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LOW-LIGHT TOLERANCE IN RICE: DECODING ADAPTATION MECHANISMS

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Rice (*Oryza sativa L.*) is the staple food for more than 3.5 billion people and accounts for nearly 20% of global caloric intake. Rice is a sun-loving, photophilic crop and being a C_3 crop, requires high light intensity to achieve optimum growth and yield. The photosynthetic rate is strongly dependent on the solar radiation with peak light demands reaching up to 60,000–80,000 lux during tillering and booting stages. In most regions where rice is grown especially tropical and subtropical areas, light availability is naturally high. However, during the monsoons or wet season, where persistent cloud cover and high humidity prevails photosynthetically active radiation (PAR) can be reduced significantly by 30–70% and this significantly reduces the crop productivity. In eastern India, Bangladesh, and Southeast Asia, grain yield losses of 15–40% due to low light stress have been reported during the wet season. Besides the environmental paramaters, agronomic practices such as dense planting, growing of tall varieties and intercrop shading also exacerbate the problem.

Low light stress significantly reduces rice productivity by limiting photosynthesis, delaying tillering and impairing panicle initiation and grain filling. Reduced light availability leads to poor carbohydrate accumulation, lower spikelet fertility, and chalky grains, while also increasing susceptibility to fungal diseases such as sheath blight. Yield losses of 20–50% have been reported in wet-season rice where cloud cover coincides with reproductive stages. With climate change intensifying cloudy spells during monsoons, low light stress is emerging as a critical abiotic constraint to rice production and food security.

While substantial progress has been made in breeding for drought, salinity, and submergence tolerance, low light tolerance remains underexplored. However, advances in quantitative genetics, molecular breeding, and functional genomics are beginning to shed light on the physiological and genetic mechanisms that enable certain rice varieties to perform well under shaded or cloudy conditions. Identifying, mapping, and deploying these traits could help close the wet-season yield gap and support sustainable intensification of rice systems.

Physiological and Proteomic Responses: Proteomic analyses under low-light stress (≈17% of control light) reveal a significant downregulation of chloroplastic proteins essential for photosynthesis. Specifically, components of the Calvin cycle, electron transport chain, and ATPase complexes were suppressed. Notably, overexpression of OsGAPB, the gene encoding the β subunit of glyceraldehyde-3-phosphate dehydrogenase, significantly improved CO_2 assimilation rates, chlorophyll content, and biomass under low-light conditions, without affecting plants under normal light (Liu et al, 2020)

Genetic Mapping of Low-Light Tolerance: A robust QTL analysis conducted across four consecutive wet seasons under artificially reduced light (≈35% of ambient) identified major yield-enhancing loci. The QTL qPNLL1.1 and qGYLL1.1, both on chromosome 1, showed high phenotypic variance explained (PVE > 30%) and consistent additive effects. Within this region lies MOC2 (*monoculm 2*, LOC_Os01g64660), upregulated in low-light tolerant genotypes—making it a promising candidate for marker-assisted selection to close the yield gap under shade (Ganguly et al 2024).

Subgenomic Resources and Photoreceptor Pathways: Recognizing the limited understanding of photomorphogenic adaptation, researchers constructed a subgenomic library from a low-light tolerant cultivar *Swarnaprabha*. This resource is intended to facilitate the isolation of genes related to light perception—such as phytochromes—and tailored photosensitivity, particularly focusing on phyA, phyB, and phyC, the dominant phytochrome types in rice (Sahu et al, 2023).

Implications for Breeding and Research

By Genetic improvement through incorporation of major QTLs (e.g., qPNLL1.1) via marker-assisted breeding approaches. Transgenic strategies can be adopted by exploring OsGAPB and other photosynthetic enhancement genes to increase the biomass under low light. Functional genomics can aim by utilization of subgenomic resources to dissect light perception pathways and develop varieties with optimized photoreceptors. Multi-omics profiling can be applied to integrate physiology and omics for comprehensive trait development, including grain quality under shade.

Conclusion

Low light stress is an underexplored but serious constraint in rice, causing 20–50% yield losses in monsoon regions due to reduced photosynthesis, poor grain filling, and higher disease incidence. Recent discoveries, including genes like OsGAPB and QTLs such as qPNLL1.1 (MOC2), show strong potential for breeding tolerant varieties. Marker-assisted selection, genomic tools, and gene-editing, combined with improved agronomic practices, can enhance resilience. Prioritizing low-light tolerance is vital for climate-smart rice production and global food security.

References

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