LODGING: A DETERMINING FACTOR IN REDUCING YIELD AND YIELD STRUCTURE OF WHEAT

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ABSTRACT

Six wheat varieties viz. Dera-98, Daman-98, Nasir-2K, Raj, Zam-04 and Hashim-8 were evaluated for their yield and yield contributing parameters under normal crop stand and lodged conditions at Agricultural Research Institute, Dera Ismail Khan, Pakistan. These varieties showed significant differences for grains spike^{-1}, grain weight spike^{-1}, 1000-grain weight and grain yield (kg ha^{-1}) under both normal crop stand and lodged conditions. Daman-98 produced more number of normal grains spike^{-1}, the highest normal grain weight spike^{-1} and the final grain yield. The most damaging effect of lodging was observed in wheat variety Dera-98. This research has opened up avenues for further studies in quantifying influence of different environmental factors on wheat yield as affected by lodging, a commonly occurring threat to this crop in the region.

Key Words: ***Lodging, Dera-98, Daman-98, Nasir-2K, Raj, Zam-04, Hashim-8***

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INTRODUCTION

Wheat (*Triticum aestivum* L.) is known as the "king of cereals" and is a major food trade commodity in the world (Khan *et al*., 1999). It is grown as a temperate (Rabi) crop with an annual production of 583 million tones (Anonymous, 2008). In Pakistan, wheat is the staple food crop and a central theme of food security in the country (Khan *et al*., 2000). The current wheat production targets are about 23.4 million tones whereas its demand in year 2010 is about 26.4 million tones in Pakistan (Islam *et al*. 2002). It is also the most important food crop cultivated in both irrigated and barani areas of NWFP (Uddin *et al*., 2005).

Wheat requirements are progressively increasing every year due to population explosion and stagnant per hectare yields. Therefore, any loss to wheat yield is not only a threat to dictate food security in the country but also lower foreign exchange bill of the treasury. Among yield contributing parameters; genetic potential, proper land preparation, judicious use of fertilizers, use of high quality seed, optimum seed rate, timely cultural operations and plant protection measures determine the yield (Shah, 1994). In recent years, however, lodging is reported to be the most limiting factor in attaining higher wheat yields (Ransom, 2005). It can cause yield losses up to 40% if happens during the 10 days after heading (Kelbert *et al.,* 2004). Previous findings suggest that lodging is induced as a result of inadequate standing power of the crop and adverse weather conditions, such as rain, strong winds, and/or hail, especially in the later part of the crop's growth (Rawson and Macpherson, 2000). It affects flowering, reduces photosynthetic capabilities of the plant and eventually affect carbohydrate assimilation. Under severe condition, lodging interferes with the transport of nutrients and moisture from the soil and restricts mechanical harvesting by taking about twice to harvest a lodged crop than a standing one (Ransom, 2005). High levels of nitrogen, high seeding rates, excessive soil moisture and use of tall varieties are the known causes of wheat lodging (Stapper and Fischer, 1990; Mavi *et al*., 2004).

Lodging resistance cultivars have been developed by improving the length of uppermost internode, thickness of stem wall, quantity and intensity of mechanical tissue, quantity of vascular bundle, content of cellulose and lignin in stem cell wall, the amount of carbohydrate stored in stem, quantity of silicon and potassium and mapping quantitative trait loci for the lodging resistance (Tripathi *et al.,* 2003; Mao-chun *et al*., 2007). It has been suggested to use plant growth retardants and sulphur in order to prevent lodging problem (Ramburan and Greenfield, 2007; Hussain and Leitch, 2007). Reduction in light integrals (photosynthetic active radiation, PAR) and light quality (red:far-red, R:FR) also increased lodging susceptibility in stem and root traits of wheat (Sparkes and King,

2008; Sparkes *et al*., 2008). Lodging control of irrigated spring wheat was achieved through both crop management practices and cultivar improvement. Bed planted genotypes demonstrated over 50% less lodging compared with flat planting provides an evidence that bed planting irrigated spring wheat may be beneficial where chronic lodging occurs (Tripathi *et al*., 2005). Keeping in view, the present study was undertaken to determine the losses caused by lodging on yield and yield contributing parameters of wheat.

