UDC: 633.16: 631.575.3
original scientific paper

Acta Agriculturae Serbica, Vol. VII, 14 (2002) 17-24

Acta Agriculturae Serbica
FACULTY OF AGRONOMY • ČAČAK •

Variability and Variance Components for Harvest Index in Winter Barley

Milomirka Madic, M. Kuburovic
Faculty of Agronomy Cacak, Serbia and Montenegro

Marija Kraljevic-Balalic, S. Petrovic
Faculty of Agriculture, Novi Sad, Serbia and Montenegro

Abstract: By diallel crossing of five divergent cultivars of two-rowed barley (Vada, Djerdap, NS-293, Jagodinac and Sladoran), 10 F_1 and F_2 hybrids were selected in order to study the variability, mode of inheritance, gene effect, components of genetic variance and heritability for harvest index. The evaluation of the mode of inheritance was done on the basis of the test of significance of mean generation values compared to the parent average (*Kraljevic-Balalic, 1991*) and the analysis of the genetic variance components and the regression VrWr analysis were made according to the method of *Mather and Jinks (1971)*.

As far as the inheritance of the harvest index in the F_1 and F_2 generations is concerned, partial dominance, dominance or overdominance were exhibited. In two crosses in the F_1 generation, dominance or overdominance of the parents with a lower value of the investigated trait was displayed.

The genetic variance components and the average degree of dominance indicated overdominance in the inheritance of the investigated trait.

The obtained value of the harvest index heritability was low (26.7 %), being the result of a great effect of environmental factors on the expression of the trait.

Key words: Barley, harvest index, variability, inheritance, gene effect, regression, heritability.

Introduction

Grain yield as a complex trait has been the subject matter of numerous investigations. However, separate studies of some of its components, their degree and mode of inheritance have been more frequently conducted.

Bearing in mind the complexity of yield as a trait, the polygenic mode of inheritance and various interactions, *Przulj and Momcilovic (1998)* stress that great progress in selection can be made even by smaller increases of barley yield and quality. According to *Kraljevic-Balalic and Borojevic (1985)*, the harvest index is recognized as a parameter determining the ratio between the economic yield (grain yield) and biological yield or total biomass (yield of grain and straw). *Matiniello et al. (1987)* conclude that grain yield increase of new two-rowed barley cultivars depends equally on both biomass increase and harvest index improvement, whereas grain yield increase of multiple row barley is more dependent on the harvest index improvement. An increase in the harvest index in a considerable number of plants is one of the biggest genetic changes being mostly the result of the stem height reduction. The stem height reduction results in higher lodging resistance, allowing plant cultivation at high density and higher rates of nutrients and causing increase of yield per surface area unit *(Borojevic 1981)*.

Kraljevic-Balalic et al. (2001) have established that the increase of harvest index up to 0.50 or more can be one of the ways to increase the yield because improved harvest index results in an increased physiological capacity of photosynthates and their translocation into economically important organs.

Information on the genetic determination of the harvest index should help breeders in the selection of genotypes with higher genetic yield potential compared to the current ones. A number of researchers (*Kertesz, 1983; Lalic, 1988; Ore, 1991*) point out also the possibility of using harvest index in early generations of barley breeding, bearing in mind the increase of harvest index and the yield increase.

Material and Method

Examinations were made of the material of five parent cultivars and their hybrids of the F_1 and F_2 generations obtained by diallel crossing. The parent choice was based on the knowledge of the trait concept, the parents being divergent in certain traits.

The following genotypes originating from different selection centres were chosen for the crossing: Vada, Djerdap, NS-293, Jagodinac and Sladoran.

