REGRESSION FUNCTIONS FOR EVALUATION OF WHEAT LODGING

Slaven Prodanovic[1], Rade Protic[2], Snežana Jankovic[3], Nada Protic[4]

ABSTRACT

Lodging of wheat varieties and hybrids was investigated in dependence on morphological-anatomical traits expression. Regression analysis was applied and marginal values of traits by which the largest lodging occures, were established. It was established that each increase of stalk height and development of (mass) root influence on lodging, too. It was determined that marginal values for clustering are 11 shoots, for diameter of basal internodes 5 mm, and for shoot mass 19.3 g. On the basis of the results, for selection of wheat lines resistant to lodging one should choose lower plants, of smaller aboveground mass, with thicker internodes and root of wide radius.

Key words: wheat, lodging, morphological and anatomical characteristics, marginal analysis.

INTRODUCTION

Lodging of wheat stalk is a very complex quantitative trait. Lodging is under the influence of numerous morphological-anatomical traits, directly or indirectly.

As basic selection criterion of resistance to wheat lodging (Dzhelepov, 1991), more frequently stalk height is taken. In recent investigations, strong correlation dependence has been established between lodging and root development, as well as between stalk diameter (Hamilton, 1951) and histologic structure of wheat stalk (Cincovic and Šinžar, 1967). Clear influence on lodging has leaf mass development and flag leaf position (Jankovic, 1996). These traits are determined by a great number of minor genes that condition a continuous variability.

In this work on modelling of wheat varieties of high genetic resistance to lodging, the purpose is to determine the direction and intensity of lodging dependence of numerous plant quantitative traits (Dencic, 1994). In this respect, previous investigations used correlation and to determination coefficients that numerically express the average degree of interdependence of lodging and other phenotypical traits, for the whole variational width of these traits (Ivanovic and Rosic, 1983; Sinha et al., 1984).

Marginal analysis as biometric method can have a special importance in improvement of certain plant traits, so that the most favou-rable effect be obtained.

MATERIALS AND METHODS

As a subject of investigation in this work, native wheat varieties characterized by different degrees of resistance to stalk lodging: Beogradjanka, Skopljnka, Agrounija (high resistance to lodging, lodging resistant = 0.03, by Djokic and Mladenovic, 1989), Žitarka and Zemunka as well as their reciprocal diallel hybrids, were used. By this way, it has been possible to investigate lodging with generations of different expressiveness of traits, but with high genetic uniformity.

Lodging is expresed in degrees of lodged plants on 25 plots, of a size of 2 m^2. Trial was carried out on the fields of Selection Station of „Agrounija" in India, during 1990-1991. Space between rows was 20 cm. Standard technology for wheat production was applied.

The following traits were investigated:

- shoot height to spike top (cm);
- number of shoots in plant-clustering;
- diameter (thickness) of the first internode above ground (mm);
- mass of one randomly selected stalk with leaves and spike in early milk maturity when lodging occured (g);
- root development expressed by plant root mass to 25 cm depth (g).

Lodging dependence on the observed traits was investigated by the method of regression equation (Heady, 1961). As the basis for selection of appropriate type of function, statistical indexes: residual error, F-values and multiple corre-

---

[1] Faculty of Agriculture, Zemun-Belgrade, Yugoslavia
[2] Institute „PKB Agroekonomik", P. Skela-Belgrade, Yugoslavia
[3] Institute for Science Applications in Agriculture, Belgrade, Yugoslavia
[4] „Eco-Lab" P. Skela-Belgrade, Yugoslavia

lation coefficient were used, at which it has been established that the square function is the form that shows the best the relation between the morphological traits and lodging. Total lodging was evaluated on the base of selected function:

$$Y = a + bx + cx^2$$

Marginal lodging was obtained on the basis of the first derivation of selected function: G = f(x). The coefficient of elasticity was obtained as the ratio of marginal and average lodging: E = G/p, where „p" is the ratio of evaluated values of total lodging and the corresponding expression of traits (p = y/x).

