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LODGING IN CEREALS – A REVIEW

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Permanent displacement of plants from their vertical stance is called lodging. It is more common in cereals like wheat, oat and barley. Stalk breakage is also observed in sorghum and maize. Lodging usually occurs close to harvest and cereals are prone to lodging near harvest. There are two types of lodging stem and root. It is a complicated phenomenon influenced by many factors including wind, rain, topography, soil type, previous crop management and disease. Intensively cultivated cereals with high inputs like irrigation and fertilizer are more prone to lodging. Lodging reduces cereal yields considerably especially under mechanized harvesting. It also increases cost of harvesting with decrease in quality. Adoption of proper method of planting and time, population, nutrition, rotation and disease management helps in reducing lodging.

In cereals, lodging is considered to be a serious malady for long time. Development of semidwarf varieties of crops reduced the problem to some extent, but not completely. Use of higher level of fertilizers, irrigation and some times reverting to older cultivars for specific needs and increase in the mechanized harvesting may lead to further losses due to lodging. Presently, development of new varities for higher yields has reached a plateau and no further increase is achieved unless biotechnological interventions are made.

Definition and types of lodging:

Lodging is the state of permanent displacement of the stems from their upright position. It is induced by external forces like wind, rain or hail. Lodging is often not distributed uniformly throughout an affected field but may be scattered over certain sections or spots. Berry *et. al.* (2004) described the types of lodging as stem lodging and root lodging.

Lodging in relation to time and space:

Occurrence of lodging is dependent on season. Time of rainfall occurrence is more related to lodging than the amount of rainfall. Root lodging in winter wheat is associated with as little as 4 mm of rain. Wind speed played secondary role in lodging. Higher than the normal wind speed resulted in lodging. Sterling *et. al*. (2003) demonstrated through tunnel experiments that root lodging could occur within 5 minutes when the soil was saturated and the crop was subjected to a mean wind speed of 8 m/s.

In cereals, lodging tends to be more when crop is near harvest. Lodging may begin as early as the emergence of the ear or panicle. Winter wheat has been observed to lodge at any time from the emergence of its ear until its grains have matured (Easson *et. al.*, 1993).

Differences in occurrence of lodging between fields were due to different management practices. This may also be due to topographical variations which affect local wind speeds. Within a field, the margins frequently show lodging. Plants next to the path ways caused by tractor movement (tram lines tend to remain upright. Under moderate lodging (10-50%), most of the margin was lodged with the lodged area extending into the center of the field. In severely lodged conditions, the entire margin of the field lodged.

Lodging effects on cereal yield:

Usually yields of cereals decreased due to lodging. In rice loss was reported up to 50% in Japan. In India wheat losses were reported to be in the range of 12-66%. Similarly in barley losses were 40% (Dyson, 1984) and oats 35-40% (Pendelton, 1954). Losses due to lodging were also reported in maize, sorghum and sugar cane. Yield was reduced by reduction in the grain size and number or by reducing the amount of crop that can be recovered by the combine

harvester. Greatest yield reductions occur when lodged at anthesis or early grain filling.

Lodging effects on cereal quality

Lodging also reduced the cereal quality considerably. Bread making quality in wheat is measured in terms of Hagberg Falling Number (HFN). For good quality wheat HFN of 250 s is desirable. Lodging at early grain filling or late grain filling significantly reduced the HFN, 1000 grain weight and specific weight. However the protein content increased significantly. The small grains and low specific weight indicate that lodging reduced the supply of assimilates to the grains and this increased the concentration of protein.

Shriveling of the grain and reduction in test weight is the most common feature due to lodging. Malting quality of barley was adversely affected (Pinthus, 1973). Sprouting in the heads has also been found to occur more frequently in lodged than standing crops.

Lodging in relation to stage of occurrence

Pinthus (1973) summarized the loss in yield of different cereals at different stages. Greater yield reductions (27-40%) were observed at heading than at 15-20 days after heading (17-39%). The reductions were greatest at heading stage irrespective of crops and locations. Jedel and Helm (1991) reported reductions in yield of barely cultivars when lodged at milk stage. Extent of lodging also dependent on cultivars, where barley variety Samson recorded 19-28% while Johnston 22-40%.