The crossings were carried out in the spring of 1997 by the diallel crossing method (without reciprocal crossings) and ten hybrid combinations in the F_1 generation were obtained. The hybrid seeding was performed in October the same year following the sparse seeding principle (in 1 m long rows at the inter-grain spacing in a row of 10 cm and inter-row spacing of 20 cm) and the seed for the F_2 generation was obtained. Crossing between parent cultivars was again simultaneously performed and hybrid seed for F_1 generation was obtained. In autumn 1999, material was planted for all generations in the same year, and the effect of environmental factors was equal for both generations. The trial was

established at the Experimental Field of the Small Grains Centre in Kragujevac using a randomized block design with three replications. The seeding was performed following the principle of sparse seeding in rows of 1 m length, at an inter-row spacing of 20 cm and an inter-plant spacing in a row of 10 cm. Equal growing conditions were provided for all the plants in the examined generations.

The plants were cultivated using the usual cultural operations and weed control included wetting and hoeing.

A random sample of plants in the full maturity stage was taken for analysis by generations:

- a total of 30 plants for all parents and F_1 combinations (3x10)
- a total of 150 plants for all F_2 combinations (3x50).

The harvest index analysis was made. Namely, total plant mass (aboveground organs) was measured first, followed by the yield per plant in grams. The harvest index was computed as the ratio between grain mass and total biological yield *(Kraljevic-Balalic and Borojevic, 1985)*.

In order to examine the variability and mode of trait inheritance for the parents and the F_1 and F_2 generations, the usual statistical parameters were calculated, i. e. mean value ($\bar{x}$), standard deviation (σ), standard error of the mean ($S\bar{x}$) and the coefficient of variability (V%).

The significance of differences between mean values of the investigated trait was estimated using the LSD test.

The evaluation of the mode of inheritance was done on the basis of the test of significance of mean generation values compared to the parent average (*Kraljevic-Balalic, 1991)*.

The heritability values (h^2) were obtained according to the formula of Mather (after Allard, 1960) because the parents and the F_1 and F_2 generations were cultivated in the same year.

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

The genetic variance components from the diallel crossings were calculated according to the method of *Jinks (1954), Hayman (1954)* and *Mather and Jinks (1971)*.

Research Results

Mean Values and Harvest Index Variability

The cultivars selected for the diallel crossings differed significantly in terms of harvest index mean values. The lowest and highest mean values of the harvest index were obtained by the cultivars Sladoran (31.4 %) and Jagodinac (48.6 %), respectively. The harvest index in the F_1 generation ranged from 34.9 % in the Djerdap x Sladoran cross to 44. 4 % in the Vada x Jagodinac cross. The

lowest harvest index in the F_2 generation was recorded in the Djerdap x Sladoran cross (40. 2 %) and the highest one in the Vada x NS-293 (48.6 %), Tab. 1.