RESULTS AND DISCUSSION

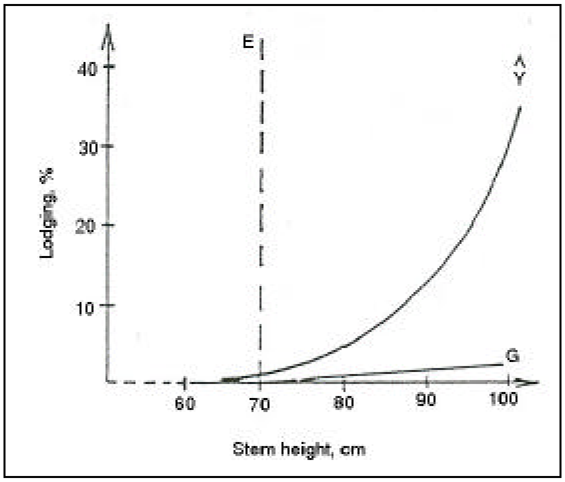
According to the results obtained in this investigation, stalk height has a very significant influence on lodging ($r_{y1.}$ 2345 = 0.94**) r = 0.94.

Lodging dependence on stalk height can be expressed by the function:

$$y = 191.37 - 5.46x_1 + 0.04\,x_1^2 \text{ (Graph 1).}$$

The function has an input course, because every increase of stalk height leads to the increase of wheat lodging (G with the increasing rate).

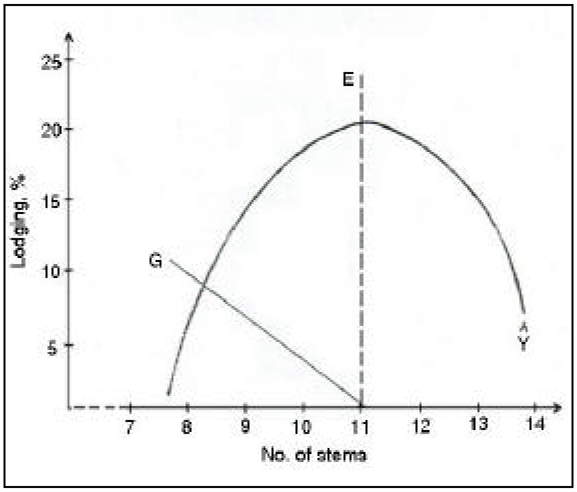
This point out that, at selection, the choice of lines with lower stalk (dwarf and semi-dwarf) reliably represents basic means for lodging decrease. In this sense, the investigation of determination, location and gene transfer for wheat shoot height, is of current interest (Korzun, et al., 1995; Petrovic and Worland, 1995).



Graph 1. Changes of lodging depending on stalk height

The number of shoots per plant-clustering influences the lodging significantly and negatively ($r_{y2.}$1345 = –0.85**). But lodging function (Graph 2) shows that there is a change of the course of dependence:

$$y = 195.02 + 38.84x_2 - 1.75\,x_2^2$$

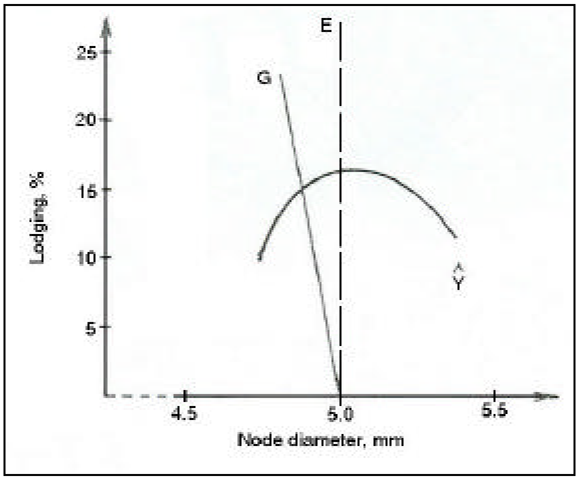


Graph 2. Changes of lodging depending on number of shoots

From data of graph 2 it is evident that in varieties of very poor and strongly expressed clustering, lodging is poorer. This shows that in the process of wheat selection one should investigate the lines in sparse seeding of breeding material and, with selection by cluster type, realize lodging control.

