STUDY OF LODGING RESISTANCE AND ITS ASSOCIATED TRAITS IN BREAD WHEAT

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ABSTRACT

Lodging is a yield barrier and has long been a problem in cereal cultivation. The objective of the study was to measure and analyze the genetic variability and evaluate the traits which are closely related to lodging resistance. The study revealed that there have significant differences among the different genotypes of bread wheat. It is observed that genotypes having higher solid pith area have higher lodging resistance capability. Some characters of bread wheat also highly heritable such as length of spike, 100-grain weight, yield etc. So these characters would be effective for selection in breeding programme. Sufi and Gourav varieties are semi dwarf. They possess higher sclerenchyma layer width, sclerenchyma layer number. They are capable to lodging resistance. Pradiv, Shatabdi and Prativa have the higher yield than other varieties are semi dwarf in nature. Higher number of vascular bundle is positively correlated with lodging resistance because vascular bundle possesses some lodging resistance properties. For lodging resistance a more practical approach would be to select amongst progeny plants for shorter and solid stems.

Keywords: wheat (*Triticum aestivum*), lodging, solid pith area, stem, vascular bundle.

INTRODUCTION

Lodging can be defined as the state of permanent displacement of stems from the upright position. Because of lodging, whole fields of cereals are often flattened after storms (Crook and Enos, 1995). This has long been a problem in cereals (Verma *et al*., 2005). Lodging can be classified into two types, the first being stem lodging, which is the bending or breaking of the lower culm internodes. This depends on the tensile failure strength of the first internodes, as well as on stem wall diameter and thickness (Verma *et al*., 2005). The second is root lodging, which refers to the straight and intact culms leaning from the crown, involving a certain disturbance of the root system.

M. J. Crook and A.R. Ennos (1993) worked on stem and root characteristics associated with lodging resistance in four winter wheat cultivars. The effects of root and shoot characteristics on the lodging resistance of wheat were investigated by combining results from a field trial with morphological and mechanical measurements on their stems systems.

A.J. Kelbert, D. Spaner, K.G. Briggs and J.R. King (2004) worked on the association of culm anatomy with lodging susceptibility in modern spring wheat genotypes. They found significant differences in different internodes.

Sterling *et al*., (2003) observed that the risk of lodging is strongly influenced by a number of husbandry decisions including variety choice, sowing date, drilling depth, soil fertility and the application of plant growth regulating chemicals. Keller *et al*., (1999) reported that higher seed density will enhance lodging by increasing culm length and decreasing culm diameter as well as total root mass. Their influence on lodging risk has been shown to be through their ability to alter crop structure by affecting certain plant characteristics (Sterling *et al*., 2003).

The aims and objectives of the present investigation are to determine the lodging resistance properties of bread wheat and evaluate the degree of genetic relationship among genotypes.

MATERIALS AND METHODS

The experiment was performed with 10 varieties. These materials were collected from the regional wheat research institute Rajshahi. They are Bijoy, Akbar, Balaka, Shatabdi, Prativa, Shourav, Barkat, Sufi, Gourav and Pradiv.

The seed of ten different genotypes were sown in the pot. After the seed sowing regular irrigation was done. After the maturation of the plant different part of the wheat plant was preserved in the laboratory. The three internodes were preserved in the solution of formalin, acetic acid and alcohol. After the slide preparation a micrometer was fixed in the stage of microscope and the section of plant part was put in the micrometer. It consists a scale in his centre. Adjusting the different magnification the photograph was taken by camera.

The data collected from the investigation are given bellow:

a) **Culm diameter:** Culm diameter was measured by millimeter.
b) **Total culm area:** Area of culm is measured in mm². It is measured by using formulae.
c) **Hollow culm area:** Area of the hollow pith was measured as like culm area.
d) **Solid culm area:** The area of hollow pith was subtracted from the area of culm, and measured in mm².
e) **Sclerenchyma layer number:** Number of sclerenchyma layers was counted.
f) **Sclerenchyma layer width:** Sclerenchyma layer width was measured in micron.