Table 1. Statistical parameters and harvest index inheritance in barley

Cross	Generation	No. of Plants	$\bar{X} \pm s_{\bar{x}}$	S	V (%)	h^2
K-1	P_1	30	41.7 ± 1.09	5.96	14.29	
Vada	F_1	30	36.1 ± 1.44 ***-od***	7.90	21.90	
x	F_2	90	41.6 ± 0.82 ***d***	7.84	18.83	34.24
Djerdap	P_2	30	40.1 ± 0.88	4.83	12.04	
K-2	P_1	30	41.7 ± 1.09	5.96	14.29	
Vada	F_1	30	36.2 ± 1.68 ***-d***	9.19	26.06	
X	F_2	90	48.6 ± 1.34 ***od***	7.44	15.30	-
NS-293	P_3	30	37.3 ± 1.44	7.80	20.91	
K-3	P_1	30	41.7 ± 1.09	5.96	14.29	
Vada	F_1	30	46.4 ± 1.30 ***od***	7.15	15.30	
X	F_2	90	45.3 ± 0.76 ***od***	7.25	16.00	22.04
Jagodinac	P_4	30	44..6 ± 1.09	5.99	13.42	
K-4	P_1	30	41.7 ± 1.09	5.96	14.29	
Vada	F_1	30	45.5 ± 1.82 ***od***	9.96	21.90	
X	F_2	90	44.3 ± 0.68 ***od***	6.47	14.59	-
Sladoran	P_5	30	31.4 ± 0.91	4.96	15.80	
K-5	P_2	30	40.1 ± 0.88	4.83	12.04	
Djerdap	F_1	30	38.1 ± 1.02 ***pd***	5.59	14.67	
x	F_2	90	45.5 ± 0.74 ***od***	6.98	15.33	15.30
NS-293	P_3	30	37.3. ± 1.44	7.80	20.91	
K-6	P_2	30	40.1 ± 0.88	4.83	12.04	
Djerdap	F_1	30	41.3 ± 1.01 ***pd***	5.56	13.50	
x	F_2	90	43.0 ± 0.90 ***pd***	8.54	19.84	47.28
Jagodinac	P_4	30	44.6 ± 1.09	5.99	13.43	
K-7	P_2	30	40.1 ± 0.88	4.83	12.04	
Djerdap	F_1	30	34.9 ± 1.13 ***pd***	6.22	17.91	
x	F_2	90	40.2 ± 0.89 ***d***	8.45	21.00	59.61
Sladoran	P_5	30	31.4 ± 0.91	4.96	15.80	
K-8	P_3	30	37.3 ± 1.44	7.80	20.91	
NS-293	F_1	30	43.9 ± 1.32 ***pd***	7.19	16.38	
x	F_2	90	43.1 ± 0.69 ***pd***	6.63	15.39	-
Jagodinac	P_4	30	44.6 ± 1.09	5.99	15.80	
K-9	P_3	30	37.3 ± 1.44	7.80	20.91	
NS-293	F_1	30	37.6 ± 1.14 ***d***	6.23	16.59	
x	F_2	90	42.4 ± 0.80 ***od***	7.58	17.86	27.90
Sladoran	P_5	30	31.4 ± 0.91	4.96	15.80	
K-10	P_4	30	44.6 ± 1.09	5.99	13.43	
Jagodinac	F_1	30	41.4 ± 1.21 ***pd***	6.61	16.00	
x	F_2	90	42.5 ± 0.79 ***pd***	7.46	17.54	22.53
Sladoran	P_5	30	31.4 ± 0.91	4.96	15.80	

pd – partial dominance; ***d*** – dominance; ***od*** –overdominance

F_1	LSD	0.05	2.79		F_2	LSD	0.05	2.38
		0.01	3.76				0.01	3.22

The harvest index variability differed between the cultivars, the lowest and the highest one being determined in the Djerdap (12 %) and NS-293 (20. 9 %) cultivars, respectively.

The variability coefficient for the F_1 generation ranged from 13.5 % to 21. 9 %. The variability coefficient and standard deviation indicated similar or somewhat lower variability of the F_2 generation as compared to the parents and the F_1 generation. The lowest variability was recorded in the Vada x Sladoran cross (14. 6 %) and the highest one in the Djerdap x Sladoran cross (21 %). The high variability recorded in the parent cultivars and the F_1 generation is an indication of a great environmental effect on the expression of the trait (Tab. 1). The results obtained are in agreement also with the similar results determined in wheat by *Zecevic and Knezevic (1997)*, whereas *Ore (1991)* pointed out somewhat higher values of the variability of the harvest index of the parents and the F_1 generation, analyzing different crossings between spring and winter barley.

Mode of Inheritance and Harvest Index Heritability

There are different modes of inheritance of the harvest index in the F_1 generation depending on the crossing combination. In the Vada x Djerdap cross a highly significant overdominance of the parents with lower harvest index was expressed, whereas in the Vada x NS-293 cross, the dominance of the parents with lower harvest index was determined to be significant (Tab. 1).

Partial dominance of the parents with higher harvest index value or of those with a lower one was exhibited in the Djerdap x NS-293, Djerdap x Jagodinac, Djerdap x Sladoran and Jagodinac x Sladoran crosses. As regards other crosses in the F_1 generation, dominance or overdominance of the parents with higher mean harvest index value was displayed.