Diameter (thickness) of the first internode influences significantly the lodging ($r_{y3.}$1245 = 0.60*). The conclusion that the thicker basal internodes induce lodging is corrected considerably by the analysis of lodging function:

$$y = -3161.75 + 1269.72x_3 - 126.8\,x_3^2 \text{ (Graph 3).}$$



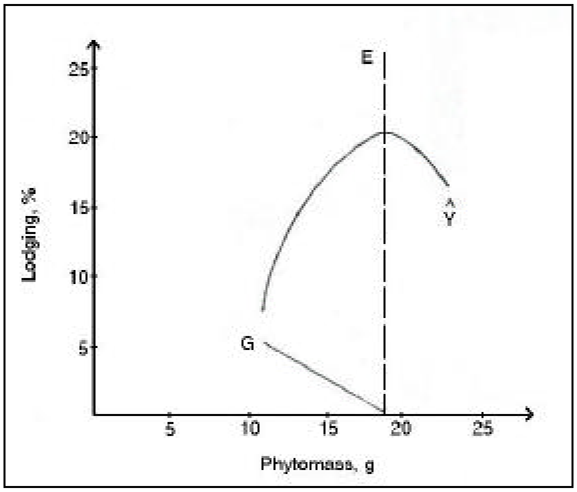
Graph 3. Changes of lodging depending on node diameter

From this analysis it is obvious that such dependence appears to one (marginal) diameter value of 5 mm. The next increases of internodes thickness condition the greatest resistance to wheat lodging.

This shows that in selection of wheat lines resistant to lodging, if parental varieties of thin and elastic stalks of specific structure of mechanical tissues are not used, one should pay attention that internodes are of larger diameter.

Shoot mass decreased lodging very significantly ($r_{y4}.1234 = –0.78^{**}$). It should be emphasized that the lodging function:

$y = –55.17 + 7.74x_4 – 20\,x_4^2$ has an asymmetrical convex shape, and this point out that there is a change of dependence course (Graph 4).

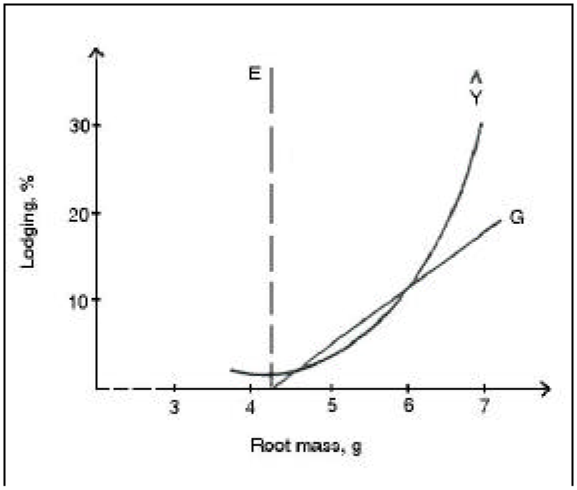


Graph 4. Changes of lodging depending on phytomass

A clear tendency has the increase of lodging with the increase of plant mass, and some decreases of lodging can be seen after marginal value of 19.3 g. This explains the frequent field observations that under the influence of rain and wind more robust plants lodge easier.

In breeding of wheat lines with the aim of achieving high resistance to lodging, plants of smaller vegetative mass but with greater photosynthesis capacity should be selected (Hall and Allen, 1993). The advantage of such a choice is the increase of harvest index in good lines.

Root development (mass) according to the above data influences relatively poor the lodging ($r_{y5}.1234 = 0.34$). Such form of dependence appears during the whole course of function: $y = 76.06 – 31.17x_5 + 3.17\,x_5^2$ (Graph 5).



Graph 5. Changes of lodging depending on root mass

A positive relation of root mass and lodging appears; because of that, the more de-veloped plants (that lodge more) have more developed roots. It should be emphasized that, in wheat selection with any trait, root mass is not used as an objective criterion. If the selection of plants could be made only on the basis of poor developed roots, lodging would decrease insignificantly, and this would have a negative influence on a larger number of the other traits. Because of that, selection of fertile lines, resistant to lodging, should be performed, first of all, through the improvement of root arrangement in the soil, and not only through their total mass (Muchow and Carberry, 1993).

