Crop Lodging in Cereals: Causes, Effects and Practices for Preventing Lodging

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ABSTRACT

Crop lodging — the permanent bending or falling of stems or roots — is a major constraint in cereal production, causing yield losses of 20–80% globally and substantial economic losses. It occurs due to environmental stresses (wind, heavy rain), agronomic practices (excess nitrogen, dense planting, waterlogging), and genetic traits (plant height, stem strength, root anchorage). Lodging is classified as stem lodging (stem bending/breakage) or root lodging (weak anchorage), each requiring distinct management. Effects include reduced photosynthesis, poor nutrient transport, lower grain quality, and increased harvesting costs. Prevention involves integrated strategies: breeding lodging-resistant varieties, balanced fertilization, proper irrigation, soil improvement, weed control, plant growth regulators, precision farming, and timely harvesting. This approach is essential for sustainable cereal production and food security under climate change.

INTRODUCTION

Cereals such as wheat, rice, barley, and oats are the most important staple crops, providing more than 50% of daily caloric intake worldwide (Rajkumara, 2008). However, cereal productivity is heavily constrained by

lodging, defined as the permanent displacement of stems or roots from their upright position due to stem bending or root failure. Lodging arises from the interplay of environmental stresses (wind, rainfall, storms), agronomic practices (excess nitrogen application, dense planting, waterlogging) and genetic traits such as plant height, stem strength, and root anchorage. Yield losses are substantial, with global estimates ranging from 20–80% depending on severity and crop stage. Severe wheat lodging can reduce yields by up to 60–80%, translating into billions of dollars in global losses annually. In India, wheat losses were reported to be in the range of 12–66% (Rajkumara 2008) due to lodging. The cost of lodging was estimated from $47 to $120 million per year (Kendall *et al*. 2017). In addition to yield losses, lodging also reduces mechanical harvesting efficiency, thereby increasing the cost, time and labour at harvest (Weng *et al*. 2017).

Types of Lodging and Their Characteristics

Lodging is generally categorized into two major types: **stem lodging** and **root lodging**. Understanding the nature of lodging is crucial for designing effective preventive strategies. **Stem lodging** occurs when the aboveground stem (culm) bends or breaks near its base, usually due to mechanical forces such as strong winds or heavy rainfall. Crops with thin, weak, or poorly lignified stems are particularly prone to stem lodging. Stem lodging is often most damaging during the reproductive stage because it disrupts the translocation of nutrients and water to developing grains. Mechanically, stem lodging complicates harvesting and increases grain losses due to uneven maturity and difficulty in threshing. **Root lodging** results when the plant tilts or falls due to inadequate root anchorage. This is usually caused by shallow root systems or poor soil conditions, and is exacerbated by environmental stresses such as waterlogging, soil compaction, or strong winds. Root lodging tends to affect larger areas of a field rather than individual plants. Unlike stem lodging, root lodging cannot be corrected mechanically and requires long-term soil and root management to prevent recurrence.

Causes of Crop Lodging

Genetic and Plant-Related Factors: Genetic characteristics play a central role in lodging susceptibility. Plant height is a critical factor because taller plants have a higher center of gravity, making them more prone to bending under wind or rain. The Green Revolution's introduction of semi-dwarf varieties greatly reduced lodging by improving stem strength and nutrient use efficiency. Stem anatomy — including lignin content, wall thickness, and vascular bundle density — also influences lodging resistance. Root system architecture is equally important, as deeper and more branched roots improve anchorage, while shallow roots increase susceptibility.

Environmental Factors:

Weather conditions such as strong winds, heavy rainfall, and storms are the primary triggers of lodging. Saturated soils caused by excessive rainfall weaken root anchorage and reduce oxygen availability.

Topography plays a role as well; sloping land increases gravitational stress on plants. Climatic conditions such as high humidity and temperature fluctuations further affect stem strength, increasing lodging risk.