Extent of lodging and yield

The degree of lodging also affected the yields. In an experiment at IRRI, Setter *et. al*. (1997) subjected three different rice cultivars to artificial lodging stress. 75% lodging significantly reduced the plant height and similarly affected the yield. Plant height and yield of any of the cultivars did not differ significantly between natural growing and 35% lodging. This indicated slight lodging at flowering did not affect the rice yields.

Management options to reduce lodging

Various factors affect lodging significantly. Environmental factors like temperature, rainfall (water/irrigation), wind velocity and light affect the lodging. Nitrogen application has higher significance, while potassium, seeding rate and seeding time had moderate effect on the lodging.

Genotypes

Lodging in semi dwarf wheat is normally associated with short and stiffer straw when grown at moderate nitrogen levels (Stapper and Fischer, 1990). In the Indian sub continent, varieties bred at moderate nitrogen level (120 kg/ha) tend to lodge when exposed to 180 kg N/ha or more (Narang *et. al*., 1994). Tripathi *et. al*. (2003) reported some of the genotypes are lodging resistant and some as susceptible despite they were semi dwarf wheat. PBW 343, UP 2338 and Seri 82 were rated as tolerant while WH 542 and HD 2329 as susceptible to lodging.

Increase in the plant height is usually attributed to lodging most of the times. However, this is not always applicable. Wheat variety Baviacora a tolerant variety despite having 103 cm plant height recorded low lodging (6%) due to low number of tillers/m^2 (413) with greater diameter of first (3.915 mm), second (4.216 mm) and third basal internodes. On the contrary Pastor with similar height (101 cm) is prone to lodging (55%) due to higher number of tillers / m^2 (482) and lesser diameter of internodes.

In a rotation, cultivar and nitrogen rates experiment Wallce *et. al*. (1999) observed some significant difference in the ability of corn hybrids when exposed to 160 km/hr of wind speed. Pioneer hybrid 3162 found to be tolerant and recorded 4% lodging or broken plants.

Depth of anchorage of the roots is important to have erect plants. Sugarcane

plants having a depth of 260 mm root anchorage had a very low lodging. However anchorage depth of 120 mm was prone to lodging. Sugarcane cultivar Q 152 was more resistant to lodging than Q 187 and Q 174 (Nils and Allan, 2005).

Any addition of genes for specific traits some times makes the genotypes susceptible to lodging (Tripathi *et. al*., 2005). Seri 82, a lodging resistant wheat cultivar became susceptible to lodging once the Lr 19 gene (for leaf rust resistance) was incorporated.

Method of planting and tillage

Information on tillage effects on lodging behaviors of crops is scarce. More lodging of spring wheat was found on ploughed land than after slit seeding into an unplowed grass sward (Hull, 1967). Subsoiling increased lodging of barley over that obtained on a regularly prepared seed bed, whereas rolling after sowing decreased it. Lodging of corn was not affected by tillage. However yield was significantly improved under conventional tillage (Pedersen and Lauer, 2002). Tillage affected the lodging when combined with higher rates of nitrogen application in wheat.

Planting on raised beds is one of the better options to control lodging (Tripathi *et. al*., 2005). Lodging prone wheat cultivars which are high yielding can be cultivated on raised beds to improve yields. Pastor a lodging susceptible wheat cultivar (37.1%) lodges only 0.8% under bed planting. But bed planting is not suitable to all cultivars. Bed planting also reduced the wheat plant height (Sayre and Hobbs, 1998) and improved the grain yields by significantly affecting the lodging score.

Use of improved seed planters in rice in Japan also improves the lodging index. Hill seeder is the new implement where it throws the rice seeds in a group which looks like hill transplanted rice. This gives more strength to the plants and increases the pushing resistance. Lodging index and lodging degree decreased with the hill seeding (Satoshi, 2005).

