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Standing Tall: How Plant Nutrition Can Prevent Crops from Falling Down

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Abstract

Crop lodging is a serious constraint that adversely affects yield, quality and harvestability of cereal crops. Crop lodging refers to a condition in which crop stems or root systems lose their upright stature. High nitrogen fertilization leads to accelerated vegetative phase development, but with low rigidity, whereas low application of phosphorus and potassium leads to poor root and tissue solidity. In addition to those mentioned, other micronutrients, such as calcium, silicon, boron and copper, also play a critical role within cell walls. Proper control of lodging can be achieved by combining balanced fertilizer application with the timeliness of fertiliser application, growing lodging-resistant crops, optimising crop population, ensuring good drainage and making strategic applications of growth regulators. Therefore, a clearer understanding of scientifically relevant nutrient management practices is essential to improve crop rigidity and yield sustainability.

Keywords:

Crop lodging, plant nutrition, nitrogen management, potassium, micronutrients, stem strength, cereals

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1. Introduction

Crop lodging remains a major constraint in intensive cereal production systems, particularly under high-input agriculture and climate-induced extreme weather events. It leads to substantial yield losses, deterioration of grain quality and increased harvesting difficulties. Among the various factors influencing lodging, plant nutrition plays a central role in determining stem strength, root anchorage and overall crop architecture.

1.1. What is lodging and why should we care

Consider the scenario of dedicating several months to cultivating a crop, only to witness its collapse immediately before harvest. This phenomenon, known as lodging, refers to the displacement of plant stems and roots from their upright position. Crops that

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experience lodging present challenges during harvest, yield lower quantities and frequently exhibit diminished nutritional quality.

Two main types of lodging affect cereal crops like wheat, rice and corn:

1. Root lodging: This occurs when plants are literally uprooted from the soil, usually early in the growing season. In such cases, failure of root anchorage causes the entire plant to collapse. Once the roots lose their grip, the entire plant topples over.

2. Stem breakage: This happens later in the season when the stems become brittle and snap, often due to weather conditions or as the plant matures.

Both types can occur together or separately, but either way, the result is the same: a weaker plant that produces fewer and lower-quality grains. Nutrient stress weakens stem and root architecture, making crops highly susceptible to lodging under adverse weather conditions (Figure 1).

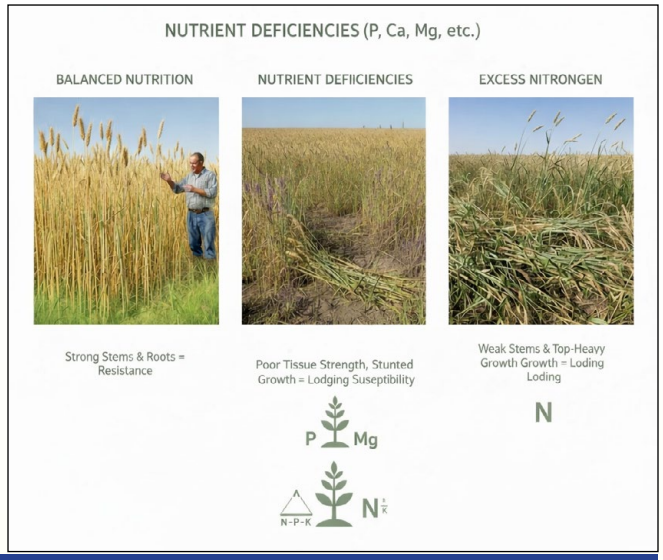

Figure 1: Effect of nutrient stress on crop lodging

2. Role of Nutrients on Crop Lodging

2.1. The nitrogen: balancing act

In terms of plant health, nitrogen is like a double-edged sword. On the one hand, plants require nitrogen to develop and yield large quantities (Jones, 2014). However, an excessive amount of nitrogen can lead to issues. Excessive nitrogen causes plants to grow quickly and focus their energy on creating lush leaves and taller stems rather than robust, sturdy ones. This situation resembles rapid structural growth without proportional mechanical reinforcement. The structure grows tall but feeble. In fact, high nitrogen levels make stem tissues more vulnerable to breaking under pressure by reducing lignification, the process that fortifies plant cell walls. This reduction in lignification lowers culm bending resistance and increases susceptibility to wind and rainfall-induced lodging. Excess nitrogen alters cereal morphology by increasing plant height and reducing stem thickness, thereby increasing lodging susceptibility (Figure 2).

