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Genetic control of morphological and physical characteristics determining resistance to lodging in barley (*Hordeum vulgare* L.)

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A b s t r a c t. In the present paper, evaluation of the effects of gene action on the properties determining resistance to lodging in barley, is presented. Genetic analysis was performed on the data for doubled haploids (DH) examined in a 3-year field experiment. The DH lines were derived from the Grit x Havila hybrids by the 'Hordeum bulbosum' method. Lodging degree and some morphological and physical characteristics such as stem length, diameter, wall thickness, and elasticity (the Young's modulus) and velocity of the ultrasound flow through the stem were determined. Heritability coefficients were calculated, and effects of the additive gene action, such as dominance and interaction of homo- and heterozygous loci, were evaluated for the above characteristics

It was found that the physical stem indices were the most differentiating characteristics of the studied DH lines. A genetic analysis showed significance of the additive gene action with regard to all morphological and physical characteristics. Heritability coefficients appeared to be the highest for the Young's modulus (78.2-85.3%) and velocity of the ultrasound flow through the stem (76.1-84.5%). The number of effective factors for the studied characteristics ranged from 1 to 5.

K e y w o r d s: *Hordeum vulgare* L., DH lines, genetic parameters, heritability, resistance to lodging, Young's modulus

INTRODUCTION

Beside yielding, resistance to lodging is a very important problem in barley breeding. As reported previously, barley lodging depends on the genetically conditioned characteristics of the morphological and physical stem structure [6,8,9]. Analysis of hybrids from early generations [13] or doubled haploid (DH) lines [1,2,16] provides valuable information on the gene action determining resistance to lodging. Since the DH lines are completely homozygous, they are a very valuable study material for determining genetic quantitative traits including characteristics conditioning resistance to lodging. On the basis of doubled haploids effects of the additive gene action, the non-allelic interaction of the homozygous loci may be evaluated [2,16]. The additive effects are stable in the selection process, which makes them important in breeding for the genotypes resistant to lodging.

MATERIAL AND METHODS

The study material covered 47 doubled haploid lines of spring barley derived from the F_1 hybrids Grit x Havila by the 'Hordeum bulbosum' method [12]. The study material was tested in a field experiment in 1993-1995. The experiment was carried out in a randomised block design with three replications. Seeds were sown in 3 m^2 - plots at the rate of 330 seeds/1m^2. Lodging degree was estimated at full maturity using a 9-degree scale, where 1 means no lodging and 9 - a complete lodging. After harvesting, the stem length, diameter and wall thickness were measured. Physical stem indices, i.e., velocity of the ultrasound flow through the stem and its elasticity (the Young's modulus) were evaluated [5].

The analysis of variance was carried out for each year and two groups of lines. The maximum and minimum values of the characteristics were separated by the use of the Danet's test. To obtain information on the genetic determination of the studied characteristics, estimation of the genetic parameters was carried out by means of an experiment with the DH lines [16]. Effects of the additive gene action [*d*] and non-allelic interaction of homozygous loci [*i*] were calculated. Heritability coefficients (the ratio of genetic to phenotypic variances) were estimated on the basis of the variance analysis. Finally, to obtain comprehensive information on the inheritance of the studied characteristics, the number of effective factors was evaluated [11].

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RESULTS

Results of the variance analysis showed that the DH lines were significantly differentiated in all the analysed characteristics, which enabled separation of two groups of lines with the maximum and minimum values of these characteristics. The mean values for both groups, as well as general means for the whole family of the DH lines and their parental cultivars are summarised in Table 1.

The heritability coefficients given in Table 2 show that the share of genetic variance in phenotypic variation of the studied morphological stem characteristics was relatively small and amounted to about 50%. Heritability coefficients higher than 50% were observed for the lodging degree (68.0-69.1%), Young's modulus (78.2-85.3%) and velocity of ultrasounds flow through the stem (76.1-84.5%).

Estimates of genetic parameters are presented in Table 3. It follows from them that effects of the additive gene action ([*d*] parameter) were significant for all the studied characteristics. Non-allelic interaction of genes in a homozygous state ([*i*] parameter) appeared to be significant for lodging degree, stem diameter and for the both studied physical characteristics of the stem.