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g) **Number of vascular bundle:** Number of vascular bundle in the outer ring and inner ring were counted and recorded.

h) **Culm thickness:** Culm thicknesses are measured.

The data which is collected is statistically analyzed through analysis of variance and significance of mean difference. Different components of genotypic and phenotypic variation, heritability also estimated for the determination of relationship among the character.

RESULT AND DISCUSSIONS

The investigation was carried out to find genetic variation among the varieties and their lodging resistance activity in relation to different characteristics.

From the morphological view, Akbar and Shourav (69.33cm) two plants height are comparatively higher than other genotypes. Bijoy also have higher height. Ten varieties also show genetic variation among them. The variety Akbar also produces higher weight in its 100 grains (5.72gm) though its length of spike and number of spikelet not so higher than other varieties. Spike length of Pradiv is the highest and its spikelet number also more than other genotypes. Its grains weight in per spike is also more than other varieties. 100 grains weight of this genotype also so high but it height is lower than Akbar. The smallest genotype in this experiment was Sufi which yield is relatively lower (4.23gm) than all other genotypes. From the yield producing point it is shown that four varieties are better than others. Those genotypes are Pradiv, Akbar, Gourav, and Shatabdi, respectively. For weight of grains in per spike 14% genotypic variations and 21% phenotypic variation is shown. It also shows 37% genotypic variation and 44% phenotypic variation for 100-grains weight in all genotype. Pawar *et al.* (2002) reported high phenotypic and genotypic coefficient of variation for the characters spike length, 100-grain weight and yield per plant.

Among the observation it is found that different genotypes show variation among them. So the grain yield and yield relating characters in wheat show variation in different degrees and this difference are accompanied by their genetic materials and effects of environmental factors.

The heritability of different character was also estimated. The heritability for length of spike, number of spikelet, weight of grains per spike, 100-grains weight are 84%, 63%, 68% and 84%. It's indicated that those characters were highly heritable.

Table-1. Mean data and mean square of analysis of variances of culm diameter (mm), culm thickness (mm), total culm area (mm^2), solid culm area (mm^2) of ten wheat genotypes.

Genotypes	Culm diameter			Culm thickness			Total culm area			Solid culm area			Hollow culm area		
	IN 1	IN 2	IN 3	IN 1	IN 2	IN3	IN 1	IN 2	IN 3	IN 1	IN 2	IN 3	IN 1	IN 2	IN 3
Bijoy	3.25	3.05	2.93	.66	.55	.50	8.30	7.31	4.87	4.54	4.06	2.62	3.77	3.35	2.25
Akbar	3.20	3.00	2.70	.53	.49	.47	8.05	7.34	4.62	4.49	4.49	2.29	3.56	2.85	2.34
Balaka	3.30	3.07	2.71	.65	.54	.51	8.62	7.26	3.99	5.14	4.06	2.20	3.15	3.2	1.78
Shatabdi	3.67	3.05	2.81	.56	.57	.48	10.57	7.01	4.97	6.07	3.76	2.67	4.50	3.25	1.95
Prativa	3.30	3.00	2.70	.52	.48	.45	8.56	7.19	5.09	5.34	4.60	3.11	3.22	2.59	1.98
Shourav	3.80	3.00	2.38	.68	.54	.47	11.85	7.42	4.40	6.34	4.31	2.32	5.51	3.11	2.08
Barkat	3.38	3.06	2.77	.59	.53	.46	8.98	7.35	6.07	4.70	4.99	3.87	4.28	2.36	2.21
Sufi	3.88	3.12	2.65	.60	.53	.51	11.86	7.73	4.69	6.98	4.16	3.03	4.68	3.51	1.59
Gourav	3.51	3.08	2.83	.61	.57	.56	9.70	7.43	6.41	5.84	4.57	3.86	3.86	2.78	2.55
Pradiv	3.60	3.00	2.93	.62	.61	.52	10.21	6.97	6.71	6.11	3.99	4.09	4.09	2.99	2.28
LSD (5%)	.31	.21	.71	.08	.06	.02	1.67	.54	1.27	1.52	.75	1.14	.76	.68	.45
LSD (5%)	.42	.27	.97	.11	.08	.03	2.32	.74	1.74	2.07	1.02	1.56	1.05	.94	.61
								ms							
Replication (R)	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Genotypes (G)	ns	ns	***	**	*	**	ns	*	**	*	ns	ns	ns	**	**
Error (G×R)	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

