

# Crop lodging: its causes and management for sustainable crop production

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*The process by which the shoots of cereals are displaced from their vertical stance is known as lodging. This usually occurs after the ear or panicle has emerged and results in the shoots permanently leaning or lying horizontally on the ground. This can reduce yield by up to 80% and causes several knock-on effects including reduced grain quality, greater drying costs and slower harvest. Intensively cultivated cereals with high inputs like irrigation and fertilizer are more prone to lodging. It can be managed well by using lodging resistance cultivars, soil, fertilizer, irrigation and other agronomic management practices.*

**Key words:** Crop, Lodging, Management, Production



Fig 1. Stem-lodging (Buckling)



Fig 2. Root Lodging

THE process by which shoots of cereals are displaced from their vertical orientation is known as lodging. It is most likely between 60 and 90 days preceding harvest, usually after ear or panicle emergence with the result that shoots permanently lean or lie horizontally on the ground. Two forms of lodging have been recognized: buckling (stem-lodging) or displacement of roots within the soil (root-lodging). In stem lodging, roots are held firmly in a strong soil where the wind force buckles one of the lower internodes of the shoot (Fig. 1). Stem lodging in wheat, barley and oat, is usually caused by one of the bottom two

internodes buckling and results in the upper stem and ear lying horizontally. Buckling of the middle internodes is more common in barley and oats. Root-lodging can be defined as the permanent displacement of the plant from its vertical position due to a failure of the soil– root system (Fig. 2). Root-lodging is usually associated with rain that weakens plant anchorage (i.e., a property of the portion of the soil–root system close to the base of the stem) combined with a wind induced force acting on the upper portion of the plant that result in a bending

moment at its base that exceeds the root failure moment. Root-lodging was observed in wheat, barley and oats. The process of root lodging results in the permanent displacement of cereal stems without any observable stem buckling. A possible outcome of this is that plants lean at less than 90° from the vertical or lie horizontally. The effects of root growth, soil type as well as the shape and mechanical properties of upper portion of the plant that capture the energy of wind gusts are decisive in defining the outcome of this interaction between the stem bending and root failure moments.

There are several indicators to measure the lodging among them lodging score and lodging index used frequently.

$$\text{Lodging score} = \frac{(\text{Lodged area/ Net plot area}) \times 100 \times \text{Angle of lodging}}{90}$$

$$\text{Lodging index} = \frac{\text{Per cent lodged area} \times \text{degree of lodging}}{100}$$

where; 0 degree of lodging = Main stem standing vertical  
100 degree of lodging = Main stem laid down horizontal

## Causes of lodging

Lodging in cereal crops is influenced by morphological (structural) plant traits as well as environmental conditions. It is often

a result of the combined effects of inadequate standing power of the crop and adverse weather conditions, such as rain, wind and hail. Lodging is also variety (cultivar) dependent. For example, a tall, weak-stemmed wheat cultivar has a greater tendency to lodge than a semi-dwarf cultivar with stiffer straw. Under conditions of high soil moisture and nitrogen fertility, semi-dwarf varieties are less prone to lodging as short thick-strawed cultivars resist lodging better than tall cultivars. Plants that are initially resistant to lodging may stand erect during favourable conditions but these plants may fall down when exceptionally bad weather, such as heavy rain or wind prevails. A crop that lodges early will recover through the formation of elbow joints at the lowest stem nodes. The cells on the lower side of the node elongate and force the stem erect. As plants mature the stem cells mature and are no longer capable of elongation to enable plant recovery. High nitrogen (N) fertilization causes plants to be more susceptible to lodging. This is due to lush growth which also provides favourable environment for the spread of diseases such as leaf, stem and stripe rust. Besides increased plant densities, heavier seeding rates, shading, and high moisture content especially under cloudy and humid conditions increase the tendency of cereals to lodge. Occurrence of lodging is dependent on season also. Occurrence of rainfall 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 but important role in lodging. Higher than the normal wind speed resulted in lodging. 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 was observed to lodge at any time from the emergence of ear until its grains have matured. Yield reductions were observed at heading (27-40%) than 15 and 20 days between after heading (17 to 39%). The reductions are greatest at heading stage irrespective of crops and locations.