MATERIALS AND METHODS

The research was conducted at Agricultural Research Institute (ARI), Dera Ismail Khan, Pakistan which lies 31° 49' N to 70° 55' E longitude. Six wheat varieties viz. Dera-98, Daman-98, Nasir-2K, Raj, Zam-04 and Hashim-8 were evaluated for their yield and yield contributing parameters under normal crop stand and lodged conditions. These varieties have been developed at ARI, Dera Ismail Khan and released by the Provincial Seed Council (PSC) for general cultivation. The lodging in wheat varieties was termed as natural lodging due to the factors like wind storm, rains etc. An area of 1 (m^2) was randomly selected for recording data using a 1 (m^2) quadrate at 4 sites for each variety both under normal and lodged conditions. Crop standing $\approx 90^0$ were considered normal or upright plants whereas plants bowed to $\geq 30^0$ were designated as lodged crop. The soil was silty clay with a pH of 8.2 and organic matter content of <1% (Table I). The weather data recoded during crop season is given in Table II. All cultural practices were followed according to Shah (1994). Data were recorded on number of grains spike^{-1}, grain weight spike^{-1}, 1000-grain weight and grain yield kg ha^{-1}. Data on each parameter were recorded in two categories i.e. normal wheat grains and shriveled wheat grains by visual observations. Also the seeds having 30% small size than normal wheat grains were classified as shriveled grains. All data were recorded at three randomly selected spots of lodged and normal crop area of each variety. Experimental design used in the study was Randomized Complete Block Design (RCBD). The data recorded during the crop season were analyzed statistically using analysis of variance technique and subsequently Least Significance Difference (LSD) test was applied for comparing the treatment means by MSTATC computer software (Steel and Torrie, 1980).

Table I ***Soil analysis report of experimental area***

Symbol	Unit	Symbol	Unit
pH	8.2	P	8.2 mg/kg
EC	0.600 ds/m	K	256 mg/kg
Ca + Mg	7.90 meq/L	Zn	1.228 mg/kg
CO_3	Nil	B	1.170 mg/kg
HCO_3	0.88 meq/L	Sand	15.2%
Cl	1.56 meq/L	Silt	42.8%
OM	0.640%	Clay	42.0%
N	0.032%	Textural class	Silty clay

Table II ***Weather data recorded during wheat crop season***

Months	Temperature C°		Wind speed (km/h)	Rainfall (mm)
	Max:	Min:		
October	33	20	56	24.0
November	26	13	55	43.0
December	22	06	63	20.5
January	22	04	60	7.0
February	22	08	71	143.0
March	26	13	69	115.0
April	39	19	72	12.0

RESULTS AND DISCUSSION

Number of Grains (spike^{-1})

Different varieties showed significant differences for number of grains spike^{-1} under lodged and normal conditions. Maximum number of shriveled grains (11.3) was produced by Nasir-2K. This is a long duration variety and was at milking stage when the lodging occurred. The normal growth process was probably disrupted and therefore it could not convert the photosynthates towards the final grains formation. Variety Hashim-8 produced the lowest shriveled grains spike^{-1} (1.55). This variety has a shorter growth period and for that reason it might have converted its photosynthates to normal grains effectively. Lodged condition enhanced the synthesis of shriveled grains to 8.58 grains spike^{-1}. There were significant differences among varieties for producing normal grains spike^{-1}.

Daman-98 showed the maximum grains spike^{-1} (58.95) under normal condition. It might be attributed to its longer spike with a shorter life span. Raj variety produced minimum normal grains spike^{-1} (37.20). It is also a long duration variety and was still at anthesis stage when lodging occurred, which ultimately affected pollination badly, causing minimum fertilization and final grain development. The differences in both lodged and normal conditions were found significant. Maximum normal grains spike^{-1} (57.89) was noted under normal crop as compared to lodged condition which produced 38.77 grains spike^{-1} under normal condition. The interaction between varieties and crop condition for grains spike^{-1} was found significant in both shriveled and normal cases (Table-III).

