladoran cultivar (8.9 g).

The F_1 generation values were established to be within parental cultivars or were higher than the higher parent value. The lowest and highest grain weights per plant were determined in the Djerdap x Sladorad (10.8 g) and Djerdap x NS-293 (14.5 g) crossing combinations, respectively. The lowest grain weight per plant in the F_2 generation was recorded with the Djerdap x Sladoran (18.5 g) generation and the highest weight with the Vada x NS-293 (14.6 g) combination.

The variability coefficient values suggested a somewhat higher variability of parental cultivars. The lowest variability was recorded with the Vada cultivar (V=20.30%) and the highest one with the cv. NS-293 (38.8%). Such high variability values of the parental cultivars could be due to the high environmental effect on the said trait. The F_1 generation variability was lower than the parental one, ranging from V=12.2% in the Vada x Sladoran to V=36.9% in the NS-293 x Jagodinac combination.

The high F_2 generation variability was indicated by the variation coefficient value ranging from 31% to 42.54% in the Vada x NS-293 and Vada x Jagodinac combinations, respectively (Tab. 1.).

Mode of inheritance and heritability of grain weight per plant

Different modes of inheritance of grain weight per plant in the F_1 generation were determined. Intermediary inheritance was recorded in the Vada x NS-293 and Djerdap x Sladoran combinations, partial dominance in the Jagodinac x Sladoran one and dominance or supedominance in the rest of the combinations.

Intermediary, partially dominant, dominant or superdominant inheritance was expressed in the F_2 generation. Superdominance (negative heterosis) in the inheritance of the grain weight per plant was determined to be present in the Djerdap x Jagodinac combination. Negative dominance was recorded in the Djerdap x Sladoran and Djerdap x NS-293 crossing combinations. The obtained heritability values for grain weight per plant were different varying from 2% to 64%, depending on the crossing combination present (Tab. 1.).

Tab. 1. Statistical parameters and inheritance of grain
weight per plant in barley

Combination	Generation	Plant no.	$\bar{X} \pm s_{\bar{x}}$	V (%)	h^2
Vada × Djerdap	P_1	30	13.0 ± 048	20.3	64.5
	F_1	30	10.2 ± 0.38 ***pd***	20.4	
	F_2	90	11.8 ± 0.49 ***-d***	39.1	
	P_2	30	11.7 ± 0.62	29.3	
Vada × NS-293	P_1	30	13.0 ± 0.48	20.3	46.90
	F_1	30	11.0 ± 0.58 ***i***	29.2	
	F_2	90	14.6 ± 0.48 ***sd***	31.2	
	P_2	30	9.2 ± 0.65	38.8	
Vada × Jagodinac	P_1	30	13.0 ± 0.48	20.3	50.00
	F_1	30	12.6 ± 0.64 ***i***	27.9	
	F_2	90	10.6 ± 0.46 ***-sd***	42.5	
	P_2	30	12.2 ± 0.60	26.7	
Vada × Sladoran	P_1	30	13.0 ± 0.42	20.3	55.00
	F_1	30	13.6 ± 0.30 ***d***	12.2	
	F_2	90	10.5 ± 0.37 ***i***	34.0	
	P_5	30	8.9 ± 0.47	28.7	
Djerdap × NS-293	P_2	30	11.7 ± 0.62	29.3	-
	F_1	30	14.5 ± 0.57 ***sd***	21.6	
	F_2	90	9.0 ± 0.36 ***pd***	38.6	
	P_3	30	9.2 ± 0.65	38.8	
Djerdap × Jagodinac	P_2	30	11.7 ± 0.62	29.3	2.05
	F_1	30	13.8 ± 0.58 ***sd***	23.1	
	F_2	90	9.2 ± 0.39 ***-sd***	40.0	
	P_4	30	12.2 ± 0.60	26.7	
Djerdap × Sladoran	P_2	30	11.7 ± 0.62	29.3	13.88
	F_1	30	10.8 ± 0.58 ***i***	29.5	
	F_2	90	8.5 ± 0.35 ***-d***	39.3	
	P_5	30	8.9 ± 0.47	28.7	
NS-293 × Jagodinac	P_3	30	9.2 ± 0.65	38.8	25.28
	F_1	30	13.8 ± 0.93 ***sd***	36.8	
	F_2	90	14.3 ± 0.54 ***sd***	32.2	
	P_4	30	12.2 ± 0.60	26.7	
NS-293 × Sladoran	P_3	30	9.2 ± 0.65	38.8	3.00
	F_1	30	10.0 ± 0.57 ***sd***	31.3	
	F_2	90	9.8 ± 0.33 ***sd***	32.2	
	P_5	30	8.9 ± 0.47	28.7	
Jagodinac × Sladoran	P_4	30	12.2 ± 0.60	26.7	37.67
	F_1	30	11.9 ± 0.43 ***pd***	19.6	
	F_2	90	11.6 ± 0.44 ***pd***	36.2	
	P_5	30	8.9 ± 0.47	28.7	