### Effect of lodging

Lodging alters plant growth and development. It affects flowering, reduces photosynthetic capabilities of the plant, hence affecting carbohydrate assimilation. Severe lodging interferes with the transport of nutrients and moisture from the soil and thus with food storage in the developing kernels. Lodging always results in some yield loss and if permanent lodging occurs shortly after heading, the yield reduction can be as high as 40%. Yield losses from lodging become smaller as the crop matures, but losses will continue until the kernels are completely filled. Incomplete filling results in small kernels, lowered carbohydrate content and lower test weight. Usually yields of cereals decreased due to lodging. In rice loss is reported up to 50% in Japan. In India wheat losses are reported to be in the range of 12 to 66%. Similarly, the losses in barley are 40% and in oats 35 to 40%. Losses due to lodging are also reported in maize, sorghum and sugarcane. Yield is reduced due to reduction in the grain size and number of grains. Greatest yield reductions occur when crop is lodged at anthesis or early grain filling. The effects of lodging on yield losses depend on the growth stage of the plant. The weather conditions prevailing after lodging has taken place, and the severity of lodging. When a crop lodges before flowering, the culms (stem) may regain their upright position, if favourable weather conditions prevail. If a crop lodges sometime after flowering, the heads will not regain their upright position. At this stage, kernel numbers are not affected, but the grain weight may be severely reduced. The extent of weight reduction depends on prevailing weather conditions after the crop had lodged. Yield loss results from poor grain filling, head loss and bird damage. Yield losses are greatest when a crop lodges during the 10 days following head emergence. Yield losses at this stage will range between 15 and 40%.

Lodging that occurs after the plant matures do not affect the yield but it may reduce the amount of

harvestable grain. For instance, when lodging occurs after the plant matures, neck breakage and the loss of the whole head can result; these often lead to severe harvest losses. In these cases, farmers who straight combine their grain are likely to incur higher losses than those who swath them. Lodging also reduces the cereal quality considerably. Bread making quality in wheat is measured in 'Hagberg Falling Number' (HFN). For good quality wheat HFN of 250 is desirable.

Lodging at early grain filling or late grain filling significantly reduced the HFN, 1000 grains weight and specific weight. However, the protein content increased significantly. The small grains and low specific weight indicated 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 are the most common features due to lodging. Malting quality of barley was adversely affected. Sprouting in the heads was found to occur more frequently in lodged than standing crops. Secondary growth in combination with a flattened crop makes harvesting difficult and can subsequently lead to poor grain quality and high yield losses. Severe lodging is costly due to its effects on grain formation and is associated with harvesting problems and losses. It takes about twice the time to harvest a lodged crop than a standing one. Lodging often contributes to uneven maturity, high moisture content and loss of grain quality due to sprouting and possible moulding. Excessive moisture has often delayed harvest and may necessitate grain drying. Lodging can cause severe pickup problems and slow harvest due to green, immature kernels and slowing of the combine speed. Above discussed may result in increased harvesting costs.

### Management options to reduce lodging

*Cultivar selection:* Development of semi-dwarf varieties of crops reduced the problem to some extent, but not completely. Lodging in semi-dwarf wheat is normally associated with short and stiffer straw when grown at



Fig 3. Lodging in conventionally sown plot

moderate nitrogen supply. 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. It was reported that some of the genotypes are lodging resistant and some as susceptible despite they are semi-dwarf wheat. PBW 343, UP 2338 and Seri 82 wheat varieties were rated as tolerant whereas 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. It is evident that even slightly tall varieties recorded low lodging due to less tillers with greater diameter of 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> basal internodes. In a rotation, cultivar and nitrogen (N) rates experiment observed some significant difference in the ability of corn hybrids when exposed to 160 km/hr of wind speed. Pioneer hybrid 3,162 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 low-lodging. However, anchorage depth of 120 mm is prone to lodging.

**Method of tillage and planting:** Information on effects of tillage on lodging behaviors of crops is scarce. More lodging of spring wheat was found on ploughed land than after slit seeding into an unplowed field. Sub-soiling 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. 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. Lodging prone wheat cultivars which are high-yielding can be cultivated on



Fig 4. Lodging in conventionally sown plot due to high dose of fertilizers and hoeing raised beds to improve yields. However, bed planting is not suitable to all cultivars. Bed planting also reduced the wheat plant height and improved the grain yields by significantly affecting the lodging score. Use of improved seed planters in rice in Japan also improved 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. Similarly 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 and 7 cm depth, sowing more shallowly than 4 cm may be expected to raise the crown and its structural roots, thus weakening anchorage. System of wheat intensification when crop planted at 20 × 20 cm<sup>2</sup> spacing exhibited no lodging even during bad weather conditions (Fig. 5). However, conventional sowing exposed to similar weather conditions subjected to heavy lodging (Fig. 3). Further, when we increase the nutrient levels the severity of lodging can be found (Fig. 4).