Table III *Number of grains spike^{-1} of wheat varieties under lodged and normal conditions at ARI, D.I. Khan*

Varieties	SHRIVELED GRAINS			NORMAL GRAINS		
	Varieties' condition		Means	Varieties' condition		Means
	Lodged crop	Normal crop		Lodged crop	Normal crop	
Dera-98	8.40 cd	4.10 def	6.25 b	38.60 de	49.50 cd	44.05 cd
Daman-98	13.6 ab	0.80 f	7.20 b	47.90 cde	70.00 a	58.95 a
Nasir-2K	16.5 a	6.20 cde	11.3 a	45.80 cde	62.40 ab	54.10 ab
Raj	2.00 ef	2.80 ef	2.40 c	21.33 f	53.07 bc	37.20 d
Zam-04	9.70 bc	1.30 f	5.50 b	35.40 e	63.90 ab	49.65 bc
Hashim-8	1.30 f	1.80 f	1.55 c	43.60 cde	48.50 cd	46.05 bcd
Means	8.58 a	2.83 b		38.77 b	57.89 a	

LSD values: (Shriveled) Varieties = 3.072 Varieties x Conditions = 4.345
(P<0.01) (Normal) Varieties = 8.913 Varieties x Conditions = 12.60
Means in respective column not sharing a common letter(s) are significant at 1% level of probability.

Grain Weight (spike^{-1})

Grain weight spike^{-1} was significantly affected in different varieties under both conditions (Table-IV). Maximum weight of shriveled grains spike^{-1} (0.18g) was noted in Daman-98, which was closely followed by Nasir-2K (0.17g). Hashim-8 produced the minimum shriveled grains weight spike^{-1} (0.03g) due to its short duration nature. Data further indicated significant differences for shriveled grains weight spike^{-1} between lodged and normal conditions. Almost similar statistical variations were observed in normal grains weight spike^{-1} of different wheat varieties. Daman-98 was the leading variety with 2.37g weight of normal grains spike^{-1} on account of its longer spike and more number of grains spike^{-1}. It was followed by Nasir-2K with 2.10g grains weight spike^{-1}. Other three varieties viz. Raj, Zam-04 and Hashim-8 remained statistically at par with each other giving 1.99, 1.99 and 1.92g weight of grains spike^{-1}. Dera-98 showed poor performance with lowest normal grains weight spike^{-1} (1.60g). The difference in grains weight spike^{-1} was almost 2-fold in normal grains under normal crop over the lodged condition with 2.54 and 1.44g grains weight spike^{-1}, respectively. Interaction between both factors also showed significant variations for shriveled grains weight spike^{-1}.

Table IV *Grain weight (g) spike^{-1} of wheat varieties under lodged and normal conditions at ARI, D.I. Khan*

Varieties	Shriveled grains			Normal grains		
	Varieties' condition		Means	Varieties' condition		Means
	Lodged crop	Normal crop		Lodged crop	Normal crop	
Dera-98	0.17 bcd	0.08 de	0.13 ab	1.31 def	1.89 c	1.60 c
Daman-98	0.33 a	0.02 e	0.18 a	1.63 cde	3.11 a	2.37 a
Nasir-2K	0.25 ab	0.09 cde	0.17 a	1.64 cde	2.56 b	2.10 ab
Raj	0.07 de	0.07 de	0.07 bc	1.10 f	2.87 ab	1.99 b
Zam-04	0.21 abc	0.02 e	0.12 abc	1.21 ef	2.77 ab	1.99 b
Hashim-8	0.03 e	0.03 e	0.03 e	1.78 cd	2.05 c	1.92 bc
Means	0.18 a	0.06 b		1.44 b	2.54 a	

LSD values: (Shriveled) Varieties = 0.08914 Varieties x Conditions = 0.1261
(P<0.01) (Normal) Varieties = 0.3490 Varieties x Conditions = 0.4936
Means in respective column not sharing a common letter(s) are significant at 1% level of probability.

1000-Grain Weight (g)

Wheat varieties significantly affected the 1000-grain weight under lodged and normal conditions (Table-V). Raj had the maximum 1000-grain weight, which produced 6.56g shriveled grain weight. Daman-98 and Hashim-8 were at par with each other giving 4.41 and 4.10g weight of 1000-shriveled grains. The lowest weight of 1000-

shriveled grains was 3.01g from Nasir-2K variety. It might be due to its small size grains. As regards varieties conditions, higher shriveled grains were observed under lodged condition. Variety Raj produced higher grain weight (7.77g) that eventually increased the average 1000-grain weight under lodged condition. The inverse was true for normal grains wherein varieties produced higher grain weight under normal condition. Maximum shriveled 1000-grain weight was noted under lodged condition (4.60g) while normal crop gave 3.99g weight. Raj remained the leading wheat variety in producing the highest 1000-grain weight under normal crop (10.6g) while the lowest was noted in Dera-98 (7.18g). 1000-grain weight of varieties was 8.78g under normal conditions whereas lodged conditions produced 7.67g normal 1000-grain weight. The interaction for two types of grains (shriveled and normal) also revealed significant differences.

