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DEVELOPMENT AND MULTI-LOCATION EVALUATION OF WGL-1488 (IET 30261): A HIGH-YIELDING LOW NITROGEN STRESS-TOLERANT RICE CULTURE FOR IRRIGATED ECOSYSTEMS

Y. HARI[1]*, V. VENKANNA[1], B. SATISH CHANDRA[1], K. RUKMINI DEVI[1], R. SHRAVANKUMAR[1], P. GONYA NAYAK[1], B. SOUNDARYA[1], G. NEELIMA[1], K. RAJENDRA PRASAD[1], B. MADHAVI[1], J. BHARGAVI[1], K. MANASA REDDY[1], CH. DAMODARA RAJU[1], P. RAGHU RAMI REDDY[1], P. JAGAN MOHAN RAO[1], R. UMA REDDY[1], M. SREEDHAR[1], M. S. ANANTHA[2] and R. M. SUNDARAM[2]

[1]Regional Agricultural Research Station (RARS), PJTAU, Warangal, Telangana
[2]Crop Improvement Section, ICAR–Indian Institute of Rice Research (ICAR-IIRR), Rajendranagar, Hyderabad, Telangana

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ABSTRACT

Nitrogen (N) deficiency is a major constraint limiting rice productivity and nitrogen-use efficiency (NUE) in both irrigated and rainfed production systems. Developing rice varieties capable of maintaining high productivity under reduced nitrogen application is an important strategy for sustainable crop production while minimizing fertilizer inputs and environmental impacts. WGL-1488 (IET 30261) is a medium-duration, high-yielding rice culture developed at the Regional Agricultural Research Station (RARS), Warangal, Professor Jayashankar Telangana Agricultural University (PJTAU), through backcross breeding using MTU 1121 (Sri Dhruthi) as the recurrent parent and Swarna as the donor parent for low nitrogen tolerance. The breeding line was evaluated in the All India Coordinated Rice Improvement Project (AICRIP) Low Nitrogen Tolerance (LNT) trials during Kharif 2021–2023 under two nitrogen management regimes comprising 0% and 50% of the recommended nitrogen dose. Across three years of multi-location evaluation, WGL-1488 recorded weighted mean grain yields of 4222 kg ha^{-1} under complete nitrogen omission and 4899 kg ha^{-1} under 50% recommended nitrogen application. Under 0% nitrogen, the culture exhibited yield advantages of 7.15%, 24.86% and 57.37% over Swarna, Rasi and Varadhan, respectively, while corresponding yield advantages under 50% nitrogen were 10.66%, 37.81% and 47.25%. Besides superior grain yield, WGL-1488 exhibited desirable agronomic characteristics, including medium maturity (130–135 days), semi-dwarf stature (99–105 cm), non-lodging habit, fertilizer responsiveness and short bold grains. The culture also recorded high milling recovery (69.4%), head rice recovery (64.9%) and intermediate amylose content (23.58%). It was resistant to bacterial leaf blight, sheath blight, sheath rot and glume discoloration, and moderately resistant to brown spot and brown planthopper. The consistent superiority of WGL-1488 across diverse agro-climatic regions under reduced nitrogen application demonstrates its potential as a nitrogen-efficient rice culture suitable for sustainable irrigated ecosystems. The culture offers an opportunity to reduce fertilizer inputs without compromising productivity, thereby contributing to environmentally sustainable rice production.

Keywords: Oryza sativa L.; Nitrogen-use efficiency; Low nitrogen tolerance; Irrigated rice; Sustainable agriculture; Rice breeding; Grain yield

Rice (Oryza sativa L.) is one of the world's most important cereal crops and serves as the staple food for more than half of the global population. It plays a pivotal role in ensuring food and nutritional security, particularly in Asia, where nearly 90% of global rice is produced and consumed (Bouman et al., 2007; FAO, 2024; Wang et al., 2023). Sustaining rice production has become increasingly challenging because of shrinking natural resources, climate variability, labour shortages and rising cultivation costs. Among all production inputs, nitrogen (N) fertilizer contributes substantially to achieving high grain yield; however, rice plants generally recover only 30–50% of the applied nitrogen, while the remainder is lost through volatilization, denitrification, leaching and runoff. These losses reduce nitrogen-use efficiency (NUE), increase production costs and contribute to environmental pollution (Fageria & Baligar, 2005; Hirel et al., 2007; Xu et al., 2012).