Lodging in rotations

Continuous cultivation of corn in 1993 and 1994 resulted in lesser broken plants percentage but corn-soybean rotation had higher broken plants (Wallace *et.al*., 1999). Pioneer hybrid 3162 did not lodge under Corn—Corn or Corn –Soybean, while other hybrids Pioneer 3379, 3394 and 3417 lodged severely under corn-soybean rotation. Similar observations were made by Pedersen and Lauer, 2002.

Nitrogen

High rates of nitrogen increases lodging by making plants taller. The increase is ranged from 2.3% to 10%. Increasing nitrogen increased length of lower internodes and decreased the upper internode length. Heavy nitrogen reduced the strength of stem base and the anchorage system, stem diameter and stem wall width (Hobbs *et.al*., 1998). Elongation of lower internodes is entirely due to self shading. Entire application of nitrogen at planting resulted in lodging, irrespective of nitrogen status of the soil. Application at early booting or at first irrigation is ideal to have lower percentage of lodging.

Higher nitrogen may also bring about restrictions in the development of coronal roots. Root anchorage of a semi dwarf wheat variety was found to be weakened due to application of high N rates. In general, its effect on root growth is less than on shoot growth and therefore increased N supply will always result in an increased shoot: root ratio, which is conducive to lodging (Pinthus, 1973).

Irrespective of the crop rotation followed increase in the nitrogen rate from 50 kg/ha increased the broken plants. However, the breakage is more under corn-soybean rotation (Wallace *et. al*., 1999). However, nitrogen application did not result in significant

lodging differences between higher N rates from 240 kg N/ha to 300 kg N/ha (Tripathi, *et. al*., 2003).

Plant population

Increased stand densities of most cereal crops of the graminae family will result in taller plants with stem smaller in diameter and subjected more to breakage. Increased lodging in corn can result in lower grain yields by placing mature ears too close to the ground to be machine harvested (Bruns and Abbas, 2005).

Berry *et. al*., (2004) reported gradual increase in the percentage of lodging in wheat increased linearly from 100 to 400 plants/sq.m. Reducing the number of plants within a row or using wider row spaces both reduced lodging. Reducing the number of plants from 400 plants/sq.m to 100 plants/sq.m reduced the lodging from 100% to negligible amounts. Establishing fewer plants result in more number of crown roots and better anchorage.

Freeze and Bacon (1990) reported significant lodging when wheat row spacing was 4 inches in comparison to 6 or 8 inches.

Higher plant populations in corn significantly increased the yield but simultaneous increase in lodging was noticed (Pedersen and Lauer, 2002 and William and Thelen, 2002). Stalk breakage is easier due to smaller diameter at higher populations. Maintaining plant population of 70,000 to 1, 00,000 plants/ha of corn found to be ideal for high yields and lower lodging percentage (Bruns and Abbas, 2005). However lodging was not consistent with varied row width in corn (William and Thelen, 2002).

Sowing date and depth of sowing

Lodging risk of wheat is almost always reduced by delaying sowing. A delay of only 2 weeks can reduce the amount of lodging by as much as 30%. Berry *et. al*. (2004) showed that sowing winter wheat 6 weeks earlier increased both root and stem lodging risk by increasing the base bending moment of the shoot by about 30%. Earlier sowing results in greater number of extended internodes (Stapper and Fischer, 1990). Earlier sowing may also increase the prevalence of stem base diseases, which may increase lodging by weakening the stem. Sowing 4 weeks earlier increased the amount of *Fusarium* foot rot in wheat.

Deeper drilling helps in adjusting the depth of crown roots of plants to a depth of 40 cm. Hence, it is better to sow between 4-7 cm. Drilling more shallowly than 4 cm may be expected to raise the crown and its structural roots, thus weakening anchorage.

Irrigation

Restriction of excessive vegetative growth by delaying or with holding first irrigation reduces the lodging. This indicates possibilities of reducing lodging by delaying or withholding first irrigation. Delaying the first irrigation from 20 DAS to 40 DAS reduced the lodging in wheat from 60% to 10.1%. However, giving irrigation at 30 DAS is found to be optimum with reduced lodging and better yields in wheat under *Tarai* conditions of Uttar Pradesh, India (Pandey *et. al*., 1997).