CONCLUSIONS

Regression functions, i.e. marginal analysis, were used for the explanation of the influence of stalk and root traits expression root on wheat lodging.

It has been established that each increase in stalk height leads to root mass increases and lodging. Lodging dependence of shoot number, diameter (thickness) of basal internode and plant mass development is more complex. These traits, by certain value influence the increase, and than, the decrease of lodging. Marginal value of shoot number is 11, diameter (thickness) of internode 5 mm, and shoot mass 19.3 g. On the basis of this investigation, for selection of wheat lines resistant to lodging, it is recommended the choice of plants with short stalk, larger internodes, smaller vegetative mass and favourable root arrangement in soil.

REFERENCES

Cincovic, T. and Šinžar, B., 1967. Anatomske karakteristike stabla nekih sorata pšenice (Anatomic characteristis of stalks of some wheat varieties). Zavod za strna žita, 2: 122–133, Kragujevac.

Dencic, S., 1994. Designing a Wheat Ideotype with Increased Sink Capacity. Plant Breeding, Vol. 112: 311–317.

Dzhelepov, K., 1991. Sources and genes for short stem in wheat (*Triticum aestivum* L.). Genetics and Breeding, 24: 87–96.

Djokic, A., Mladenovic, N., 1989. Agrounija, nova sorta ozime pšenice (Agrounija, the new winter variety). Savremena poljoprivreda, 37: 213–228.

Hamilton, D. G., 1951. Culm, crown and root development in oats as related to lodging. Sci. Agr., 31: 286–315.

Hall, A.E., Allen, L. M., 1993. Designing cultivars for the climatic conditions of the next century. Inter. Crop Sci. I CSSA, Madison, USA: 291–297.

Heady, E., 1961. Agricultural production function. Ames, SAD, 33: 153–64.

Ivanovic, M., Rosic, K., 1983. Parcijalne i semiparcijalne korrelacije izmedu nekih svojstava stabla kukuruza. (Partial and semipartial correlations between some corn stalk traits): Arhiv za poljoprivredne nauke, 44: 173–186.

Jankovic, M., 1996. Nasledivanje otpornosti pšenice prema poelganju (Wheat resistance heritability to lodging), Zbornik radova Zavod za strna žita, Kragujevac.

Korzun, V., Worland, J., Laurie, D. A., Borner, A., 1995. Comparative genetic studies of dwarfness and daylength response in cereals. Joint Proceedings of 5th Public Workshops of the ITMI. Norwich, UK: 146.

Muchow, R. C., Carberry, P. S., 1993. Designing improved crop plants for the semi-arid tropics. An agronomist, Viewpoint – Kluver Academic Publ. Dordrect, Netherlands: 37–61.

Petrovic, S., Worland, J., 1992. Geni reduktori visoke stabljike i determinaci ja prisustva u jugoslovenskim soratama. (Genes of shoot height reducers and determination of presence in Yugoslav varieties). Contemporary agriculture, Vol. 6, No. 15: 81–85.

Sinha, B. C., Rai, S. N., Saha, B. C., 1984. Correlation and path analysis in advanced generations of wheat. Genetika 16 (2): 131–138.

Table 1. Reproduction ability of the *E. integriceps* recent generations, as compared with multiannual average (1970-2000) and with the specific years: favourable (1986) and unfavourable (1989).

Natural generation of *E. integriceps*	Prolificacy (egg/female)		
	under field conditions	under controlled conditions	
		average	maximum/female
1970-2000	40.2	57.9	311
1986	56.3	71.3	298
1989	18.8	27.1	87
1996	47.1	69.9	302
1997	46.6	68.6	197
1998	37.5	53.8	209
1999	38.8	54.5	219
2000	39.3	55.7	208

Table 2. Prolificacy level of some *E. integriceps* populations (fertile females), from generations with different fat body levels, collected from the field, at the beginning of migration and studied under controlled conditions.

