

Enhancing rice plant architecture and reducing lodging: A novel approach with growth regulators

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Rice, a staple food for over half the world's population, faces substantial challenges in cultivation; untimely rains, hailstorms etc. leading to crop lodging being a major concern which hampers crop yield, downgrade quality and complicates harvesting. Factors like tall plants with poor tillering, improper water management, high planting density, and excessive fertilizer use contribute to lodging, exacerbated by heavy rains and strong winds. Plant growth regulators show promising results in mitigating this problem by inhibiting gibberellin biosynthesis, thereby shortening internodes and strengthening stems. Integrating plant growth regulators into comprehensive rice production systems can induce stem robustness, enhance lodging resistance, and ensure sustainable and productive rice farming.

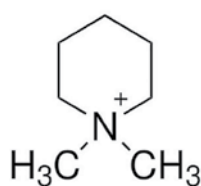
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Rice is a staple food for over half of the world's population, particularly in Asia, where it is integral to the diet and economy. As the global population continues to grow, increasing rice production is crucial to ensure food security. However, rice farming faces several challenges, one of the most significant being lodging. Lodging occurs when vertical plants experience permanent displacement, typically due to stem lodging (refers to the bending or breaking of the lower culm internodes as a result of excessive bending pressure at the higher internodes) or root lodging (results from intact and unbroken culms leaning from the crown due to a failure of root anchorage in the ground), making harvesting difficult and reducing yield. The tall phenotypic feature of the plant is one of the major factors for crop lodging, along with factors like inadequate water management, high planting density, and excessive fertilizer use. It is more prevalent with heavy rains and strong winds. Lodging

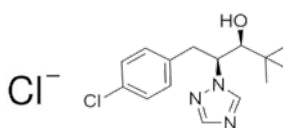
destroys the plant canopy structure, reducing the efficiency of nutrient assimilation, remobilization, and utilization. This, coupled with insufficient light penetration, leads to poor grain quality and yield. Besides yield losses, lodging also hampers mechanical harvesting efficiency, thereby increasing the time and labour costs associated with harvest. In recent years, researchers have explored various methods to improve rice plant architecture and minimize lodging, and one promising approach involves the use of various growth regulators. The use of Mepiquat chloride, Paclobutrazol, Chlormequat Chloride/Cycocel (CCC), or their compounds as seed treatments

or foliar applications is gaining importance for good crop harvest without imposing any deleterious effect on the environment and human health as well.

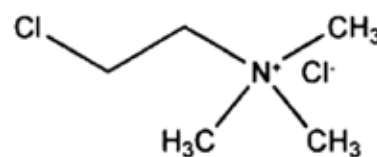
Mepiquat chloride and Chlormequat chloride/Cycocel (CCC), a quaternary ammonium compound; Paclobutrazol, a triazole compound inhibit the enzyme entkaurene oxidase, which is crucial in the gibberellin biosynthesis, a plant hormone responsible for cell elongation. They have been extensively used in cotton cultivation since 1975 to reduce plant height and enhance structural stability. Recently, their potential application in rice cultivation has attracted considerable attention due to their



Mepiquat chloride



Paclobutrazol



Chlormequat chloride/Cycocel



Lodging in rice field of IARI, New Delhi

ability to shorten internodes and strengthen stems which contribute to increased plant stability and reduced lodging risk. Numerous studies have shown that the application of Mepiquat chloride, Paclobutrazol or Chlormequat chloride/Cycocel (CCC) can significantly reduce the lodging rate in rice crops. For instance, a study reported that Mepiquat chloride at a rate of 50 g a.i./ha reduced the lodging rate by 63.3% and improved yield components, ultimately

leading to a 35.4% increase in grain yield, a 19.3% increase in straw yield and a 19.3% increase in B:C compared to the control. Another study showed that the application of Paclobutrazol at a rate of 400 mg/L before the panicle initiation stage effectively reduced plant height by 10.4%, internodal length by 6.5% and lodging by 21.8% compared to control, and improved grain and straw yields.