Nitrogen fertilizer accounts for a major share of the cultivation cost in irrigated rice ecosystems. Excessive nitrogen application not only increases production expenses but also contributes to greenhouse gas emissions, eutrophication of water bodies and deterioration of soil health. Consequently, improving NUE has become an important strategy for achieving sustainable rice production while reducing environmental impacts (Cassman et al., 2003; Good & Beatty, 2011).

Considerable genetic variation exists among rice genotypes for nitrogen uptake, utilization and remobilization efficiency, providing opportunities for developing varieties capable of maintaining high productivity under reduced nitrogen application. Recent advances in rice genetics have further improved our understanding of genes regulating nitrogen uptake and utilization, thereby facilitating the development of

E-mail: itsyhari@**yahoo.co.in**

nitrogen-efficient cultivars (Hirel et al., 2007; Hu et al., 2023; Liu et al., 2022).

Recognizing the importance of nitrogen-use efficiency, the All India Coordinated Rice Improvement Project (AICRIP) initiated coordinated evaluation of breeding materials under low nitrogen environments to identify genotypes capable of sustaining grain yield with reduced fertilizer inputs. Such cultivars are expected to reduce cultivation costs, improve fertilizer-use efficiency and contribute to environmentally sustainable rice production.

In this context, the rice breeding line WGL-1488 (IET 30261) was developed jointly by the Regional Agricultural Research Station (RARS), Warangal, Professor Jayashankar Telangana Agricultural University (PJTAU) and the ICAR–Indian Institute of Rice Research (ICAR-IIRR), Hyderabad through backcross breeding using MTU 1121 (Sri Dhruthi) as the recurrent parent and Swarna (MTU 7029) as the donor parent. The breeding line was evaluated in the AICRIP Low Nitrogen Tolerance (LNT) coordinated trials during Kharif 2021–2023 under 0% and 50% recommended nitrogen levels, where it demonstrated superior grain yield, broad adaptability, desirable grain quality and favourable reactions to major diseases and insect pests.

Therefore, the present investigation was undertaken to evaluate the agronomic performance, grain yield, adaptability, disease and insect pest reactions, and grain quality characteristics of WGL-1488 (IET 30261) under low nitrogen environments and to assess its suitability as a high-yielding, low nitrogen stress-tolerant rice culture for irrigated ecosystems.

Materials and Methods

Development of WGL-1488 (IET 30261)

The advanced rice breeding line WGL-1488 (IET 30261) [RP 6317-RMS-S35-BC, F„ -49-25-12-18] was developed at the Regional Agricultural Research Station (RARS), Warangal, Professor Jayashankar Telangana Agricultural University (PJTAU), Telangana, in collaboration with the ICAR–Indian Institute of Rice Research (ICAR-IIRR), Hyderabad.

The breeding programme aimed to develop a high-yielding rice culture possessing improved adaptation to low nitrogen (N) environments without compromising grain yield, plant type or grain quality. The variety MTU 1121 (Sri Dhruthi) was used as the recurrent parent because of its high yield potential, medium-slender grain quality, desirable agronomic characteristics and farmer acceptance, whereas Swarna (MTU 7029) served as the donor parent owing to its adaptation and superior performance under low soil nitrogen conditions. The cross MTU 1121 × Swarna was made during Kharif 2015, followed by two successive backcrosses with MTU 1121 as the recurrent parent. Subsequent pedigree selection under low nitrogen environments was practiced from segregating generations to recover the desirable phenotype of MTU 1121 while retaining improved adaptation to nitrogen-deficient conditions. Selection was primarily based on plant type, grain yield, maturity, grain quality and performance under reduced nitrogen availability. The superior breeding line RP 6317-RMS-S35-BC, F„ -49-25-12-18 consistently exhibited superior performance under low nitrogen screening and was nominated to the All India Coordinated Rice Improvement Project (AICRIP) Low Nitrogen Tolerance (LNT) trials, where it was assigned IET 30261 and designated as WGL-1488.

Multi-location Evaluation

The advanced breeding line WGL-1488 was evaluated under the AICRIP Low Nitrogen Tolerance (LNT) coordinated varietal trials during Kharif 2021, 2022 and 2023.