Table 1. Mean values of the analysed stem characteristics of barley doubled haploid lines

Character	Year	DH lines			Parents	
		max.	min.	mean	Grit	Havila
Lodging degree (1-9)	1993	4.81	1.21	4.76	4.00	5.00
	1994	2.72	1.00	2.00	2.00	3.66
	1995	4.50	1.00	3.80	4.30	5.00
Stem length (cm)	1993	78.11	51.03	65.58	61.40	66.42
	1994	79.28	50.21	63.76	55.90	62.43
	1995	78.90	52.60	64.90	62.60	67.00
Stem diameter (mm)	1993	3.44	3.01	3.28	3.36	3.42
	1994	3.71	2.47	3.21	3.12	3.22
	1995	3.55	2.91	3.25	3.20	3.31
Stem wall thickness (mm)	1993	0.27	0.13	0.20	0.21	0.22
	1994	0.28	0.13	0.20	0.19	0.19
	1995	0.28	0.14	0.24	0.21	0.20
Velocity of ultrasound flow (m s^{-1})	1993	4112	3101	3321	3524	3481
	1994	4680	2480	3501	3837	3872
	1995	4471	2982	3420	3790	3820
Young's modulus (MPa)	1993	26.31	14.01	16.89	18.62	18.21
	1994	32.85	11.60	18.98	22.18	22.49
	1995	29.98	13.33	17.54	21.54	21.88

Table 2. Estimates of heritability coefficients for the analysed stem characteristics of barley doubled haploid lines

Character	Heritability coefficient (%)		
	Year		
	1993	1994	1995
Lodging degree	69.1	68.0	65.3
Stem length (cm)	51.2	44.0	46.1
Stem diameter (mm)	49.4	60.1	50.2
Stem wall thickness (mm)	53.2	57.1	51.1
Velocity of ultrasound flow (m s^{-1})	84.3	84.5	76.1
Young's modulus (MPa)	78.2	85.3	81.5

T a b l e 3. Estimation of genetic parameters for the analysed stem characteristics of barley doubled haploid lines

Parameter	Year	Lodging degree	Stem length (cm)	Stem diameter (mm)	Stem wall thickness (mm)	Velocity of ultrasound flow (m s^{-1})	Young's modulus (MPa)
[*d*]	1993	1.80±0.33	13.54±1.78	0.22±0.06	0.07±0.01	505.5±72.51	6.15±0.32
	1994	0.86±0.30	14.53±6.21	0.62±0.02	0.08±0.03	1100.0±59.81	10.62±0.48
	1995	1.75±0.21	13.15±1.20	0.32±0.04	0.07±0.02	744.5±62.34	8.32±1.41
[*i*]	1993	-1.75±0.33	-1.01±1.72	-0.06±0.01	0.00±0.02	285.5±34.01	3.27±0.52
	1994	-1.29±0.21	0.98±4.22	-0.12±0.04	0.00±0.01	79.0±30.04	3.26±2.15
	1995	-2.05±0.56	0.85±1.38	-0.02±0.01	-0.03±0.02	306.5±41.26	4.12±1.45

Estimates of the number of effective factors are given in Table 4. As follows from the table, estimates of the effective factors ranged from 1 to 2 for the lodging degree, from 2 to 3 for the physical stem characteristics and wall thickness, and from 3 to 5 for the stem length.

T a b l e 4. Estimation of the number of effective factors for the studied characteristics in the barley cross Grit x Havila

Character	Year		
	1993	1994	1995
Lodging degree	1	2	2
Stem length (cm)	5	3	3
Stem diameter (mm)	4	3	4
Stem wall thickness (mm)	2	3	3
Velocity of ultrasound flow (m s^{-1})	2	3	2
Young's modulus (MPa)	2	3	2

DISCUSSION

The results obtained, estimation of genetic parameters and heritability coefficients in particular, are consistent with the results of previous studies on the subject [7,10]. It can be expected that the selection for high values of stem physical (mainly the Young's modulus - elasticity coefficient) and morphological characteristics (stem diameter and wall thickness), will be profitable from the breeding point of view, as it will increase resistance to lodging in barley. This is further supported by the earlier studies conducted in our Institute [6,9] as well as by the investigations of other authors [3,15]. However, it should be remembered that estimations of genetic parameters and heritability coefficients for the above characteristics depend also on the environmental conditions as well as on the studied cross combination or the DH lines family [4,10].

