

CORRELATIONS BETWEEN TRAITS RELATED TO LODGING RESISTANCE IN BARLEY

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Abstract

Mihova, G., R. Mihailov, T. Tonev, Vl. Demirov, 2006. Correlations between traits related to lodging resistance in barley.

The correlations between the main traits related to stem lodging in barley were investigated. The trial was carried out at Dobroudja Agricultural Institute - General Toshevo, within the breeding nursery and the check varietal trial. During the period of investigation (2003-2005), as a result from the considerable rainfalls during grain filling and maturation, lodging of the breeding materials to various degrees was observed. It was established that among the morphological traits, plant height, number of spike bearing tillers, length and diameter of second and third internodes were most important for the resistance of the plant. Among the elements of productivity, these were length and weight of spike, as well as number of grains per spike in *var. pallidum*. When comparing the individual systematic groups, the least number of significant correlations were established in subsp. *distichum*.

Key words: Barley - Lodging - Correlations

Резюме

Михова Г., Р. Михайлов, Т. Тонев, Вл. Демирев, 2006. Корелационни зависимости между признаци свързани с устойчивостта към полягане при ечемика.

Проучени са корелационните зависимости между основни признаци свързани със стъбленото полягане при ечемика. Опитът е проведен в Добруджански земеделски институт, гр. Генерал Тошево, в рамките на селекционния питомник и контролния сортов опит. През периода на изследването 2003-2005 год. в резултат на значителните количества валежи през фазите на наливане и зреене, се наблюдава в различна степен полягане на селекционните материали. Установи се, че от морфологичните признаци, най-голямо значение за устойчивостта на растението имат височината, броят класоносни броя, дължината и диаметъра на второто и трето междувъзлие. От елементите на продуктивността това са дължината и теглото на класа, а при *var. pallidum* и броя зърна от клас. При сравнение на отделните систематични групи, най-малко достоверни корелации са установени при subsp. *distichum*.

Ключови думи: Ечемик – Полягане – Корелационни зависимости

INTRODUCTION

Lodging of cereal crops has been in individual years a significant factor for yield decrease. According to its degree, the phenological stage and the specific weather conditions, the losses can reach 40 % (Easson et al., 1993). This problem is even more serious in barley, and the losses reach up to 60 % in critical years (Jerowski, 1998). In this relation, lodging resistance has always been given special attention. It can be root or stem lodging. Resistance to the first type is referred to development and the position of the roots. The second type is affected by weather conditions and by the specifically mechanical characteristics of the plants. They directly depend on the morphological, anatomic, biochemical and physiological peculiarities of the genotype. This determines the leading role of the variety in solving the problem. Modern intensive agriculture requires to also take into account the agronomy practices which ensure the realization of the variety's genetic potential. The formation of the trait resistance to lodging can be controlled by using various methods of analysis (Briggs, 1990; Crook & Ennos, 1993; Dolinski, 1990; Dunn & Brigs, 1989; Jerowski et al., 2001). A large part of these methods are of fundamental character and not easily available in practical work. In the opinion of many researchers, specific methods and evaluation criterion should be applied to each stage of the breeding process (Baker, 1998; Zuber et al., 1999). Selection in hybrid population is often carried out by several characters. Understanding their interrelations will to a large extent help to perform this selection.

The aim of this study was to investigate the correlation among the main traits related to stem lodging of barley.

MATERIAL AND METHODS

Table 1. Investigated cross combinations and systematic affiliation of selected progenies

№	Cross combinations	Systematic affiliation of selected progeneis
1	Skorohod x Hemus	subsp. <i>vulgare</i> var. <i>parallelum</i>
2	Kozyr x Jerun	subsp. <i>vulgare</i> var. <i>parallelum</i>
3	Knyajich x Secret	subsp. <i>vulgare</i> var. <i>parallelum</i>
4	Bastion x Izgrev	subsp. <i>vulgare</i> var. <i>parallelum</i>
5	Vavilon x Vesletc	subsp. <i>vulgare</i> var. <i>pallidum</i>
6	Makas x Miraj	subsp. <i>vulgare</i> var. <i>pallidum</i>
7	Radical x Hemus	subsp. <i>vulgare</i> var. <i>pallidum</i>
8	Toman x Vavilon	subsp. <i>vulgare</i> var. <i>pallidum</i>
9	Ruen x H-N-01	subsp. <i>distichum</i> var. <i>nutans</i>
10	M-1-94-5 x Laura	subsp. <i>distichum</i> var. <i>erectum</i>
11	103-493 x H-N-01	subsp. <i>distichum</i> var. <i>erectum</i>
12	Ruen x Laura	subsp. <i>distichum</i> var. <i>nutans</i>