**Sowing time:** Lodging risk of wheat is almost always reduced by delayed sowing. A delay of only 2 weeks can reduce the amount of lodging by as much as 30%. Sowing of 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. Earlier sowing may also increase the



Fig. 5. System of SW wheat intensification even in during bad weather condition

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.

**Plant population:** Increased stand densities of most cereal crops of the gramineae family resulted in taller plants with smaller stem in dia and subject to more breakage. The gradual increase in the percentage of lodging in wheat, increased linearly from 100 to 400 plants/m<sup>2</sup>. Reduced number of plants within a row or using wider row spaces both reduced the lodging. Reducing the number of plants from 400 to 100 plants/m<sup>2</sup> can reduce the lodging from 100% to negligible amount. Establishing fewer plants result in more number of crown roots and better anchorage. Significant lodging was reported in wheat when the row spacing was kept at 10 cm in comparison to 15 or 20 cm. Higher plant populations in maize significantly increased the yield but simultaneous increase in lodging was noticed. Stalk breakage is easier due to smaller dia at higher populations. Maintaining plant population of 70,000 to 1,00,000 plants/ha of maize found to be ideal for high yields and lower lodging percentage.

**Nutrient management:** High rates of nitrogen (N) increases lodging by making plants taller. Increase in nitrogen (N) increased length of lower internodes and decreased the upper inter-node length. Heavy dose of nitrogen reduced the strength of stem base and the anchorage system, stem dia and stem wall girth. Elongation of lower internodes is entirely due to self-shading. Entire dose of nitrogen (N) applied at

planting resulted in lodging, irrespective of nitrogen status of the soil. Application at early boot stage or at first irrigation is ideal to have lower percentage of lodging. Higher nitrogen may also bring 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 nitrogen rates. In general, its effect on root growth is less than on shoot growth and therefore increased nitrogen supply do always result in an increased shoot: root ratio, which is conducive to lodging. Effects of phosphorus, potassium and trace elements are less pronounced than that of nitrogen in respect of lodging. However, most of the reports cite reduction in lodging due to potassium application. On potassium (K) 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. Lodging in maize reduced from 60% to 27% due to continuous application of 120 kg K<sub>2</sub>O/ha. However, in control (without the application of muriate of potash K<sub>2</sub>O) plot, stalk lodging percentage remained high. Potassium imparts resistance to lodging by increasing the rind thickness (mm) and crushing strength. Potassium fertilization also reduced the disease incidence. Addition of silicon (Si) also 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. Root weight was significantly increased by application of silicon.

**Application of plant growth regulators:** Plant growth regulators (PGR's) are chemically synthesized or biologically extracted compounds, which are used to reduce the shoot length of plants. This is mainly achieved by reducing cell elongation and to some extent 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-west European countries as well as in

Canada and the USA. In the United Kingdom, 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 application before the emergence of ear reduces lodging significantly. Research showed that applying chlormequat and choline chloride to winter wheat at the beginning of stem extension could reduce the percentage of lodged area from about 73% to less than 8%. Most growth regulators remain active for a few days only 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%. So the careful use of recommended doses of PGR's in particular crops at right time is necessary to get better and positive results otherwise the yield losses can be found. Wheat yields were also improved by 1 tonne/ha by application of ethephon. In India PGR's are also being tried on wheat crop to reduce the lodging and the results are quite encouraging.

**Irrigation management:** Restriction of excessive vegetative growth by delaying or with holding first irrigation reduces the lodging. Delaying the first irrigation from 20 to 40 day after sowing reduced the lodging in wheat from 60% to 10%. However, giving irrigation at 30-day after sowing is found to be optimum with reduced lodging and better yields in wheat under *tarai* conditions of Uttar Pradesh, India. 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. 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 following the later irrigations. This suggests withholding spring irrigation as long as possible preferably until the early boot stage. Trials with winter wheat showed that lodging was promoted less by sprinkler irrigation than by furrow irrigation.

**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 the 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 clipping.

## SUMMARY

In cereals, considerable loss in yield and quality occurs due to lodging. Crops are more susceptible to lodging at the later stages of crop maturity. Losses in yields due to 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 mechanized agriculture. All high-yielding factors like varieties, fertilizers, population and irrigation affect the lodging. Careful management of the factors like selection of resistant genotypes, following raised bed cultivation, proper application of nitrogen (N) and potassium (K) fertilizers, irrigation at optimum time and quantity and application of plant growth regulators may undeniably reduce the lodging and improve the yield and quality of crops.

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