In the present study it was also possible to obtain information on the number of effective factors controlling characteristics relating to lodging resistance. It should be mentioned that the term effective factor in the genetics of quantitative characteristics means a gene or a group closely linked genes acting as a single gene. However, it should be added that the values of effective factors obtained do not concern all genes controlling a given character, but only the segregated genes of the cross combination studied. The results obtained, indicated that observed variation in the morphological and physical characteristics of barley DH lines was caused by the segregation in the 1-5 loci. Information on the number of effective factors is important from both genetic and breeding point of view. It enriches our knowledge on the genetic determination of metrical characteristics relating to the resistance to lodging and it may contribute to an increase of plant breeding effectiveness through an adequately developed strategy [1,14,17].

CONCLUSION

Morphological and physical stem characteristics determining resistance to lodging in barley is conditioned by the genes of additive and epistatic effects. The above effects may become stable in the selection process while breeding of self-pollinated plants, including barley.

REFERENCES

1. **Adamski T., 1993.** The use of doubled haploid lines for genetic analysis of quantitative traits (in Polish). Treatises and Monographs, No. 2. Institute of Plant Genetics PAN, Poznań.
2. **Choo T.M., 1981.** Doubled haploids for studying the inheritance of quantitative characteristics. Genetics, 99, 525-540.
3. **Doliński R., 1986.** Influence of environment on mechanical parameters and geometrical traits of the stem in 14 winter wheat varieties (in Polish). Hodowla pszenicy. Prace Grupy Problemowej, IHAR Radzików.
4. **Doliński R., 1990.** The inheritance of elastic properties of the stem sclerenchyma in winter wheat hybrids (*Triticum aestivum* L.). Genet. Pol., 31, 199-204.
5. **Gawda H. and Haman J., 1983.** An ultrasonic method of determining Young's modulus in cereal plants. Trans. ASAE, 26, 250-254.
6. **Jeżowski S., 1981.** Analysis of relationship between lodging grade and some morphological characteristics determining lodging resistance of barley. Genet. Pol., 28, 333-3.
7. **Jeżowski S., 1994.** The use of doubled haploids in genetic analysis of traits determining lodging resistance in barley (in Polish). Zesz. Ogrodu Botanicznego PAN, 55-65.

8. **Jeżowski S. and El-Bassam N., 1985.** Analysis of relationship between the lodging grade and some morphological characteristics at early stages of plant development. Genet. Pol., 26, 233-241.
9. **Jeżowski S., Surma M., and Adamski T., 1987.** Diallel analysis of characteristics determining lodging resistance of barley. Genet. Pol., 28, 333-340.
10. **Jeżowski S., Surma M., and Adamski T., 1993.** Genetic parameters for some morphological and physiological characteristics of the stem of barley DH lines (in Polish). Zesz. Nauk. AR Wrocław, 223, 215-221.
11. **Kaczmarek Z., Surma M., and Adamski T., 1988.** Epistatic effects in estimation of the number of genes on the basis of doubled haploid lines. Genet. Pol., 20, 353-359.
12. **Kasha K.J. and Kao K.N., 1970.** High frequency haploid production in barley (*Hordeum vulgare* L.). Nature 225, 874-876.
13. **Mather K. and Jinks J., 1982.** Biometrical Genetics. 3rd ed. Chapman and Hall, London-New York.
14. **Powell W., Caligari P.D.S., and Jinks J.L., 1985.** The usefulness and limitations of estimating the number of genes in a barley breeding programme. J. Agric. Sci., Camb., 105, 285-290.
15. **Skubisz G., 1978.** Estimation of Young's modulus for winter wheat stem on the basis of field and laboratory measurements (in Polish). Zesz. Probl. Post. Nauk Roln., 203, 21-24.
16. **Surma M., Adamski T., and Kaczmarek Z., 1984.** The use of doubled haploid lines for estimation of genetics parameters. Genet. Pol., 25, 7-32.
17. **Werhahn C. and Allard R., 1965.** The detection and measurements of the effects of individual genes involved in the inheritance of a quantitative characteristics in wheat. Genetica 51, 109-119.