Overdominance as a mode of inheritance predominated in most combinations in the F_2 generation. Partial dominance of the parents with higher harvest index was expressed in the Djerdap x Jagodinac, NS-293 x Jagodinac and Jagodinac x Sladoran crosses.

Negative heritability values were obtained in the Vada x Djerdap, Vada x Sladoran and NS-293 x Jagodinac crosses, resulting from high variability of the parents being higher than the variability of the F_2 generation. The highest variability (59.6 %) was obtained in the Djerdap x Sladoran cross (Tab. 1).

Genetic Variance Components

The analysis of the genetic variance components shows that dominant gene effect has the highest impact on genetic variability in the F_1 and F_2 generations because the values of the H_1 and H_2 dominant components are higher than those for the additive component D. Positive value F shows that in the phenotypic expression of the harvest index dominant alleles predominate over the recessive ones.

The $H_2/4H_1$ value indicates that dominant and recessive alleles are not evenly distributed in the parents. Average degree of dominance is higher than 1, meaning that the mode of inheritance of the harvest index in the F_1 and F_2 generations is overdominance. Since K_D/K_R is higher than the unit in both generations investigated, it can be concluded that the dominant alleles prevailed over the recessive ones, bearing in mind all the parents included in the diallel.

The calculated heritability value, in a narrower sense, is 26.73 %, being in accordance with the results of *Ore (1991)* who describes the low values of the harvest index variability as resulting from great variability of the parents that, in some crosses, was higher than the F_2 generation variability.

Tab. 2. Genetic variance components for harvest yield

Variance Components	Values	
	F_1	F_2
D	29.568	29.840
H_1	120.264	52.188
H_2	99.624	44.930
F	24.230	26.413
E	0.928	0.678
$H_2/4H_1$	0.207	0.215
u	0.707	0.686
v	0.293	0.314
$\sqrt{H_1/D}$	2.017	1.322
K_D/K_R	1.510	2.006
Heritabiity (%)		26.73

Bouzerzour and Djakoune (1998) and *Bhatnagar and Sharma (1998)* stress that higher effect in the inheritance of the harvest index of barley is being exerted by dominant and epistatic genes, whereas *Guo and Xu (1995)*, in their analysis of the F_1 and F_2 generation of the harvest index inheritance, underline the greater influence of additive genetic effects and the epistasis occurrence. In his analysis of the diallel (5x5) in wheat, *Pavlovic (1997)* concludes that harvest index is more controlled by non-additive genes, which is confirmed by the average degree of dominance and the regression analysis. Using the VrWr and WrW' analysis, the same author has also determined the presence of inter-allelic interaction in the inheritance of the trait, being in accordance with the results obtained in this paper.

Conclusion

Based on the results of these investigations, the following conclusions may be drawn:

A significant difference in mean harvest index values was obtained between the examined cultivars and their progeny in the F_1 and F_2 generations. The lowest mean value was exhibited by the Sladoran cultivar, and the highest one by cv. Jagodinac.

Partial dominance, dominance and overdominance were modes of inheritance of the harvest index in the F_1 and F_2 generations. In the two crosses in the F_1 generation, dominance or overdominance of the parents with low value of the investigated trait was expressed.

Genetic variance components and the average degreee of dominance indicated overdominance in the inheritance of the given trait.

The obtained value of the harvest index heritability was low (26. 7 %), being the result of a great effect of environmental factors in the expression of the trait.

References

Bhatnagar V. K., Sharma S. N. (1998): Diallel analysis for grain yield and harvest index in barley under diverse environments. Rashis, 16, 1/2, 22-27.

Borojević S. (1981): Doprinos genetike i oplemenjivanja u proizvodnji hrane. Genetika, 13, 3, 198-213.

Bouzerzour H., Djakone A. (1998): Inheritance of grain yield and grain yield components in barley. (Abstracts), P.B.A. 68, 12.

