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LODGING IN WHEAT: ITS CAUSES, ILL EFFECTS AND MANAGEMENT FOR HIGHER PRODUCTIVITY AND PROFITABILITY

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Lodging in wheat is the displacement of stems permanently from their perpendicular position through creation of an angle from the vertical as a result of wind-induced buckling or breakage in stems or roots or both. Lodging causes a drastic reduction in grain yield and quality of wheat, which ultimately leads to lower profitability. Wheat lodging can occur at any time from the booting stage to harvesting stage (*i.e.*, period of 60 days). After lodging, stems of wheat plants create different angles with its base and sometimes stems laid down horizontally on the ground. Tall cultivars, early sowing, excess use of fertilizers and irrigation water for extracting higher yield are some of the main reasons of wheat lodging. Use of lodging resistant cultivars, optimum use of fertilizers and irrigation water, delayed sowing and foliar application of plant growth regulators at certain doses are some important agronomic practices for lodging management.

Cereals are the staple food of the world's population. Wheat (*Triticum aestivum* L.) is one of the leading cereals. India's share in global wheat production was 15.36% in the year 2017-18. In India, wheat is the second most important staple foodgrain after paddy. India took the 2nd top position after China in wheat production during 2017-18 and wheat consumption is oscillating around 50-60 kg per capita per year in our country. Indo-Gangetic plains region (IGPR) extends from the arid and semi-arid zones in Rajasthan and Punjab to the humid and per-humid deltaic plains in West Bengal over a length of about 1600 km and a width of 320 km. Rice-wheat system is the major cropping system in the IGPR covering an area of around 10.5 mha. Lodging affects wheat production seriously. In wheat, lodging occurs more near harvestable maturity. Lodging can reduce grain yield of wheat up to 80% (Piñera-Chavez *et al.*, 2016). In India, the range of grain yield loss in wheat is 12-66% due to lodging (Rajkumara, 2008).

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Causes of Lodging in Wheat

Early sowing results in high vegetative growth due to long winter spell and ultimately bending of stems at the internodes occurs due to wind gusts. Nitrogen fertility increasing beyond a certain limit enhance the vegetative growth the crop vigorously and resulted in bending of the stems and ultimately decreased the yield attributes and grain yield. Tall varieties of wheat (≥120 cm) are highly susceptible to lodging. Due to wind pressure or high soil moisture, tall plants lodged easily. Heavy irrigation or adverse weather condition (e.g. rainfall, strong winds and hail) at dough stage of wheat also causes lodging. Intensive tillage operation for land preparation and weed management pulverizes the soil, breaks the soil structure and creates a hardpan below the surface soil. Root growth of wheat plants is affected due to this hardpan, and root anchorage of the plants also reduces due to loose soil. This increases root lodging tendency of wheat plants.

Mechanisms of Wheat Lodging

The nature and extent of lodging are closely related to culm characteristics. There are 2 types of failure mechanism, (i) stem lodging: it occurred when the bending moment of a shoot (shoot leverage) exceeds the failure moment of the stem base (stem strength) and (ii) root lodging: it occurred when the bending moment of a plant (plant leverage) exceeds its anchorage failure moment (anchorage strength). In stem lodging, roots are held firmly in a strong soil where the wind force buckles one of the lower internodes of the shoot. Root lodging is associated with rainfall that weakens plant anchorage combined with the wind-induced force acting on the plant. When lodging happened from the buckling of the stem just below the spike, it is known as necking.

Angle of Wheat Lodging

No lodging occurs when the angle of lodging is 0° from the vertical. Smaller yield losses have been observed when the angle of lodging is ≤30° from the vertical. Lodging at 45° angle shows one quarter to one half of the grain yield loss incurred from lodging at 80° angle in wheat.

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Deleterious Effect of Lodging in Wheat

In wheat, lodging increases the chance of pest and disease susceptibility and induces negative impact on crop development. Lodging may limit grain yield improvement by 2 ways: a) directly by reducing photosynthetic capacity due to changes in canopy architecture and b) indirectly by improper partitioning of dry matter into the support structures. Lodging also increases the risk of grain sprouting in spike due to the moist environment and reduces Hagberg falling number (HFN), which is a parameter to measure bread-making quality. HFN of at least 250 s is required to produce good quality bread. Wheat lodging induced during early grain filling reduced grain quality by reducing the HFN from 289 s to 114 s, test weight from 42.2 g to 37.2 g and specific grain weight from 70.3 kg Hl^{-1} to 65.8 kg Hl^{-1} (Weibel and Pendleton, 1964). Lodging after early grain filling stage caused a smaller effect on the grain quality of wheat.