The entry was evaluated sequentially in

- Initial Varietal Trial-LNT (IVT-LNT; 2021),
- Advanced Varietal Trial-I LNT (AVT-I LNT; 2022), and
- Advanced Varietal Trial-II LNT (AVT-II LNT; 2023).

The coordinated trials were conducted across representative irrigated rice-growing environments of India covering Zone VII (Telangana, Andhra Pradesh and Karnataka), Zone III (Odisha, Jharkhand and Bihar), Zone II (Haryana) and Zone VI (Maharashtra). These locations represent diverse agro-climatic conditions, soil types and native soil fertility levels, thereby enabling comprehensive assessment of varietal adaptability under reduced nitrogen environments.

Low Nitrogen Stress Evaluation

The coordinated trials were conducted under two nitrogen management regimes prescribed under the AICRIP Low Nitrogen Tolerance programme:

- 0% of the recommended nitrogen dose (complete nitrogen omission)
- 50% of the recommended nitrogen dose

All other crop management practices were maintained according to the recommended package of practices for the respective locations. The proposed entry was evaluated against nationally designated positive and qualifying checks. Positive checks included Swarna, Rasi and Varadhan, whereas qualifying checks consisted of IET 29577, IET 30270 and IET 30273, depending on the year of testing.

Experimental Design and Crop Management

Experiments at all AICRIP centres were conducted following the standard experimental protocols prescribed under the All India Coordinated Rice Improvement Project (AICRIP). The trials were laid out under irrigated transplanted conditions using a Randomized Complete Block Design (RCBD) with three replications, following the experimental design adopted at each coordinated centre.

Twenty-one-day-old seedlings were transplanted at the recommended spacing of 20 cm × 15 cm, with two seedlings per hill. Recommended agronomic practices, including irrigation scheduling, weed management and plant protection measures, were uniformly followed at all locations. Nitrogen was applied according to the designated treatment (0% or 50% recommended dose), whereas phosphorus and potassium fertilizers were applied as per local recommendations to avoid nutrient deficiencies other than nitrogen. Uniform crop management minimized environmental variation among testing locations, enabling reliable assessment of genotype performance under low nitrogen conditions.

Recording of Agronomic Observations

Agronomic observations were recorded according to the Standard Evaluation System (SES) for Rice (IRRI, 2013) and AICRIP evaluation guidelines.

The following observations were recorded:

- Days to 50% flowering
- Days to maturity
- Plant height (cm)
- Number of productive panicles (m{ ^{2})
- Panicle exertion
- Lodging resistance
- Grain type
- Test weight (g)
- Grain yield (kg ha^{-1})
- Adaptation under low nitrogen conditions

Observations were recorded from representative plants in each experimental plot following the standard descriptors prescribed under the coordinated rice improvement programme.

Evaluation of Diseases and Insect Pests

Disease and insect pest reactions were evaluated under the coordinated AICRIP screening programme during Kharif 2021–2023 at designated national screening centres. Screening included

- Bacterial leaf blight
- Sheath blight
- Sheath rot
- Glume discoloration
- Brown spot
- Brown planthopper (BPH)

Disease reactions were recorded using the Standard Evaluation System (SES) for Rice, whereas brown planthopper resistance was evaluated under both greenhouse and field conditions using standard AICRIP protocols. Disease severity and insect damage scores assigned by the respective national screening centres were used for interpretation of resistance levels.

Grain Quality Evaluation

Grain quality evaluation was carried out at designated AICRIP grain quality laboratories following standard IRRI laboratory procedures.

The following quality parameters were determined:

- Hulling recovery (%)
- Milling recovery (%)
- Head rice recovery (%)

- Kernel length (mm)
- Kernel breadth (mm)
- Length-to-breadth ratio
- Amylose content (%)
- Alkali spreading value
- Gel consistency (mm)

The grain quality characteristics of WGL-1488 were compared with those of the recurrent parent (MTU 1121) and donor parent (Swarna) to assess recovery of desirable grain quality traits and consumer acceptability.