Surplus moisture in the upper soil layer weakens the anchorage of the root system. On the other hand, dryness of the upper layer may, restrict the development of the coronal root system and thus promote lodging. Lodging on clay soils under dry conditions may be due to cracking of the soil which damages the roots (Hurd, 1964).

Poor soil aeration may increase susceptibility to lodging due to the effects on respiration inhibition and changes in metabolism which promote cell elongation and thus increase lodging. The promotion of lodging due to poor aeration and high moisture content of the soil is especially evident in water logged fields. Soil aeration and soil structure also affect nitrogen availability, which in turn affects lodging.

Reductions in early vegetative growth and plant height greatly reduce susceptibility to lodging during and following later irrigations. This suggests withholding spring irrigation as long as possible preferably until the early boot stage. Irrigation is conducive to lodging, which is particularly detrimental during the period of grain development.

Trials with winter wheat in the northern Caucasus showed that lodging was promoted less by sprinkler irrigation than by furrow irrigation (Pinthus, 1973).

Clipping and Grazing

Excessive foliage during the period of elongation of the lower culm internodes may be prevented by clipping or grazing. This should be done before culm elongation has proceeded sufficiently. This method is successful in controlling lodging and in certain cases caused subsequent increase in grain yield. However, in most cases grain yield was reduced following grazing or chipping. This method is effective in reducing lodging but it reduced the yields.

Application of chemicals/Growth regulators

Plant growth regulators (PGR's) are synthetic compounds, which are used to reduce the shoot length of plants. This is mainly achieved by reducing cell elongation, but also by decreasing the rate of cell division. In cereals, PGR's are used to reduce lodging. They are most commonly used for this purpose in north and western European countries and in Canada and the USA. In the UK, 84% of the winter wheat is treated with PGR's. The most commonly used are chlormequat chloride and mepiquat chloride. Ethephon is the most commonly used ethylene–releasing compound used on cereals. PGR's applied before the emergence of the ear reduced lodging in almost all the experiments. Herbert (1982) showed that applying chlormequat and choline chloride to winter wheat at the beginning of stem extension could reduce the percentage area lodged from about 73% to less than 8%. Most growth regulators are only active for a few days after application and can therefore shorten internodes most effectively when applied during their extension.

Application of ethephon (480 g/ha) controlled lodging by reducing plant height but also decreased average grain yield by 8.3% (Tripathi, *et. al.* 2003). Wheat yields were also improved by 500-1000 kg/ha by application of ethephon in wheat varieties (Hobbs *et.al*. 1998).

Potassium Trace Elements Application:

Effects of P, K, and trace elements are less pronounced than that of nitrogen. Most of the reports cite reduction in lodging due to potassium application. On potassium deficient soils, applying 100 kg/ha mostly reduced lodging in wheat and rye. No further effects were observed when an extra 200 kg/ha was applied. Corn lodging reduced from 60% to 27% due to continuous application of 120 lbs/acre of K_2O (Anonymous, 1998). However in control, without the application of K_2O stalk lodging percentage remained high. Potassium imparts resistance to lodging by increasing the rind thickness (mm) and crushing strength (kg). Potassium sulphate and potassium chloride were ideal for the reduced effect on lodging. Potassium fertilization reduced the disease incidence.

Addition of silicon significantly increased the rigidity of rice stalk and this increase was remarkably higher at lower dose of nitrogen. The larger quantities of nitrogen greatly reduced the efficiency of silicon in imparting rigidity of plants (Idris *et.al.*, 1975). Root weight was significantly increased by application of silicon (Srivastava and Kumar, 2003).

Diseases

Important diseases like stalk rot in sorghum caused lodging. Under experimental condition 100% lodging occurred and grain yield losses were 23 to 64% in CSH-6 hybrid, at three locations in India and Sudan. This is because natural charcoal rot infection of plants was

induced by subjecting them to drought by withdrawing irrigation at different growth stages (Mughogho and Pande, 1983). At Dharwad nearly 100% lodging was noticed when irrigation was given upto boot swollen stage or ligule visible stage and not throughout the crop period.