Critical Growth Stages for Lodging

The effect of lodging on yield losses depends on the growth stages of wheat. A crop that lodges early (*i.e.*, at tillering and jointing) recovers through the development of 'elbow joints' at the lower stem nodes. The cells on the lower side of the node elongate and force the stem to erect. At booting stage, the stem cells mature and are no longer capable of elongation to enable plant recovery. Wheat plants can lodge at any time from booting to harvest (*i.e.*, period of 60 days). The highest lodging-induced reduction in grain yield occurs when wheat is lodged flat (90° angle from vertical) at flowering or early grain filling. Yield reduction in wheat from this type of lodging is up to 80%. Fischer and Stapper (1987) reported that grain yield of wheat was decreased in the range of 7-35% when lodging occurred within the first 20 days after flowering. The lodging score at harvest may be wholly due to a single, late lodging event immediately before harvest and not reflect on the development of lodging through the season. Lodging occurred at the end of the crop cycle imposed lower effect on grain yield than lodging at other growth stages but the yield significantly reduced in case of lodging-prone wheat cultivars.

Measurement of Lodging

Among the several indicators, lodging score and lodging index are frequently used to measure lodging. Lodging score was calculated by the formula of Fischer and Stapper (1987).

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$$\text{Lodging score} = \frac{(\%\ \text{plot area lodged} \times \text{angle of lodging from the vertical})}{90}$$

where, % plot area lodged = (lodged area/net plot area) × 100; 0° angle from vertical = Main stem standing upright; 90° angle from vertical = Main stem laid down horizontally

The formula of lodging index was given by Wiersma *et al.*(1986). It has been modified.

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

where, % plot area lodged = (lodged area/net plot area) × 100; degree of lodging 0 = Main stem standing upright; degree of lodging 100 = Main stem laid down horizontally

The loss of potential yield due to lodging can be calculated by the equation developed by Stapper and Fischer (1990). They showed that approximately 0.5% of potential yield is lost for each % area of wheat lodged averaged over each day of the grain filling period.

$$\text{Yield loss of wheat} = 0.000125\alpha \sum_{T=10}^{50} \%\ \text{plot area lodged}$$

where, the grain filling period (T) lasts from days 10 to 50 (generally 10 days in India) of the 60 days lodging risk period and the potential grain yield of wheat α is taken as 8 t ha^{-1}.

Table 1: Lodging scores at different growth stages of timely sown, irrigated wheat at Instructional farm, UBKV, West Bengal (pooled data of 2016-17 and 2017-18)

Treatments	***Lodging score at flowering stage**	***Lodging score at dough stage**
Fertilizer application		
No fertilizer	0.00	0.00
RDF	0.77	1.10
150% RDF	2.25	3.54
150% RDF + 15 t ha^{-1} FYM	3.69	5.81
S.Em (±)	**0.343**	**0.495**
CD (P=0.05)	**2.28**	**2.89**
Growth regulator spraying		

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Water spray	3.21	4.77
Chlormequat chloride (CCC) @0.2%	1.15	1.77
Tebuconazole @0.1%	1.90	2.44
CCC @0.2% + Tebuconazole @0.1%	0.46	1.48
S.Em (±)	**0.208**	**0.344**
CD (P=0.05)	**1.42**	**2.04**

RDF: Recommended dose of fertilizer; FYM: Farmyard manure; *Angle of lodging was 45°

Management of Wheat Lodging

Delayed sowing of wheat enhances lodging resistance. Wheat plant does not get enough time to complete its growth stages properly, which causes dwarfing in a plant. This reduces lodging in wheat but grain yield also reduced to some extent. Optimum rate of nitrogen (N), phosphorus (P) and potassium (K) application instead of higher application rate of N alone enhance lodging resistance through better partitioning of photosynthate in all the support structures. Foliar application plant growth regulators (PGRs) such as chlormequat chloride, ethephon, trinexapac-ethyl and tebuconazole etc. at certain rates twice during 1st node and flag leaf stage controls wheat lodging. PGRs reduce the shoot length of wheat plants which is mainly achieved by reducing cell elongation and the rate of cell division. PGRs control wheat lodging by 2 ways: (i) inhibition of gibberellic acid biosynthesis which reduces plant height and subsequently reduces lodging and (ii) release of ethylene which improves root growth, formation and elongation of root hairs and cluster root formation to control root lodging. Application of the recommended rate of N in 3 or 4 splits instead of a single application as basal increases lodging resistance. Semi-dwarf wheat varieties having a stiffer straw, thicker internodes and smaller above-ground biomass than tall varieties should be used for obtaining higher grain yield due to reduction in lodging. To avoid lodging, many farmers in South Asia forego the last irrigation. This may be crucial for grain filling. Light irrigation can be given at dough stage of wheat if required. Conservation agricultural practices such as zero tillage and maintaining crop residues in the field improve soil structure and root anchorage of the wheat plants, which ultimately reduces the risk of lodging.

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Conclusion

From the above study, it can be concluded that lodging is a serious threat in wheat cultivation. To overcome this problem, some agronomic management practices should be followed. Among these practices, spraying of PGRs at certain rates twice during the 1st node and flag leaf stage of wheat is gaining popularity in India. Grain yield and quality of wheat can be enhanced through adoption of the above-mentioned lodging management practices which ultimately increases the net return and benefit-cost ratio.

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