The trial was carried out during 2003-2005 at Dobroudja Agricultural Institute. During the first year the filed observations were done within the breeding nursery. Among F_4 crosses, in which stem lodging was observed in various degrees, six progenies were selected alternative to this trait (Table 1). Each cross combinations was sown on 54 rows 1.5 m long, with 30 cm between the rows. Five plants from the selected progenies were subjected to biometrical analysis. On the following year the progenies were sown for control testing. The trial plots were of 6 m² each. Sowing norm was 420 germination seeds per m². Analysis was performed on 5 plants from each variant. Lodging was registered at the end of vegetation, before harvesting, according to a 9-degree scale: 1 - erect plants without lodging; 9- complete lodging (IPGRI, 1994). The previous crop during both years of investiga-

tion was peas. Fertilization was not applied. All agronomic practices not specifically considered in this study were in accordance with the methods accepted for growing of this crop.

The combination of weather conditions during the years of study allowed to evaluate the breeding materials by their resistance to lodging. Harvest year 2003/2004 was one of the most successful for barley production. The long drought which began in early spring had to some extent a negative effect on the initiation and formation of the reproductive parts. Rainfalls in May and July had a decisive role for the formation of high yield (Figure 1). Due to the compensatory abilities of the crop, most of the genotypes realized their production potential. As a result from the considerable amount of rainfalls during grain filling and maturation, a part of the material included in the individual trials lodged to various degrees. The percent of lodging was higher in fodder barley. A limiting factor for production in 2004/2005 was the spreading of the barley yellow dwarf virus. The delayed harvesting of spring crops, the untimely performance of the main agronomic practices and the warm autumn favored the distribution of some aphids and cecidians, vectors for the disease. In this direction it was necessary to take into account the registered degree of infection when analyzing the obtained results. The observed phenotype variation of the traits was in direct correlation with the response of the individual genotypes. This required to exclude from the investigation the selected lines with high degree of infection and to focus only on those given in Table 1. The high amount of rainfalls since the beginning of heading, and especially at the end of vegetation instigated lodging in the lines with normal development, but to a much lesser degree than in the previous year.

The statistical processing was done with the help of the software STATISTICA, version 5.0 for Windows 95.