Statistical Analysis

Grain yield data generated from the coordinated trials across years and locations were compiled following AICRIP procedures. Weighted mean grain yield across testing locations was calculated separately under 0% nitrogen and 50% recommended nitrogen environments. Yield superiority (%) over the positive checks was estimated using the following equation:

Yield Advantage (%) = [(Y‘ “ Yc) / Yc] × 100

where Y‘ = mean grain yield of WGL-1488 and Yc = mean grain yield of the respective check variety.

Pooled analysis across locations and years was used to assess the stability and adaptability of WGL-1488 under reduced nitrogen conditions. The performance summaries presented in this manuscript are based on the official AICRIP coordinated trial data generated during Kharif 2021–2023.

RESULTS

Development of WGL-1488 (IET 30261)

The promising rice culture WGL-1488 (IET 30261) [RP6317-RMS-S35-BC, F„ -49-25-12-18] was developed at the Regional Agricultural Research Station (RARS), Warangal, Professor Jayashankar Telangana Agricultural University (PJTAU), through backcross breeding using MTU 1121 (Sri Dhruthi) as the recurrent parent and Swarna (MTU 7029) as the donor parent. The breeding programme aimed to combine the superior agronomic and grain quality characteristics of MTU 1121 with enhanced adaptation to low nitrogen environments contributed by Swarna.

The initial cross was made during Kharif 2015, followed by two successive backcrosses with MTU 1121. Pedigree selection was practiced in the segregating generations under reduced nitrogen environments, with emphasis on plant type, grain yield, maturity, lodging resistance and grain quality. After rigorous phenotypic selection, the breeding line RP6317-RMS-S35-BC, F„ -49-25-12-18 consistently exhibited superior performance and was nominated to the All India Coordinated Rice Improvement Project (AICRIP) Low Nitrogen Tolerance (LNT) trials, where it was assigned IET 30261 and designated as WGL-1488.

The breeding history is summarized in Figure 1, illustrating the crossing programme, backcross generations, pedigree selection and progression through coordinated varietal evaluation.

Agronomic Performance

WGL-1488 exhibited desirable agronomic characteristics suitable for irrigated rice ecosystems. The culture was medium in duration, requiring 130–135 days to maturity, and possessed a semi-dwarf stature (99–105 cm), which contributed to good lodging resistance under irrigated conditions. Complete panicle exertion, non-shattering behaviour and fertilizer responsiveness were consistently observed across testing locations.

The grain type was short bold, comparable to the donor parent Swarna, while maintaining acceptable agronomic performance. These characteristics make WGL-1488 suitable for cultivation under diverse irrigated environments where medium-duration varieties are preferred. The principal agronomic characteristics of WGL-1488 are presented in Table 1.

Table 1. Agronomic and morphological characteristics of WGL-1488 (IET 30261)

Character	WGL-1488 (IET 30261)
Parentage	MTU 1121 × Swarna (MTU 7029)
Breeding method	Backcross breeding followed by pedigree selection
Plant height (cm)	99–105
Maturity (days)	130–135
Plant type	Semi-dwarf
Grain type	Short bold
Adaptation (Irrigated)	Zones II, III, VI and VII

Grain Yield Performance under Reduced Nitrogen

The grain yield performance of WGL-1488 was evaluated during Kharif 2021–2023 under coordinated AICRIP Low Nitrogen Tolerance trials across representative rice-growing regions of India. Across three years of evaluation, WGL-1488 recorded weighted mean grain yields of 4222 kg ha^{-1} under complete nitrogen omission (0% nitrogen) and 4899 kg ha^{-1} under 50% of the recommended nitrogen dose.

Under complete nitrogen omission, WGL-1488 out-yielded Swarna by 7.15%, Rasi by 24.86%, and Varadhan by 57.37%. Under 50% recommended nitrogen, the culture maintained superior performance with yield advantages of 10.66%, 37.81%, and 47.25% over Swarna, Rasi, and Varadhan, respectively. These results indicate that WGL-1488 maintains high productivity even under reduced nitrogen availability, suggesting improved adaptation to nitrogen-limited environments. The grain yield data are presented in Table 2, while the comparative performance is illustrated in Figure 2.