Agronomic Practices: Excessive nitrogen fertilization promotes rapid vegetative growth, leading to taller plants with weaker stems. High planting density also increases lodging risk by forcing plants to elongate to compete for light. Late sowing exposes crops to adverse weather at sensitive stages, while inadequate weed control increases competition and stem elongation. Poor crop management thereby significantly enhances lodging potential.

Soil Factors: Soil properties strongly influence lodging. Loose, sandy soils provide insufficient anchorage, while waterlogging deprives roots of oxygen, weakening their ability to support plants. Soil compaction limits root penetration, reducing stability. Nutrient deficiencies — especially potassium and silicon — weaken both stems and roots. Soil pH and salinity can also impair root growth, exacerbating lodging risk.

Biotic Stress Factors: Diseases such as Fusarium crown rot and pests such as stem borers weaken stem and root structures, increasing lodging susceptibility. Biotic stresses often interact with environmental factors, amplifying lodging risk.

Traits Associated with Lodging Resistance

Improving lodging resistance requires identification of key plant traits. Shorter culm length reduces leverage and bending forces. Basal internode traits such as diameter, length, and wall thickness enhance mechanical strength. Higher lignin and cellulose content strengthen the culm. Root traits such as length, diameter, branching, and root plate size improve anchorage. Mechanical properties such as bending resistance, breaking strength, and root-pulling resistance are useful indicators of lodging resistance.

Effects of Lodging on Crop Growth and Yield

Lodging reduces light interception, canopy photosynthesis, and assimilate translocation. Lodging during vegetative growth decreases biomass production, while lodging during grain filling significantly reduces yield and quality. Lodged crops have increased susceptibility to diseases due to poor air circulation and higher humidity. Grain quality declines due to sprouting, shrivelling, and fungal attack. Lodging increases harvesting difficulty, costs, and grain loss, thereby reducing profitability for farmers.

Practices for Preventing Lodging

Genetic Approaches: Breeding lodging-resistant varieties remains the most effective long-term strategy. Semi-dwarf varieties developed during the Green Revolution are a prime example. Modern breeding focuses on improving culm strength, root architecture, and adaptability to environmental stresses. Molecular breeding tools and marker-assisted selection accelerate lodging-resistance breeding programs.

Agronomic Practices: Balanced fertilization is crucial, with careful management of nitrogen and adequate supply of phosphorus and potassium to strengthen stems and roots. Proper irrigation management prevents waterlogging. Crop rotation and residue management improve soil structure. Timely weed control and intercultural operations prevent excessive elongation. Mechanical interventions such as strip cropping, shelterbelts, and windbreaks reduce lodging risk.

Plant Growth Regulators: Growth regulators like chlormequat chloride, trinexapac-ethyl, and ethephon limit excessive stem elongation and strengthen culms. These are effective under high nitrogen and irrigated conditions.

Precision Agriculture: GPS-guided fertilization, soil and crop sensors, and drone monitoring allow early detection and site-specific interventions to prevent lodging.

Harvest Management: Timely harvesting is essential to minimize lodging risk. Delayed harvest increases lodging due to stem weakening and grain weight.

Economic Impact

Lodging causes global yield losses ranging from 5% to 20%, with extreme cases reaching 50%. In addition to yield reduction, lodging increases harvesting costs, lowers mechanical efficiency, and reduces grain market value. Investing in lodging prevention is more cost-effective than attempting to recover losses post-lodging. Prevention improves productivity, efficiency, and sustainability of cereal production.

CONCLUSION

Lodging remains one of the most significant constraints to cereal productivity, affecting yield, quality, and profitability. An integrated lodging management strategy combining genetic improvement, balanced agronomy, plant growth regulators, precision farming, and timely harvesting is essential. With climate change increasing the frequency and intensity of extreme weather events, lodging prevention will become even more critical for sustaining global food security. Adoption of lodging-resistant cultivars alongside sound agronomic practices will help ensure stable cereal production and farmer livelihoods in the future.

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