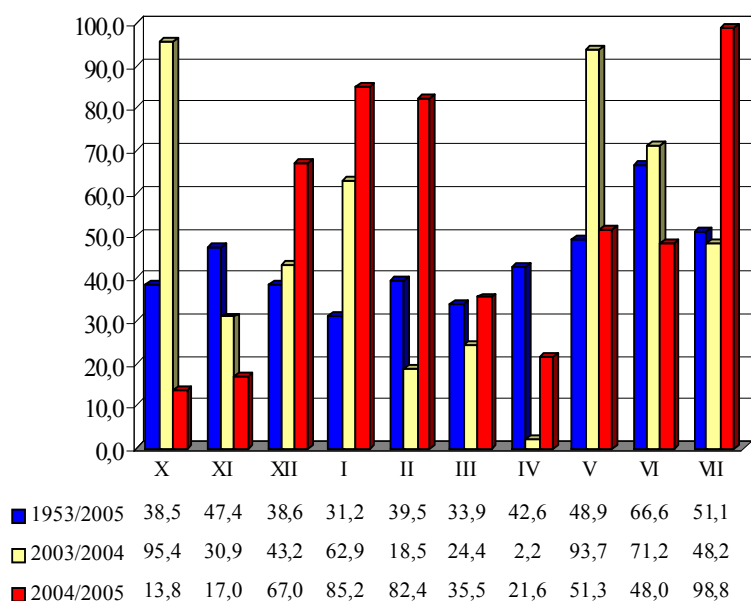


Figure 1. Amount of rainfalls by months (mm) during the period of investigation

RESULTS

The main direction of breeding work with barley at Dobroudja Agricultural Institute is the improvement of winter hardiness (Mihova & Petrova, 2005). The conditions in the region where the institute is situated provide a suitable background for selection of forms tolerant to this type of abiotic stress. Barley is one of the winter cereal crops which have highest susceptibility to low temperatures. At the same time the world gene pool is rather limited with regard to this trait. The main donors are varieties with origin from Ukraine, Russia and Rumania. Similar to the other winter cereals, barley is a microclimate-dependent crop. Most of the accessions used to develop genetic variability react differently to environmental factors, as compared to the region where they have been selected. Many of the donors used to improve frost resistance are inclined to lodging. Therefore careful selection in the hybrid population is needed. The lack of a stress factor during individual years makes this evaluation difficult. Understanding the correlation between the traits related to lodging resistance will allow to more objectively evaluating the materials selected for further testing.

The lines involved in the investigation differed considerably both by the investigated morphological characters and by main structural elements of yield (Table 2). Differences were found in the systematic groups, as well.

Table 2. Marginal values and variation of investigated traits by systematic groups

Traits	subsp. <i>vulgare</i> var. <i>parallelum</i>			subsp. <i>vulgare</i> var. <i>pallidum</i>			subsp. <i>distichum</i>		
	min	max	Vc	min	max	Vc	min	max	Vc
Plant weight (g)	8.17	22.88	36.35	8.90	19.47	25.07	7.03	16.48	32.66
Spike per plant (number)	3.00	4.50	27.14	3.50	5.00	12.85	3.67	5.50	15.73
Plant height (cm)	83.60	99.88	6.82	90.97	104.8	5.20	91.88	98.96	2.24
Nodes, (number)	3.81	5.50	12.19	4.08	5.05	7.68	3.79	5.03	7.91
Internodes length (cm)									
1st	2.00	4.56	31.77	2.31	5.32	24.65	2.3	4.98	38.66
2nd	7.03	14.07	20.26	8.55	12.79	14.55	6.14	11.39	19.75
3rd	10.33	16.22	14.26	13.69	17.14	7.41	11.34	16.08	10.76
4th	11.75	26.23	27.27	14.35	20.38	11.99	15.11	25.64	15.78
last	24.33	34.62	12.13	26.79	34.37	6.70	30.00	38.58	10.96
Internodes diameter (mm)									
1st	3.10	3.60	4.63	3.10	3.90	8.33	2.90	3.80	8.19
2nd	3.60	4.40	5.88	3.80	4.50	6.52	3.40	4.40	8.35
3rd	3.60	4.45	6.82	3.70	4.50	6.51	3.50	4.40	8.43
4th	3.60	4.20	6.58	3.50	4.40	7.14	3.40	4.50	9.61
last	2.10	3.40	14.15	2.50	3.10	7.58	2.20	2.90	9.65
Spike length (cm)	3.37	4.92	11.04	5.15	7.18	10.93	5.71	8.59	14.24
Spike weight (g)	1.30	2.29	16.28	1.59	2.34	14.95	0.93	2.30	29.50
Spikelet per spike (number)	47.49	69.09	10.95	51.73	73.75	11.32	20.88	35.89	17.13
Kernels per spike, (number)	36.29	54.73	12.78	34.78	55.21	14.74	18.44	33.98	18.95
Grain yield (g/plant)	4.73	12.36	34.78	5.03	10.49	24.41	3.09	9.26	36.58
Harvest index (%)	53.06	58.40	3.51	53.31	57.60	2.86	35.65	57.63	14.15

The barley plant strongly responds to greater nutrition area, which was the reason for the high values of the variation coefficients obtained.

Based on the determined mean values of the traits during the period of study, their correlation with the degree of lodging was calculated.