Table 2. Grain yield performance under low nitrogen conditions

Nitrogen	Yield	Over Swarna	Over Rasi	Over Varadhan
0% nitrogen	4222 kg ha^{-1}	+7.15%	+24.86%	+57.37%
50% recommended nitrogen	4899 kg ha^{-1}	+10.66%	+37.81%	+47.25%

Multi-location Adaptability

One of the most important attributes of WGL-1488 was its stable performance across diverse agro-climatic regions. The coordinated AICRIP trials covered Zones II, III, VI and VII, representing a wide range of soil types, climatic conditions and management practices. Despite this environmental variability, WGL-1488 consistently maintained superior grain yield under both nitrogen regimes, demonstrating broad adaptation and stable performance across testing environments. Such consistency is an important prerequisite for varietal identification and release under the AICRIP system. The stable performance across locations indicates that WGL-1488 possesses wide adaptation and can be recommended for cultivation under irrigated ecosystems experiencing reduced nitrogen availability.

Disease and Insect Pest Reactions

WGL-1488 was evaluated under the coordinated AICRIP disease and insect screening programme during Kharif 2021–2023. The culture exhibited resistant reactions to bacterial leaf blight, sheath blight, sheath rot and glume discoloration. Moderate resistance was observed against brown spot and brown planthopper under both greenhouse and field conditions. The combination of superior grain yield and favourable biotic stress reactions contributes to the production stability of WGL-1488 and enhances its suitability for sustainable rice cultivation. The pooled disease and insect pest reactions are summarized in Table 3 and illustrated in Figure 3.

Table 3. Pooled disease and insect pest reactions of WGL-1488

Disease/Insect	Score	Reaction
BLB	5.5	Resistant
Brown spot	4.5	Moderately resistant
Sheath blight	6.5	Resistant
Sheath rot	5.1	Resistant
Glume discoloration	4.8	Resistant
BPH (Greenhouse)	4.11	Moderately resistant
BPH (Field)	3.00	Moderately resistant

Grain Quality Characteristics

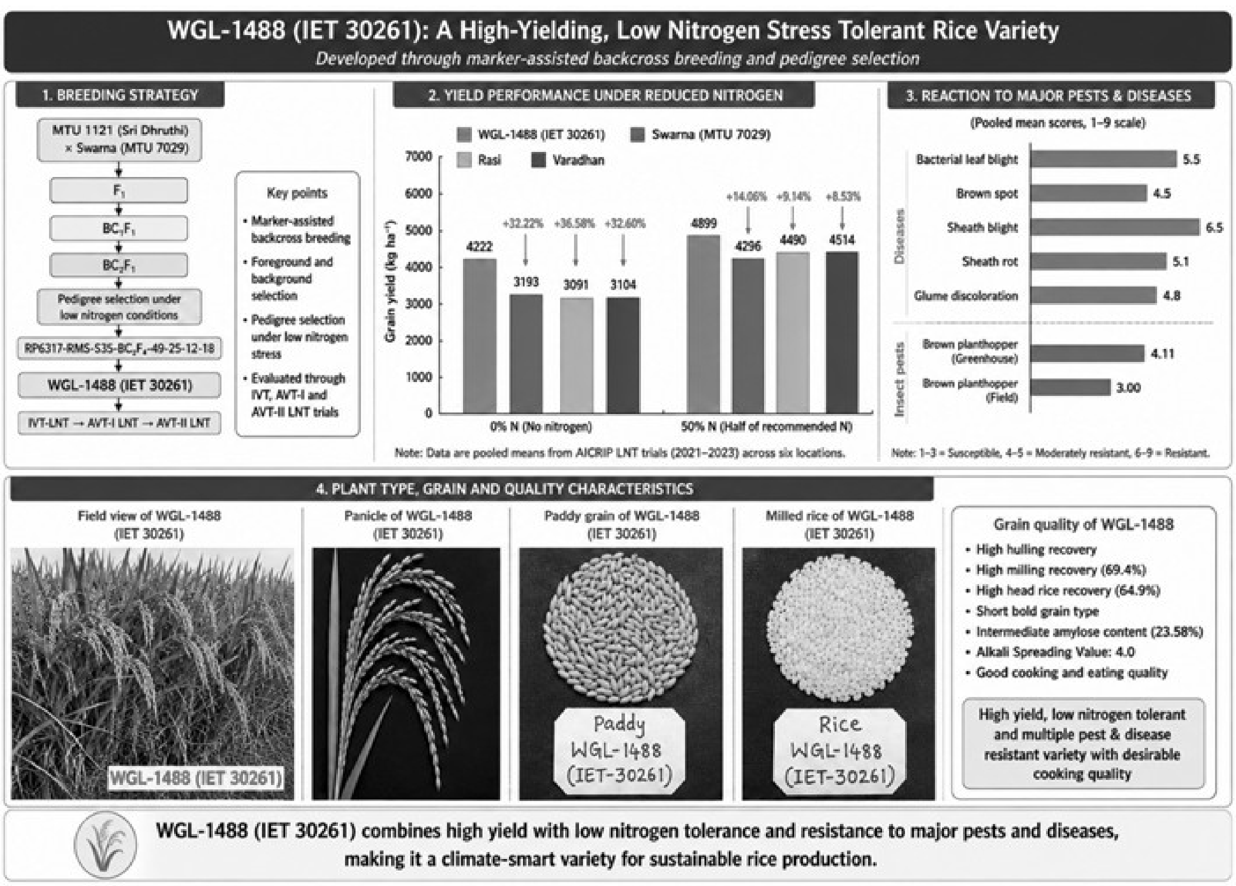
Grain quality evaluation demonstrated that WGL-1488 retained desirable post-harvest and cooking quality characteristics comparable to its parents. The culture recorded hulling recovery of 80.3%, milling recovery of 69.4%, and head rice recovery of 64.9%. The kernels were short bold with an average length of 4.89 mm, breadth of 2.04 mm, and length-to-breadth ratio of 2.22. The amylose content (23.58%), alkali spreading value (4.0), and gel consistency (43 mm) indicate acceptable cooking quality. These results demonstrate that the improvement for low nitrogen adaptation was achieved without adversely affecting grain quality. The comparative grain quality characteristics are presented in Table 4, while representative photographs of the crop, panicle, paddy grain and milled rice are shown in Figure 4.