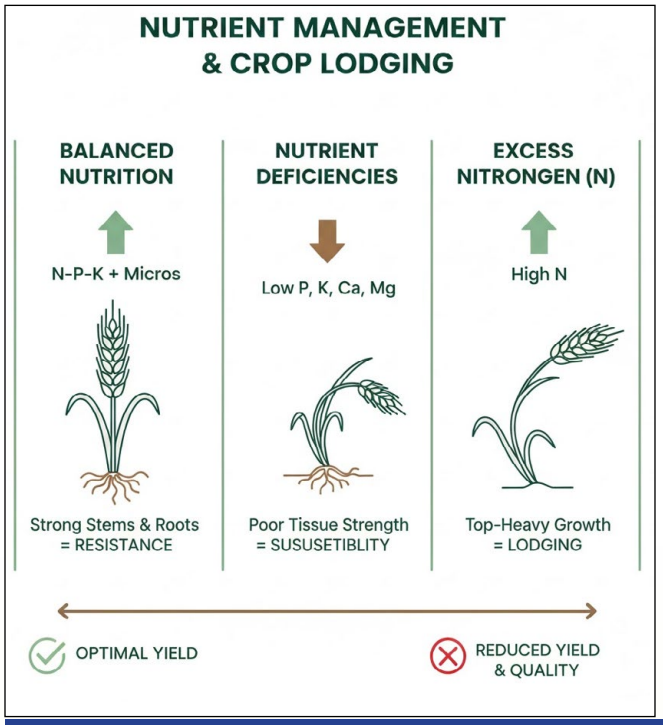

Figure 2: Impact of nutrient on cereal morphology

Certain crop varieties are more vulnerable to nitrogen-induced lodging than others. Nitrogen application timing is also crucial. Root lodging may occur if nitrogen is applied too soon, before plants have established robust root systems. A lot of experts advise against applying nitrogen fertilizer until crops are three to four weeks old.

2.2. Phosphorus: the growth regulator

Although phosphorus is essential for plant growth, it has a complicated relationship with lodging. Lack of phosphorus causes plants' roots and stems to grow poorly, making them less resilient to the forces that lead to lodging. Interestingly, excessive phosphorus can also raise the risk of lodging. This occurs because high soil phosphorus levels increase the uptake of nitrogen, thereby intensifying the detrimental effects of nitrogen on stem strength.

2.3. Potassium: the strength builder

Potassium is the strength enhancer if phosphorus is the growth regulator and nitrogen is the growth promoter. Potassium plays a role in the synthesis of proteins and the metabolism of carbohydrates, two processes necessary for the development of robust plant tissues. Lack of potassium causes plants to produce less sclerenchymatic tissue, which is the robust, supporting tissue in stems. This results in weaker stems that are more likely to lodge. A potassium shortage in corn can further jeopardize the stability of the plant by reducing the formation of brace roots. Potassium fertilization has been found to considerably lessen lodging in cereals. Applications of potassium chloride (KCl) and potassium sulphate (K_2SO_4) have proven especially successful. In fact, it has been demonstrated that applying about 100 kg of K_2O per hectare significantly reduces lodging (Jiger et al., 2018).

2.4. The supporting cast: micronutrients

While nitrogen, phosphorus and potassium are the main components in lodging prevention, several micronutrients also play supporting roles:

• **Molybdenum (Mo) and boron (B):** These nutrients are involved in carbohydrate metabolism, which affects **stem strength.**

• **Copper (Cu):** Increased lodging has been associated with copper deficiency in organic soils.

