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Inheritance of Grain Proteins in Wheat

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Summary. Diallel crosses between five divergent vulgare wheat cultivars were made in order to evaluate the mode of inheritance and combining ability of grain proteins. Significant differences in grain protein content were found between cultivars and their hybrids. It was established that the inheritance of seed protein in the F_1 generation included both additive and non-additive gene action.

Key words: – *Triticum aestivum* – Grainprotein – Gene action – Regression – Diallel cross

Introduction

Proteins are compounds having a fundamental importance for all functions in the cell (Dose 1980), and investigations in this field are very diverse. Plant proteins are of special importance because they are used as food for both men and animals.

With regards to human nutrition, these proteins comprise 80% of the diet (Gašić 1979) and demand is increasing. Therefore, the development of high yielding varieties by breeding increases the quantity of protein with improved nutritional quality and is an important scientific challenge.

In plant breeding programmes considerable attention has been given to improving the nutritional quality of cereals by increasing the protein content. A major problem in such programmes is combining high grain yield with increased grain protein content. Negative correlation between grain yield and per cent protein is well known in wheat (Reiz 1964; McNeal et al. 1972; Duffield et al. 1972; Whitehouse 1973; Kramer 1979), although some winter wheat cultivars combining high yield and grain protein content have been obtained (Johnson et al. 1973; Borojević 1971; Mihaljev 1981). In some crosses there was no correlation between the grain protein content and grain yield.

Bhattia (1975) found that grain protein per cent was negatively correlated with grain yield, grain number and harvest index. The same author concluded that the grain protein yield/unit area provides the best criterion for making early generation selection in breeding programmes aimed at improving protein productivity per unit area.

The protein content of wheat grains varies roughly between 8 and 20%. For a large part, this variation is caused by environmental influences, especially the amount of nitrogen fertilizers applied and nitrate reductase activity (Gašić et al. 1981). Temperature, light intensity and water availability may affect grain protein content considerably. Genetic differences explain the remaining smaller part of the variation in grain protein content (Kramer 1979).

Pepe and Heiner (1975) showed that the tendency for lower grain protein percentage in high yielding semidwarfs does not result from undesirable linkages involving the dwarfing genes, but from the inverse yield – protein relationship. It appears that the increased sink size in some wheat cultivars, resulting in higher grain yields, occurs at the expense of protein concentration.

Having all this in mind, the combining ability, the mode of inheritance and gene action for grain protein content will be discussed. A knowledge of the genetic control of this character is of considerable value because it will enable the breeder to develop an efficient breeding and selection programme.

Materials and Methods

The diallel analysis (excluding reciprocals) involved the five genetically divergent vulgare wheat cultivars: 'Sava' from Yugoslavia, 'Talent' from France, 'Bezostaia-1' from U.S.S.R., 'Atlas 66' from the U.S.A. and 'Siete Cerros' from Mexico. These cultivars were crossed and their F_1s were used for grain protein analysis in the field trials. From each parent and cross we took samples in three replications for grain protein content analysis. These were analysed according to standard micro-Kjeldahl method.

The combining ability analyses were made following the method 2, model I by Griffing (1956). Analysis of genetic components of variance was done according to methods used by Jinks (1954), Hayman (1954) and Mather and Jinks (1971).

Results and Discussion

Among the examined cultivars significant differencies in mean values for grain protein content were observed. The parent 'Atlas 66' had the highest protein content, 20.64% and 'Sava' the lowest, 13. 53%. (Table 1).

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Table 1. Mean values for seed proteins in wheat (parents and F_1)

Parents	'Sava'	'Bez-1'	'Talent'	'Atlas 66'	'S. Cerros'
'Sava'	<u>13.53</u>	16.33[d]	14.22	16.10[i]	13.85
'Bez-1'		<u>16.37</u>	15.81[d]	17.52[pd]	14.92[i]
'Talent'			<u>13.87</u>	15.29[pd]	15.37[h]
'Atlas 66'				<u>20.64</u>	14.23[d]
'S. Cerros'					<u>13.81</u>

d = dominant inheritance
i = intermediate inheritance
pd = partial dominant inheritance
h = heterosis occured (over-dominance)
LSD 0.05 = 0.98
0.01 = 1.32

Table 2. Analysis of variance for combining ability for seed protein content in wheat (parents and F_1)

Sources of variation	DF	SS	MS	Fe	Ft	
					0.05	0.01
GCA	4	36.31	9.08	75.6**	2.69	4.02
SCA	10	1934.73	193.47	1611.4**	2.16	2.89
E	28		0.12			

** Significant at 1% level

In the F_1 generation intermediate inheritance was observed in two combinations ('Sava'×'Atlas 66' and 'Bezostaia-1'×'Siete Cerros'). The combination 'Talent'×'Siete Cerros' was not significantly different from both parents. In all other crosses, partial or full dominance was observed (Table 1).