Denčić S. and Borojević S. (1992): Harvest index and spike index in crosses between wheat genotypes with different spike architecture. Plant Breeding 109, 151-158.

Guo Y.Y., Xu S. Y. (1995): Genetic analysis of yield traits in two-rowed barley. P.B.A. 65. 12. 1762.

Kertesz Z. (1983): Improvement of harvest index. Proceedings of the 10th Congress of Eukarpia, Wageningen (The Netherlands), 19-24.

Kraljević-Balalić Marija i Borojević S. (1985): Nasle|ivanje visine stabljike i četvenog indeksa pšenice. Arhiv za poljoprivredne nauke, 46, 163, 253-265.

Kraljević-Balalić Marija, Petrović S., Vapa Ljiljana (1991): Genetika. Poljoprivredni i Prirodno-matematički fakultet, Novi Sad.

Kraljević-Balalić Marija, Worland A. J., Porceddu E. and Kuburović M. (2001): Variability and gene effects in wheat. Genetics and breeding of small grains. Belgrade, 2001.

Lalić A. (1988): Uporedna analiza komponenata prinosa i prinosa zrna ječma F_3 populacija dvoredog i višeredog tipa. Magistarski rad, Poljoprivredni institut Osjek.

Martiniello P., Delogy G., Odoardi M., Boggini G., Stanca A. M. (1987): Breeding progress in grain yield and selected agronomic characters of Winter barley *(H.vulgare L.)* over the last quarter of century. Plant Breeding, 99, 289-294.

Mather K., and Jinks J. L. (1971): Biometrical Genetics. Sec. En. Champan and Half., London, England.

Ore R. (1991): Genetička analiza četvenog indeksa i njegov uticaj na prinos zrna ječma. Magistarski rad, Univerzitet u Novom Sadu, Poljoprivredni fakultet, Novi Sad.

Pavlović M. (1997): Fenotipska varijabilnost i nasle|ivanje nekih parametara efikasnosti ishrane azotom kod hibrida pšenice. Doktorska disertacija. Univerziet u Beogradu, Poljoprivredni fakultet-Zemun.

Pržulj N., Momčilović Vojislava (1998): Novosadske sorte pivskog ječma za proizvodne uslove Jugoslavije. Zbornik radova, Institut za ratarstvo i povrtarstvo Novi Sad, 30, 453-462.

Zečević Veselinka and Knežević D. (1997): Variability and components of variance for harvest index in wheat (*Triticum aestivum* L.) Genetika, 29, 3, 195-202.

VARIJABILNOST I KOMPONENTE VARIJANSE ZA ŽETVENI INDEKS KOD OZIMOG JEČMA

- originalni naučni rad -

Milomirka Madić, M. Kuburović
Agronomski fakultet Čačak

Marija Kraljević-Balalić, S. Petrović
Poljoprivredni fakultet, Novi Sad

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 varijabilnosti, načina nasle|ivanja, efekata gena, komponenti genetičke varijanse i heritabilnosti za žetveni indeks.

Za ocenjivanje načina nasle|ivanja primenjen je test signifikantnosti srednjih vrednosti generacija u odnosu na roditeljski prosek *(Kraljević-Balalić, 1991), a* komponente genetičke varijanse i regresiona VrWr analiza urađena je po *Mather and Jinks (1971).*

U nasle|ivanju žetvenog indeksa u F_1 i F_2 generaciji bila je ispoljena parcijalna dominacija, dominacija ili superdominacija. U dve kombinacije ukrštanja u F_1 generaciji se ispoljila dominacija ili superdominacija roditelja sa nižom vrednošću ispitivanog svojstva.

Komponente genetičke varijanse i prosečan stepen dominacije ukazali su na superdominaciju u nasle|ivanju datog svojstva.

Dobijena vrednost heritabilnosti žetvenog indeksa je niska (26,7%) što je posledica velikog uticaja ekoloških faktora u ekspresiji date osobine.