Fat body	Generation	Prolificacy (egg/female)	
		average	maximum
23.4	1989-1990	32.1	97
22.5	1972-1973	33.4	127
26.5	1971-1972	46.4	148
27.9	1977-1978	67.5	186
28.0	1984-1985	83.6	210
29.7	1985-1986	95.3	234
29.8	1994-1995	104.7	246

Table 3. Level and stages of fat body diminution at *E. integriceps* (multigeneration average).

Stages	Fat body level		Diminution	
	limits	average	limits	average

Diapause beginning	33.03-37.58	35.69	0	0
End of diapause	21.97-27.64	25.43	24.57-36.33	27.39
End of oviposition	8.12-10.39	8.78	66.50-78.69	74.43

Table 4. Mortality registered at the *Eurygaster integriceps* populations, during diapause in different generations, from Romanian area

E. integriceps natural population	Mortality (%)	
	Limits in counties	Total area (mean)
2000-2001	4.6-35.7	8.7
1995-1996	3.7-36.4	10.2
2001-2002	5.1-32.3	12.7
1985-1988	3.8-41.2	14.8
1999-2000	4.8-97.6	24.5
1973-1974	11.6-85.0	39.5
1988-1989	17.5-68.4	48.2

Table 5. Fat body value at *Eurygaster integriceps* populations, established on female groups, distributed in weight classes, at the beginning of diapause (multigeneration average).

Weight (mg)	% from the total of population		Fat body (%)	
	limits	average	limits	average
below 0.110	3.7-7.7	5.6	26.2-26.6	26.4
0.111-0.118	7.6-23.1	13.3	26.5-28.8	28.7
0.119-0.126	15.9-24.7	19.7	32.8-33.5	33.6
0.127-0.134	32.5-34.8	33.7	34.9-36.4	35.4
over 0.145	22.4-30.8	28.6	35.7-39.8	38.7

Table 6. Fat body value at *Eurygaster integriceps* populations, established on male groups, distributed in weight classes, at the beginning of diapause (multigeneration average).

Weight (mg)	% from the total of population		Fat body (%)	
	limits	average	limits	average
below 0.105	7.0-19.7	12.3	25.3-26.7	26.2
0.106-0.113	16.8-19.9	17.3	27.2-28.5	27.7
0.114-0.121	20.3-29.5	23.7	29.4-33.8	31.5
0.122-0.129	19.2-32.7	28.5	31.2-35.5	32.6
over 0.130	15.5-23.9	19.4	31.4-36.6	33.8

Table 7. Mortality (%) registered at *Eurygaster integriceps* female populations, depending on the fat body (multigeneration average).

Fat body (%)	Mortality (%)			
	During August-October		During November-March	
	limits	average	limits	average
26.4	17-22	20.4	59-64	61.3
28.7	13-15	12.9	43-54	47.6
33.6	9-17	12.5	41-52	46.2
35.4	4-11	6.6	29-34	33.6
38.7	4-7	5.8	26-35	30.9

Table 8. Mortality (%) registered at *Eurygaster integriceps* male populations, depending on the fat body (multigeneration average).

Fat body (%)	Mortality (%)			
	During August-October		During November-March	
	limits	average	limits	average
26.2	22-31	22.6	62-71	67.1
27.7	11-24	20.4	53-62	57.4
31.5	12-19	14.3	39-47	44.0
32.6	9-18	12.7	30-44	37.6
33.8	5-14	9.1	24-45	32.3

Table 9. Sterility and prolificacy registered at the *Eurygaster integriceps* populations, depending on the fat body (multigeneration average).

Fat body (%)	Females sterility (%)		Mean prolificacy (egg/female)		
	limits	average	limits	average	maximum
26.4	100	100	0	0	0
28.7	60-72	63.5	4.1-6.6	5.4	42
33.6	54-63	57.3	16.2-22.8	19.5	78
35.4	35-44	39.1	26.4-33.1	30.3	135
38.7	25-32	29.8	38.9-51.7	45.8	194

Table 10. Multiplication index at the *Eurygaster integriceps* populations, depending on the fat body (multigeneration average).

Fat body (%)	Multiplication index (egg/female)	
	limits	average
26.4	0	0
28.7	0.37–2.47	1.54
33.6	4.54–9.62	6.95
35.4	28.57–40.18	35.22
38.7	49.38–64.83	56.47