• **Silicon (Si) and calcium (Ca):** These elements strengthen cell walls. Plants are more prone to lodging when they are deficient.

Collectively, micronutrients influence enzymatic activity, cell wall composition and hormone regulation, thereby indirectly determining stem rigidity and lodging resistance. The combined influence of macro and micronutrients on lodging mechanisms and their practical management options are summarized in Table 1.

3. Practical Strategies for Farmers

Effective prevention of crop lodging requires an integrated crop management approach rather than reliance on nutrient management alone. A combination of varietal selection, optimized plant density, judicious nutrient application and appropriate agronomic interventions can significantly enhance stem strength and root anchorage.

Table 1: Influence of macro- and micronutrients on crop lodging mechanisms and management strategies

Nutrient	Net effect on lodging	Mechanism (how it changes lodging risk)	Practical management to reduce lodging	References
Nitrogen (N)	↑ (excess) / ↓ (optimum)	High nitrogen (N) rates lead to rapid vegetative growth, causing taller plants and thinner stems, which can weaken stem strength and increase lodging risk. The timing of nitrogen application, especially late or split applications, plays a crucial role in this risk. Adjusting nitrogen levels or timing can help reduce lodging while still supporting yield	Use recommended total N (avoid over-fertilization), split applications, use controlled-release N or nitrification inhibitors and match N to cultivar lodging susceptibility and sowing date	(Zhai et al., 2022)
Potassium (K)	↓ (generally reduces lodging)	K enhances cell wall strength, boosts lignin/cellulose in stalks and improves carbohydrate distribution, leading to greater stalk bending strength and rind thickness. It can also mitigate the negative effects of high nitrogen levels	Maintain a balanced N:K ratio (avoid K deficiency, especially when N is high); apply adequate K fertilizer (soil test based rates); split or banded placement can improve uptake	(Wu et al., 2023)
Silicon (Si)	↓ (strong effect reported for rice and cereals)	Si enhances cell wall strength, increases culm rigidity, promotes lignin and cellulose production and improves stem thickness and root anchorage. It also helps reduce biotic and abiotic stresses that can lead to lodging	Apply Si where soils are low (rice: slag, silicic acid donors, potassium silicate, or foliar Si); include Si in nutrient programs for rice, wheat and other Si-accumulating crops	(Bhatt and Sharma, 2018)

Table 1: Continue...

Nutrient	Net effect on lodging	Mechanism (how it changes lodging risk)	Practical management to reduce lodging	References
Phosphorus (P)	↓ (often reduces lodging)	Adequate P promotes early root development and thicker stems; improves anatomical traits (vascular bundles, stem wall thickness) that enhance mechanical strength. P timing (early P) can be important	Ensure adequate P at establishment (banding/ placement), correct soil P deficiencies, avoid late P stress	(Loudari et al., 2022)
Calcium (Ca)	↓ (supports structural integrity)	Ca stabilizes cell walls and membranes, is important for middle lamella and mechanical strength; deficiency can weaken stems and root-anchorage tissues	Correct Ca deficiencies (liming acidic soils, gypsum or Ca fertilizers), consider foliar Ca in sensitive growth stages	(Chandramony and George, 1975)
Magnesium (Mg)	± (indirect)	Mg is essential for photosynthesis and carbohydrate partitioning; Mg deficiency can reduce carbohydrate supply to stems (weakening internode filling), indirectly increasing lodging	Maintain adequate Mg (soil test recommendations), Mg sulphate or dolomitic lime where needed	(Chandramony and George, 1975)
Sulfur (S)	± (indirect)	S is required for protein synthesis and structural compounds; severe S deficiency reduces vigor and may reduce stem strength indirectly	Maintain S where soils are low; use sulphate fertilizers or fertilizers containing S	(Narayan et al., 2023)
Boron (B)	↓ when adequate / ↑ if deficient	B is crucial for cell wall structure (cross-linking pectins), meristem activity and lignification; B deficiency leads to weak stems and increased lodging in some crops	Monitor B on susceptible soils (sandy/low OM), apply small corrective B fertilizers (soil or foliar) carefully (narrow window between deficiency and toxicity)	(Wu et al., 2017)
Zinc (Zn)	± (indirect)	Zn is involved in auxin metabolism and enzymatic systems; deficiency can reduce stem strength via weaker tissue development and reduced lignification	Correct Zn deficiencies with soil or foliar Zn; avoid extreme imbalances	(Lilay et al., 2024)
Manganese (Mn), Copper (Cu), Iron (Fe)	± (indirect/ trace)	These micronutrients are co-factors in lignin/cell wall biosynthesis enzymes or affect hormone balance; deficiencies can reduce lignification or root strength, increasing lodging susceptibility	Soil testing and targeted correction (foliar or soil) where deficiencies are diagnosed	(Lilay et al., 2024)