Table 3. Correlation between lodging degree and investigated traits

Traits	subsp. <i>vulgare</i> var. <i>parallelum</i>	subsp. <i>vulgare</i> var. <i>pallidum</i>	subsp. <i>distichum</i>
Plant weight (g)	0.460	0.555	0.506
Spike per plant (number)	0.665	0.575	0.646
Plant height (cm)	0.653	0.619	0.258
Nodes, (number)	-0.102	0.138	0.142
Internodes length (cm)			
1st	-0.012	-0.177	-0.086
2nd	0.560	0.443	0.358
3rd	0.501	0.597	0.309
4th	0.140	-0.061	-0.005
last	0.697	0.539	0.368
Internodes diameter (mm)			
1st	-0.262	-0.167	0.072
2nd	-0.495	-0.635	-0.161
3rd	-0.409	-0.528	-0.135
4th	-0.227	0.128	0.099
last	0.103	0.289	0.023
Spike length (cm)	0.376	0.544	0.285
Spike weight (g)	0.298	0.719	0.182
Spikelet per spike (number)	-0.057	0.275	0.105

DISCUSSION

The degree of lodging is a highly heritable trait (Verna et al., 2005). This is an indication that the trait is conservative and selection can be carried out in earlier generations, as well. In identification and characterization of quantitative traits loci for morphological traits related to lodging resistance, Keller et al. (1999) found nine QTL distributed over the whole genome in a bread wheat. Hayes et al. (1995) identified six QTL explaining 72 % of the variation in barley. The authors reported a significant effect of plant height on its resistance. Based on the genotypes included in the investigation, highest correlation between plant height and lodging was established in var. *parallelum* and var. *pallidum*. In the two-rowed barley the correlation was low indicating that it can be easily broken.

In all three systematic groups the increase of plant weight and spike-bearing tillers was related to increase of lodging degree. Probably the effect of the second trait was related to the increased density of the crop. According to some authors (Terentyev, 1974), stem lodging is determined in such cases by insufficient development of mechanical tissues, changes in the distribution of phytohormones and the metabolism.

Plant height is not always the most suitable trait for indirect breeding (Dunn & Briggs, 1989; Easson et al., 1993; Zuber et al., 1999). According to the above authors length and diameter of lower internodes have greater importance. In this study we did not establish a correlation between first internode length and lodging. The coefficients were close to zero. The correlation with second and third internode length was significant, being more expressed in the poly-row forms. Last internode length was also important. Its elongation was related to plant's resistance decrease, especially in var. *parallelum*.

The higher values of the individual internodes diameter are also a priority in the breeding of genotypes with higher resistance. More significant were the correlations with the second and third internode where stem lodging was most often observed. High coefficients of traits heritability have been reported (Jerowski, 1998; Jerowski et al., 2001). This implies low phenotypic variation, which would allow to use them as efficient criterion in selection.

On the whole, significant correlation coefficients of the main morphological traits with

lodging degree were established in poly-row barley. In two-row barley, the correlations were weak and unstable, except with plant weight and number of spike-bearing stems. Similar tendencies were established when investigating the correlation with some yield elements. The increase of spike weight and length was related to increase of lodging degree. The correlation was lowest in two-row barley.

Low and insignificant were the correlations with yield and harvest index. The reason for their positive values is the increase of straw as affected by the increasing weight of spike. A correlation with number of spikelets was not found. In var. *pallidum* the correlation with number of grains per spike was high and significant.

When analyzing the results, it should be taken into account that conditions for stem lodgings during the investigated period developed at the end of vegetation. During this period reproductive parts were already formed and their effect on lodging degree was mostly due to the increased weight of grain. If a stress factor was available at the earlier stages of development, the correlation with the elements determining yield would have most probably differed not only by value, but by direction, as well.

This investigation is a part of a more large-scale study on the problem of lodging. Possibilities are being sought for easy and objective evaluation of the breeding materials, including: determining the effect of the main weather factors and agronomic practices on the degree of lodging, change of the plant's physical and mechanical characteristics during the different stages of development, investigation on some anatomic peculiarities of straw, etc.

CONCLUSIONS

Among the morphological traits, plant height, number of spike-bearing tillers, and length and diameter of second and third internode were most important for lodging resistance.

Among productivity elements, highest correlation coefficients were established with length and weight of spike, and in var. *pallidum* - with number of grains per spike.

The use of the correlation of lodging degree with the main traits characterizing plant architectonics and productivity was most uncertain in two-row barley. The established correlation was in most cases low and insignificant.

ACKNOWLEDGMENTS

Thanks are due to Prof. Dr. Stoyan Tsvetkov, author of some of the cross combinations included in this study.

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