IN indicates Internode, LSD indicates the least significant differences at 5% and 1% level and *, ** indicate significant at 5%, 1% level of probability, respectively. ns denotes non-significant.

Jedyneski (2001) estimated high heritability for 100-grain weight and grain yield per plant.

High heritability and high yielding characters are suitable for selection. Plant height, spike length, 100- grain weight, number of spikelet, weight of grains in per spike had high phenotypic coefficient of variation and they had also high heritability. So selection for this character would be effective.

The basal internode of Sufi had relatively larger culm diameter (3.88mm). Its internode 2 and 3 also had relatively larger culm diameter. Variety Bijoy had the highest culm thickness but Sufi had also higher culm

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thickness in basal internode. Culm area of Sufi's also higher than other varieties. Culm area of Shatabdi, Shourav and Pradiv are also high (Table-1). It was reported that short plants with fewer short, wide internodes with thick culm walls and a higher number of vascular bundles were characteristic of the lodging tolerant genotypes. Plant height and the length of the basal internodes were the two main culm characters closely associated with natural and artificially induced lodging for all genotype studies, while other culm characteristics did not appear to be related to lodging (Kelbert *et al*., 2004).

The solid culm area of Sufi is higher than other varieties and it was estimated 6.98mm².Pradiv and Shourav also had higher solid culm are whish were 6.11 and 6.34mm² respectively.

Sufi also had higher sclerenchyma layer compared to other genotypes. Gourav, Barkat and Shatabdi also had relatively more sclerenchyma layer. They had 4-5 sclerenchyma layers in their basal internode. The sclerenchyma width in Balaka, Prativa is higher than others. Sufi, Gourav and Shatabdi had similar width of sclerenchma.

Pradiv had relatively higher number of vascular bundle in its inner cycle, Sufi had smaller number of vascular bundle but Stanca *et al*., (1979) found no association between the numbers of vascular bundles stem diameter or culm wall thickness of the basal internodes and artificially induced lodging. Stem diameter explained almost half of the phenotypic variation in lodging resistance and Kelbert *et al*., (2004) did not find stem diameter to be a significant character related to lodging resistance. In Sufi, Pradiv, and Akbar nearly same number of vascular bundles were found in their outer area. They were 19.0, 20.33 and 21.3, respectively. In Shatabdi higher number of vascular bundle found in its outer ring Table-2.

Table-2. Mean data and mean square of analysis of variances of sclerenchyma layer number, sclerenchyma layer width (µm), vascular bundle number outer and inner of ten wheat genotypes.