The mechanism behind plant growth regulators' ability to

enhance lodging resistance lies in its impact on plant physiology. They have been shown to reduce plant height and internode length, while increasing the thickness and lignin content of the stem. These structural changes contribute to enhanced stem physical strength, making the plants more resistant to lodging. Additionally, they have been found to improve the allocation of photosynthates, directing more resources towards the development of yield components, such as the

Table 1. Effects of plant growth regulators on lodging%, growth and yield of rice

Study area	Plant growth regulators rate	Findings	Reference
Mepiquat chloride			
West Bengal, India	50 g a.i./ha	↓ Plant height 9.3%, Internodal length 16.2%, Lodging 63.3% ↑ Grain yield 35.4%, Straw yield 19.3%, B:C 16.5%	Mukherjee (2020)
Karnataka, India	5% AS at a rate 1250 mL/ha	↓ Plant height 15.5%, Internodal length 17.5%, Lodging 76.2% ↑ Grain yield 10.1%, Straw yield 11.9%	Meena <i>et al.</i> (2020)
Ludhiana (Punjab), India	500 ppm	↓ Plant height 6.7%, Lodging 36.5%, Straw yield 1.1% ↑ Grain yield 8.5%	Singh <i>et al.</i> (2021)
Karnataka, India	5% AS at a rate 1500 mL/ha (two sprays) (plus 150% RDN)	↓ Plant height 13.9%, Lodging 88% ↑ Grain yield 11.9%, Straw yield 10.1%, B:C 17.1%	Priyanka <i>et al.</i> (2023)
Paclobutrazol			
Kedah State, Malaysia	400 mg/L	↓ Plant height 10.4%, Internodal length 6.5%, Lodging 21.8% ↑ Grain yield 10.7%	Syahputra <i>et al.</i> (2016)
Serdang, Malaysia	400 mg/L	↓ Plant height 8.4%, First internodal length 26.4% ↑ Hardness 10.8%, Brittleness 8.1%	Dorairaj and Ismail (2017)
West Bengal, India	50 g a.i./ha	↓ Plant height 10.1%, Internodal length 13.2%, Lodging 67.3% ↑ Grain yield 33.5%, Straw yield 27.1%, B:C 14.7%	Mukherjee (2020)
Karnataka, India	23% SC at a rate 200 mL/ha	↓ Plant height 0.6%, Internodal length 2.3%, Lodging 62.9% ↑ Grain yield 2.2%, Straw yield 2.2%	Meena <i>et al.</i> (2020)
Chlormequat chloride/Cycocel (CCC)			
Giza, Egypt	80 ppm	↓ Plant height 8.5% (2014) ↑ Grain yield 17% (2014)	Hashem <i>et al.</i> (2016)
Tirupati (Andhra Pradesh), India	500 ppm	↓ Plant height 17.5%, No. of nodes on main culm 14.8% ↑ Harvest index 17.4%	Naidu <i>et al.</i> (2021)
Kanpur (Uttar Pradesh), India	2000 ppm	↓ Plant height 5.2% (2012) ↑ Grain yield 6.8%, Total dry matter 12.1% (2012)	Kushwaha <i>et al.</i> (2021)



Control plot and PGR-applied rice plot

growth regulators may vary, and it is important to identify the most responsive varieties. Additionally, the application of these plant growth regulators should be complemented with appropriate nitrogen fertilizer management, as the two factors can interact to influence plant growth and development.

SUMMARY

Plant growth regulators offer a promising solution to the challenge of lodging in rice cultivation. By strengthening plant architecture, they reduce lodging risk, increase yield, and improve harvest efficiency and combat the adversaries of climate change. While challenges remain, particularly regarding dosage, timing, and varietal differences, ongoing research and field trials continue to unlock their full potential. As global demand for rice grows, innovative approaches like the application of these plant growth regulators will play a crucial role in ensuring sustainable and productive rice farming practices.

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number of panicles, panicle length, and grain yield.

The timing and dosage of these plant growth regulators application are crucial factors in maximizing its effectiveness. Studies have indicated that the optimal application time is during the panicle initiation stage, typically 30-45 days after transplanting (DAT). This stage is critical for the plant's development, and the application of plant growth regulators can effectively modulate its growth and enhance its lodging resistance. In terms of dosage, the available research suggests that the

application of different plant growth regulators differs depending on the cultivar or crop. Higher rates have also been found to be effective, but the incremental benefits may not justify the additional cost.

To fully harness the benefits of these plant growth regulators, it is essential to integrate their use into a comprehensive rice production system. This includes considering factors such as cultivar selection, nutrient management, and other agronomic practices. For instance, the response of different rice cultivars to different plant

HANDBOOK OF INTEGRATED PEST MANAGEMENT

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TECHNICAL SPECIFICATIONS

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