Similar results were reported by Chapman and McNeal (1970); Sozinov et al. (1970); Bojadzieva (1974); Halloran (1975); Vorobjeva (1975); Bhullar et al. (1978); Bede (1981). Kaul and Sosulski (1965) reported lack of dominance of either low or high protein content. Some authors found heterosis for grain protein content, (Hsu and Sosulski 1969; Parodi et al. 1974; Sharma et al 1975; Rustamova 1977).

Combining Ability

The analysis of variance for combining ability revealed that both GCA and SCA variances for grain protein content were highly significant with the preponderance of non-additive gene action (Table 2).

The same results were found by Brown et al. (1966). The preponderance of non-additive gene effects for grain protein content might have resulted from the non-allelic interactions in the crosses involving cultivars exibiting overdominance (Bains et al. 1972, Ram and Srivastava 1975; Ketata et al. 1976; Mihaljev et al. 1979; Mihaljev and Kovačev-Djolai 1978). Bede (1981) reported that both GCA and SCA were significant for grain protein content, but with preponderance of additive gene action.

The best general combiner for grain protein content was the cultivar 'Atlas 66', which has also the highest mean value for this character (Table 3). 'Atlas 66' has proven to be a highly useful genetic source of protein (Johnson et al. 1978). The genes from 'Atlas 66' appears to provide capability for 2–4 percentage points more protein than that of ordinary wheats and is effective over a wide range of fertilizer (Konzak 1977). Therefore, the use of the cultivar 'Atlas 66' as a parent in the crosses is recommended by which one selects segregates for higher grain protein content.

Genetic Components of Variation

Estimates of the genetic and environmental components of variation for grain protein content showed that both additive (D) and dominance component (H_1) were important for this character (Table 4). Similar results were obtained by Bebiakin (1978) and Jatastra et al. (1978) who found that grain protein content is mainly determined by additive genes. On the contrary, Bede (1981) reported dominance effects for this character in the crosses of mutant winter wheat lines.

Positive values of F revealed the excess of dominant alleles. The degree of dominance measured by $\sqrt{H_1/D}$ (0.57) was found to be less than unity, indicating partial dominance in the inheritance of grain protein content. The K_D/K_R ratio (2.99) showed that the total number of dominant genes were in excess over the total number of recessive genes in all the parents included in the diallel (Table 4).

Table 3. GCA effect for seed proteins

Parents	GCA	Rank	SE	LSD	
				0.05	0.01
'Sava'	−0.74	4	0.12	0.92	2.11
'Bez-1'	0.64	2	0.12	0.92	2.11
'Talent'	−0.61	3	0.12	0.92	2.11
'Atlas 66'	1.67*	1	0.12	0.92	2.11
'S. Cerros'	−0.95	5	0.12	0.92	2.11

* Significant at 5% level

Table 4. Components of genetic variance

Values	Components
D	8.99
H_1	4.16
H_2	4.00
F	6.80
E	0.12
$\sqrt{H_1/D}$	0.57
K_D/K_R	2.99

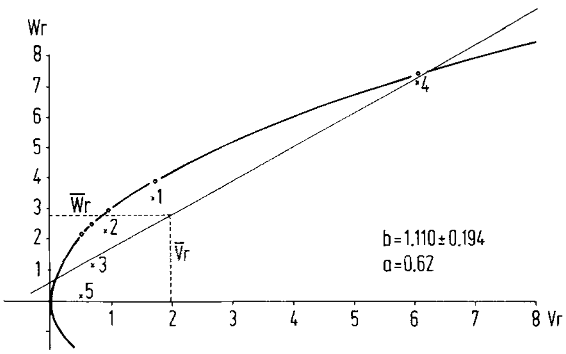

Fig. 1. Wr/Vr regression for grain protein content

Graphical Analysis

The regression coefficient of Wr on Vr was not significantly different from unity (b = 1,110 ± 0,194), showing the absence of interallelic interaction for grain protein content. The regression line cut the Wr axis above the point of origin which indicated the presence of partial dominance in the inheritance of grain protein content (Fig. 1).

The cultivar 'Atlas 66' prossesses an excess of recessive genes for this character. Arrays 2 ('Bezostaia-1'), 3 ('Talent') and 5 ('Siete Cerros') were nearer to the point of origin possessing dominant genes, while the cultivar 'Sava' (1) possessed approximately an equal proportion of dominant and recessive genes for grain protein content.

Cultivars with superior grain protein content can be developed by selecting segregates from crosses involving genotypes predominantly governed by additive gene effects. The significance of additive genetic effects for the crosses 'Sava' × 'Atlas 66', 'Bezostaia-1' × 'Atlas 66', 'Talent' × 'Atlas 66' and 'Bezostaia-1' × 'Siete Cerros' indicated the potential for selecting for higher grain protein content. Protein content could be increased in 'Sava', a very high yielding wheat variety, by crossing it with 'Atlas 66' and then choose segregates from it.

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