Genotypes	Sclerenchyma layer number			Sclerenchma layer width (µm)			Vascular bundle number (outer)			Vascular bundle number (inner)		
	IN 1	IN 2	IN 3	IN 1	IN 2	IN 3	IN 1	IN 2	IN 3	IN 1	IN 2	IN 3
Bijoy	4	3.7	2.7	5.98	5.35	4.5	15.3	18.3	17.7	21.7	23.3	14.3
Akbar	4.4	3.7	3.0	5.71	4.91	4.3	21.3	17.7	18.3	26.3	29.0	28.6
Balaka	4.4	3.3	3.0	6.23	5.49	4.6	17.7	17.0	17.3	26.0	28.6	18.6
Shatabdi	5.0	4.0	3.3	5.43	4.87	4.5	22.7	19.0	18.0	23.3	28.3	24.3
Prativa	4.0	3.3	3.3	6.43	5.73	4.6	13.7	17.3	21.3	22.7	27.0	28.6
Shourav	4.0	3.7	3.0	6.24	5.47	4.3	18.7	16.7	14.0	25.3	27.6	28.0
Barkat	4.4	3.7	2.67	5.73	5.09	4.7	15.0	17.3	20.3	21.3	24.0	25.3
Sufi	4.7	4.0	2.0	5.43	4.75	3.7	19.0	14.3	21.7	23.7	27.0	22.3
Gourav	4.6	3.7	3.0	5.56	5.08	4.9	15.7	13.7	23.0	21.0	25.3	25.0
Pradiv	4.3	4.0	2.6	5.56	5.06	4.6	20.3	14.3	19.0	30.6	26.6	29.3
LSD (5%)	1.04	.82	.68	.91	.77	.96	3.99	4.28	4.88	6.31	3.45	4.56
LSD (5%)	1.43	1.13	.94	1.24	1.05	1.31	5.46	5.87	6.69	8.65	4.72	6.25
								ms				
Replication (R)	ns	ns	ns	ns	ns	ns	Ns	ns	Ns	ns	ns	ns
Genotypes (G)	ns	ns	**	**	*	**	Ns	*	**	*	ns	ns
Error (G×R)	ns	ns	ns	ns	ns	ns	Ns	ns	Ns	ns	ns	ns

IN indicates Internode, LSD indicates the least significant differences at 5% and 1% level and *, ** indicate significant at 5%, 1% level of probability, respectively. ns denotes non-significant.

A close correlation was calculated between the lodging resistance of wheat and the carrying capacity of the culms at maturity. This was calculated from the weight per unit length of the culms basis (g per 10 cm), plant height and the weight of the ear (Zuber *et al*., 1999). A greater diameter of the lower internodes and the greater weight per unit length of the stem basis of wheat was also suggested as a possible reason for better lodging resistance (Zuber *et al*., 1999).

However Pinthus (1967) found no significant correlation between culm diameter and lodging resistance in wheat. This may be due to the fact that plant material in these studies had not been selected for plant height (Zuber *et al*., 1999). Therefore more of the variation for lodging resistance was caused by plant height and less by culm diameter than in their study. Stem weight per cm is of less importance for lodging resistance in plants shorter than 90 cm (Zuber *et al*., 1999). Genotypes with heavier ears appear to reach the same level of lodging resistance compared to genotypes with lighter ears. This occurs only when their stem weight per centimeter values are higher, i.e., heavier ears increase lodging. Increased lodging caused by heavier ears was compensated for by heavier stems which help to reduce lodging (Zuber *et al*., 1999). The influence of ear weight on lodging can also vary depending on the stage of plant development.