Table V ***1000-grain weight (g) of wheat varieties under lodged and normal conditions at ARI, D.I. Khan***

Varieties	Shriveled grains Varieties' condition		Means	Normal grains Varieties' condition		Means
	Lodged	Normal		Lodged	Normal	
Dera-98	3.91 bc	3.98 bc	3.95 bc	6.72 e	7.65 cd	7.18 d
Daman-98	4.83 bc	3.98 bc	4.41 b	6.82 e	8.89 b	7.86 bc
Nasir-2K	3.02 c	3.00 c	3.01 c	7.09 de	8.17 bc	7.63 cd
Raj	7.77 a	5.36 b	6.56 a	10.4 a	10.8 a	10.6 a
Zam-04	3.92 bc	3.59 bc	3.76 bc	6.81 e	8.66 b	7.74 c
Hashim-8	4.15 bc	4.05 bc	4.10 bc	8.15 bc	8.48 b	8.31 b
Means	4.60 a	3.99 b		7.67 b	8.78 a	

LSD values: (Shriveled) Varieties = 1.372 Varieties x Conditions = 1.941
(P<0.01) (Normal) Varieties = 0.5398 Varieties x Conditions = 0.7633
Means in respective column not sharing a common letter(s) are significant at 1% level of probability.

Grain Yield (kg ha^{-1})

Significant variations were observed in grain yield due to lodging in normal as well as lodged crop (Table VI). Variety Daman-98 out yielded all other wheat varieties tested. It is due to the short duration nature of Daman-98 that also produced more number of normal grains spike^{-1} and high normal grain weight spike^{-1} which contributed towards increased grain yield of this variety (5091 kg ha^{-1}) followed by Nasir-2K with 4535 kg ha^{-1}. Dera-98 revealed poor performance with grain yield of 3452 kg ha^{-1} followed by Hashim-8 with 3887 kg ha^{-1}. On the other hand, normal crop stand produced the highest grain yield (5192 kg ha^{-1}) as against the lowest (3240 kg ha^{-1}) obtained under lodged conditions. The interaction between two factors also gave significant results. Kelbert *et al.* (2004) obtained similar results and reported that lodging can cause yield losses up to 40% if happens during the 10 days after heading. Therefore, it is considered to be the most limiting factor in attaining higher wheat yields (Ransom, 2005; Navabi *et al*., 2006).

Table VI ***Grain yield (kg ha^{-1}) of wheat varieties under lodged and normal conditions at ARI, D.I. Khan***

Varieties	Varieties' Condition		Means
	Lodged	Normal	
Dera-98	2947.62 de	3957.28 c	3452.45 c
Daman-98	3919.64 c	6263.40 a	5091.52 a
Nasir-2K	3770.26 cd	5300.24 b	4535.25 ab
Raj	2353.95 e	5889.24 ab	4121.59 b
Zam-04	2839.56 de	5579.24 ab	4209.40 b
Hashim-8	3609.14 cd	4165.89 c	3887.51 bc
Means	3240.03 b	5192.55 a	

LSD values: Varieties = 659.9 Varieties x Conditions = 933.3 (P<0.01)
Means in respective column not sharing a common letter(s) are significant at 1% level of probability.

CONCLUSION

Present research findings demonstrate that lodging is an important factor in reducing yield up to 38% than that obtained in normal wheat crop. Lodging in this study was provoked due to high velocity winds in February, March and April (71, 69 and 72 Km/h) coupled with rainfall especially in February and March (143 and 115 mm) at milky stage of the crop. The situation further aggravated due to soil textural class (silty clay), which created temporarily water logged condition and this favored the root lodging of the crop. Care should be taken while applying the final irrigation to wheat that might be light & at early grain filling stage.

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