3.1. Selection of lodging-resistant varieties

The use of semi-dwarf and lodging-tolerant cereal varieties reduces plant height and improves stem rigidity, thereby lowering susceptibility to lodging while maintaining high yield potential.

3.2. Regulation of plant population

Avoiding excessive plant density minimizes competition for light, water and nutrients, leading to stronger stems and improved mechanical stability of the crop stand.

3.3. Timing of fertilizer application

Delayed and split application of nitrogen, particularly after establishment of a strong root system, helps prevent excessive vegetative growth and reduces the risk of root and stem lodging.

3.4. Drainage and soil moisture management

Adequate field drainage is essential to prevent waterlogging, which weakens root anchorage and increases lodging susceptibility under windy or rainy conditions.

3.5. Use of plant growth regulators

Growth regulators such as chlormequat chloride (CCC) reduce internode elongation, enhance stem thickness and

improve lodging resistance, especially in high-nitrogen production systems.

3.6. Balanced application of potassium and micronutrients

Adequate potassium and essential micronutrients strengthen cell walls, enhance lignification and improve overall plant structural integrity, thereby reducing lodging incidence.

In many cereal-growing regions, particularly under high-input systems, adoption of these integrated practices has shown consistent improvement in crop standability.

4. The Bottom Line: Yield Impact

Crop lodging causes substantial yield and quality losses by disrupting canopy architecture, photosynthesis, assimilate translocation and harvest efficiency. The magnitude of yield reduction depends upon crop species, growth stage at lodging, severity and duration of lodging and post-lodging weather conditions. Lodging during vegetative or early reproductive stages may allow partial recovery through stem reorientation and compensatory growth. However, lodging after flowering or during grain filling produces severe and often irreversible yield penalties.

Physiologically, lodged plants face the reduction in light interception due to canopy collapse, which causes lower photosynthetic rates and impairs carbohydrate supply to developing grains. When a stem bends or breaks, vascular transport is restricted, reducing grain filling and kernel weight. In addition to this, the prolonged contact of lodged panicles or ears to soil raises the plant's susceptibility to diseases, sprouting and grain discoloration, further diminishing market quality.

Mechanically, lodging complicates harvesting operations, causing significant grain losses due to incomplete threshing, shattering and inefficient combine performance. Several studies have reported yield losses ranging from 10–30% under moderate lodging and exceeding 50% under severe lodging conditions. In addition to yield reduction, lodging lowers grain protein concentration, test weight and overall economic returns. Therefore, effective lodging management through balanced nutrition and agronomic practices is essential to sustain yield stability under intensive and climate-variable production systems.

5. Conclusion

Crop lodging significantly reduces yield, quality and harvesting efficiency in cereals. Balanced plant nutrition plays a central role in strengthening stem and root systems and improving lodging resistance. While excessive nitrogen increases lodging risk, adequate potassium, phosphorus and essential micronutrients enhance structural integrity. Integrating nutrient management with resistant varieties, optimal plant density, proper drainage and growth regulators offers an effective strategy to minimize lodging. Adoption of these practices can help farmers achieve stable yields and resilient cropping systems.

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