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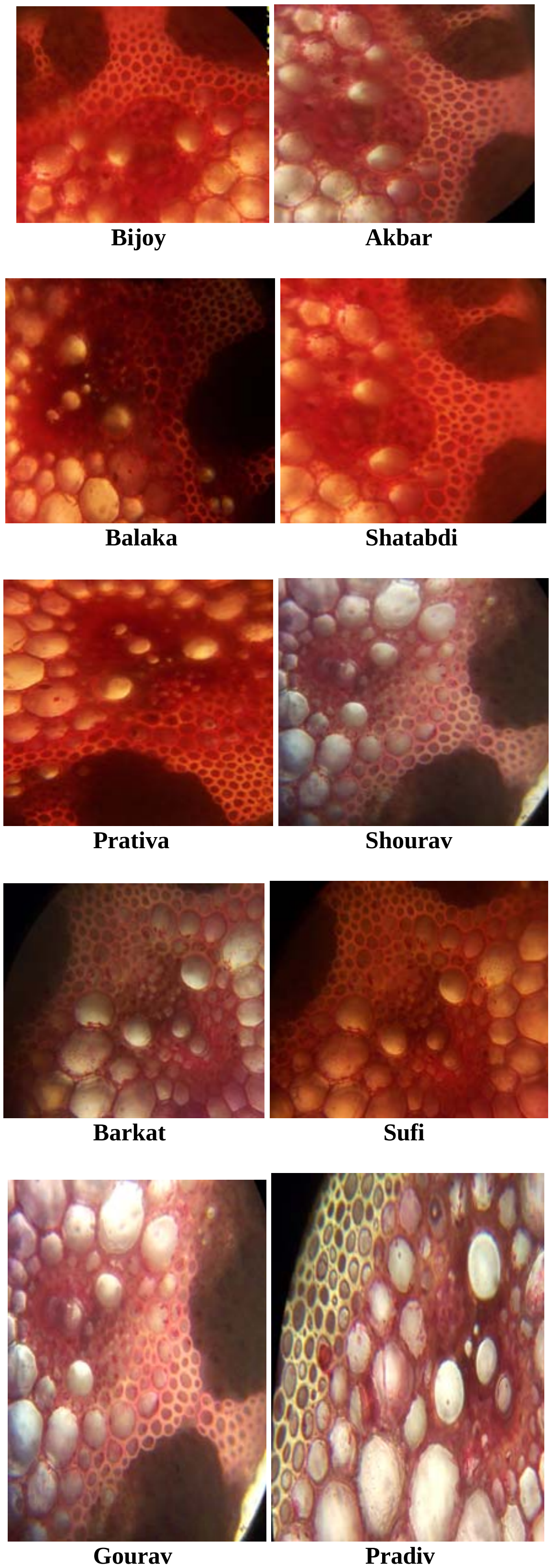

Figure-1. Sclerenchyma layer in ten different varieties.

Certain studies have shown that longer, more rigid coronal roots, larger root spreading angles, or anchorage strength of root, usually increase lodging resistance. Morphological root parameters are difficult to measure and are highly influenced by environmental conditions such as nitrogen fertilization and temperature. The suggestion is that besides plant height, stem weight per centimeter and culm diameter may be of value in breeding for better lodging resistance. If a simple method for scoring culm diameter in the field could be established, this could be an adequate selection criterion for lodging resistance among genotypes of similar height (Zuber *et al*., 1999). Berry *et al*., (2003) suggested that breeders should opt for wider, deeper root plates and wide stems with thicker stem walls, for the greatest improvement in lodging resistance.

Hai *et al*., (2005) suggested that more efforts to improve stem strength should be an important focus in wheat breeding for lodging resistance. They reported that the heritability for culm length was relatively high, thus indicating selection for culm length would be effective. Lodging resistance scoring is very difficult under natural field conditions (Hai *et al*., 2005). It is important to realize that stem strength is not only associated with morphological and anatomical traits of the stem, but is also with several physiological traits (Hai *et al*., 2005). According to Li (1998) the soluble carbohydrate content of basal internodes of the stem was significantly correlated with lodging resistance, and the lignin content of basal internodes of strong stems was higher than that of weak stems.

According to Keller *et al.* (1999) plant height is probably the best trait for an indirect assessment of lodging resistance. In their study they found that the mechanical parameter of culm stiffness was as highly correlated to lodging as to plant height, while culm stiffness is easy to assess by hand scoring. Some breeders use this trait as an indirect selection parameter for lodging resistance.

CONCLUSIONS

From the above investigation, it was found that Sufi is suitable for selection because of its lodging resistance character. Gourav and Pradiv also have this lodging resistance character.

Sufi and Gourav varieties are semi dwarf. They possess higher sclerenchyma layer width, sclerenchyma layer number. They are capable to lodging resistance. Pradiv, Shatabdi and Prativa have the higher yield than other varieties are semi dwarf in nature.

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