i – intermediary; pd – partial dominance; d – dominance; sd – superdominance

Analysis of variance of combining abilities

The analysis of variance of combining abilities showed highly significant differences in the GCA and SCA in the F_1 and F_2 combinations indicating that grain weight per plant was controlled by additive and dominant gene action. The GCA values in both hybrid generations of the research were higher than the SCA ones (Tab. 2.).

Tab. 2. ANOVA for combining abilities of grain weight per plant

Source of variation	Generation	DF	MS	F_e	F_t 0.01	F_t 0.05
GCA		4	4.88	24.75**	4.08	2.72
SCA	F_1	10	4.41	22.38**	3.04	2.19
E		28	0.20			
GCA/SCA				1.09		
GCA		4	6.31	21.55**	4.08	2.72
SCA	F_2	10	3.96	13.53**	3.04	2.19
E		28	0.29			
GCA/SCA				1.59		

The Jagodinac cultivar in the F_1 and F_2 generations was determined to be the best general combiner for grain weight per plant. The positive GCA values were also recorded with the Vada and Djerdap cultivars. (Tab. 3.).

Tab. 3. GCA values for grain weight per plant

Parents	GCA values in F_1	Rank	SE	GCA values in F_2	Rank	SE
Vada	0.427	2		0.712*	2	
Djerdap	0.299	3		0.380	3	
NS-293	-0.362	4	0.150	-0.468	4	0.183
Jagodinac	0.895**	1		0.815**	1	
Sladoran	-1.258**	5		-1.439**	5	
F_1 LSD	0.05	0.486		F_2 LSD	0.05	0.592
	0.01	0.656			0.01	0.799

The highest value of special combining abilities, which was significantly higher than the other ones, in the F_1 and F_2 generations was determined with the Vada x Sladoran, Djerdap x NS-293, Djerdap x Jagodinac crossings (Tab. 4.).

Tab. 4. SCA values for grain weight per plant

Crossing combination	F_1 SCA	SE	F_2 SCA	SE

	values		values	
Vada x Djerdap	-0.947		-2.270**	
Vada x NS-293	-1.085		-1.169	
Vada x Jagodinac	-0.599		-0.732	
Vada x Sladoran	3.504**		3.802**	
Djerdap x NS-293	3.572**	0.306	3.217**	0.373
Djerdap x Jagodinac	1.518**		1.148	
Djerdap x Sladoran	-0.739		-1.078	
NS-293 x Jagodinac	0.833		0.938	
NS-293 x Sladoran	-0.657		-1.084	
Jagodinac x Sladoran	0.176		-0.454	
F_1 LSD	0.05 1.086 0.01 1.466		F_2 LSD	0.05 1.325 0.01 1.787

Discussion

The dominance of parents with lower grain weight per plant and the dominance or partial dominance of parents with a higher value of the trait were exhibited in the inheritance of grain weight per plant in certain crossing combinations. The superdominant inheritance of the grain weight per plant was also reported by Madic (1995), Madic et al. (2000), Singh and Singh (2001), in barley and Prodanovic (1992), Knezevic and Kraljevic-Balalic (1993), in wheat.