CONCLUSION

In cereals, considerable loss in yield and quality occurs due to lodging. Crop is more susceptible to lodging at the later stages of crop maturity. Losses in yields due lodging vary from crop to crop and the loss is greatest in crops like wheat, rice, barley and millets. Losses will be greatest under high input and mechanised agriculture.

All high yielding factors like variety, fertilizers, population and irrigation affect the lodging. Careful management of the factors like selection of resistant genotypes, following raised bed cultivation, proper N and K fertilizer application, irrigation at right time and quantity, pest management and disease management and growth regulator application will reduce the lodging and improve the yield and quality.

REFERENCES

Anonymous, (1998). *Better Crops.* 82: 37-39.
Berry, P.M. *et.al*.,(2004). *Adv Agron.* **84** : 217-271.
Bruns, H.A. and Abbas, H.K.(2005). *Agron. J.* **97**: 1136-1140.
Bryan, L.D. *et.al*.(2004). *Agron. J.* **96**: 818-824.
Freeze, D.M. and Bacon, R.K.,(1990). *J. Prodn. Agril.* **3**:345-348.
Dyson, D.H. *et.al*.(1984). *Barley news letter,* **28** : 59-60.
Easson, D.L. *et.al*.(1993). *J. Agri. Sci.* **121**, 145-156.
Herbert,C.D. (1982). In "*Chemical Manipulation of Crop Growth and Development*" (J.S.MCLaren Edt,). Butterworth scientific, London. pp. 315-327
Hobbs, P.R. *et.al*.(1998). In : *Wheat Research Beyond 2000*.. (Nagarajan, S. *et.al.* Ed) Narosa Publishing House, New Delhi, India.
Hull,R.(1967). *Rothamsted Exp.Sta. Rep.* 265-294.
Hurd,E.A. (1964). *Can. J. Plant Sci.* 44, 240-248.
Idris, M. *et.al*.(1975).*Plant and Soil.* **43** : 691-695.
Jedel, P.E. and Helm, J.H.(1991). *Agron. J.* **83**: 158-161.
Mughogho, L.K. and Pande. S. (1983). In: Sorghum Root and Stalk Rots, ICRISAT, 11-24.
Narang, R.S. *et.al.*(1994).*In* Satellite symposium ID-5 research for maximum yield in harmony with nature. Transactions: 15th World Congress of Soil Science. p 46-57.
Nils,B. and Alan, P.H. (2005). *Field Crops Res.* **92**:261-275.
Pandey, D.S. *et.al*.(1995).*Indian J. Agron.* **4** (1):86-89.
Pedersen, P. and Lauer, J.G. (2002). *Agron.J.* **94**: 968-974.
Pendelton, J.W. (1954). *Agron. J.* **46**: 265-267.
Pinthus, M.J. (1973). *Adv. Agron.,* **25**: 209-263.
Sayre, K.D. and Hobbs, P. (1998). The Raised-Bed system of cultivation for irrigated production conditions. www.css.cornell.edu/faculty/hobbs/papers/5491-3_Lal_CH20_111903_R1_Chap.pdf
Setter, T.L. *et.al*.(2003). *Field Crops Res.* **49**:95-106.
Satoshi, Y. (2005). *Japan Agril.Res. Quarterly,* **39** (3): 147-152.
Splide, L. (1992). *Agron. J.* **84** :399-402.
Srivastava, J.P. and Kumar, V. (2003).*Indian J. Plant Physiol.* (Special Issue): 570-575.
Stapper, M. and Fischer, R.A. (1990). *Australian J. Agrilc. Res.***41**, 1021-1041.
Streling, M. *et.al*.(2003). *Agric.Forest Meteorology*, **119**, 149-165.
Tripathi, S.C. *et.al*.(2005 a). *Crop Sci.* **45** : 1448-1455.
Tripathi, S.C. *et.al*.(2005 b). *Field Crops Res.* **87**: 207-220.
Tripathi, S.C. *et.al*.(2003). *Field Crops Res.* **84**: 271-290.
Wallace, W.W. *et.al*.(1999) *Agron.J.* **91**:160-165.
William, D.W.,and Thelen, K.E. (2002). *Agron. J.* **94**:1020-1023.