The analysis of variance of combining abilities showed highly significant differences for general and special combining abilities. The same results were reported by Bhantnagar and Sharma (1995 and 1998) in their analysis of the diallel crossing of 10 parental cultivars. The authors also pointed out more significant values of special combining abilities. Similar results were likewise obtained by Phogat et al. (1995) and Pal and Singh (1996) in their diallel crossings of 7 parental barley cultivars.

Bouzerzour and Djakoune (1998) and Zeng and Chen Liang Zheng (2001) established significant variances of general and special combining abilities. Higher values of general combining abilities were stressed by Bhatnagar and Sharma (1998), Zeng and Chen Liang Zheng (2001)**,** as opposed to the prevailing dominant genetic effects in the grain yield inheritance being underlined by Bouzerzour and Djakoune (1998).

The genotypes with the highest mean values determined were recorded to be the best combiners for grain yield per plant. The best combinations were obtained by crossing of one parent with a high GCA value and one parent with a low GCA value (Madic 1995). Grain weight per plant and biological yield were highly variable traits greatly dependent on other yield components (productive tillering, plant height, spike length, grain number and grain weight per spike).

Conclusion

Based on the research results the following conclusions can be drawn:

The examined cultivars and their progenies in F_1 and F_2 generations differed significantly in the means for grain yield per plant. The lowest mean was recorded in the Sladoran cultivar and the highest in the Vada.

Different modes of inheritance of the grain weight per plant trait in the F_1 and F_2 generation were registered, being intermediary partial dominance, dominance or superdominance, depending on the crossing combinations.

The highly significant differences for general and special combining abilities in F_1 and F_2 generations suggest that the grain weight per plant was determined by genes with additive and non-additive or dominant effects.

The GCA variance was found to be higher in both F_1 and F_2 generation than the SCA variance. Positive GCA values were found with the Vada and Djerdap cultivars. The Jagodinac cultivar was the best general combiner for grain weight per plant in F_1 and F_2 generations, and it can be used as a parent in barley breeding for increased grain yield per plant.

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KOMBINACIONE SPOSOBNOSTI MASE ZRNA PO BILJCI KOD HIBRIDA DVOREDOG JEČMA

- originalni naučni rad -

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Rezime

Dialelnim ukrštanjem pet divergentnih sorti dvorednog ječma (Vada, Đerdap, NS-293, Jagodinac i Sladoran) dobijeno je 10 F_1 i F_2 hibrida, radi proučavanja načina nasleđivanja i kombinacionih sposobnosti za masu zrna po biljci ječma..

Za ocenjivanje načina nasleđivanja primenjen je test signifikantnosti srednjih vrednosti generacija u odnosu na roditeljski prosek (Kraljević-Balalić, 1991). Analiza varijanse kombinacionih sposobnosti je urađena po metodu 2, matematički model I, za nepotpuni dialel (Griffing, 1956).

Nasleđivanje mase zrna po biljci u F_1 i F_2 generaciji je različito, intermedijarno ispoljena parcijalna dominacija, dominacija ili superdominacija.

Visoko signifikantne razlike za opšte (OKS) i posebne (PKS) kombinacione sposobnosti u F_1 i F_2 generaciji, ukazuju da je masa zrna po biljci u ovim istraživanjima uslovljena genima sa aditivnimm i neaditivnim, odnosno dominantnim delovanjem. Varijansa OKS je veća i u F_1 i F_2 generaciji od varijanse PKS. Pozitivne vrednosti OKS imale su i sorte Vada i Đerdap, a najbolji opšti kombinator za masu zrna po biljci je sorta Jagodinac u F_1 i F_2 generaciji.