Table 4. Comparative grain quality characteristics of WGL-1488 and its parents

Parameter	MTU1121	Swarna	WGL-1488
Hulling recovery (%)	81.0	79.0	80.3
Milling recovery (%)	73.3	69.2	69.4
Head rice recovery (%)	71.9	66.1	64.9
Kernel length (mm)	5.68	4.87	4.89
Kernel breadth (mm)	2.09	2.19	2.04
L/B ratio	2.67	2.39	2.22
Grain type	Medium slender	Short bold	Short bold
Amylose (%)	22.82	23.99	23.58
ASV	4.0	4.0	4.0
Gel consistency (mm)	22	29	43

Overall Performance of WGL-1488

The coordinated evaluation clearly demonstrated that WGL-1488 successfully combines high grain yield under reduced nitrogen application with desirable agronomic traits, broad adaptation, favourable disease and insect pest reactions, and acceptable grain quality. Across three consecutive years of national evaluation, the culture consistently outperformed the designated positive checks under both complete nitrogen omission and reduced nitrogen application, highlighting its potential for improving nitrogen-use efficiency in irrigated rice production. The combined performance indicates that WGL-1488 is a promising low nitrogen stress-tolerant rice culture suitable for sustainable rice production systems and merits consideration for varietal release and cultivation under irrigated ecosystems.



DISCUSSION

The development of rice varieties capable of maintaining high productivity under reduced nitrogen application is a key strategy for achieving sustainable rice production. Nitrogen fertilizer is indispensable for maximizing rice yield; however, its utilization efficiency in rice is generally low because a substantial proportion of the applied nitrogen is lost through volatilization, denitrification and leaching, leading to increased production costs and environmental pollution (Fageria and Baligar, 2005; Hirel et al., 2007; Xu et al., 2012). Consequently, breeding rice varieties with improved nitrogen-use efficiency (NUE) has become an important objective of rice improvement programmes worldwide (Cassman et al., 2003; Good and Beatty, 2011).

The present investigation demonstrated that WGL-1488 (IET 30261) consistently produced superior grain yield under both complete nitrogen omission (0% nitrogen) and 50% recommended nitrogen across three consecutive years of coordinated AICRIP evaluation. The weighted mean grain yields of 4222 kg ha^{-1} under 0% nitrogen and 4899 kg ha^{-1} under 50% recommended nitrogen, together with significant yield advantages over the designated positive checks, indicate that WGL-1488 possesses enhanced adaptation to nitrogen-limited environments. Although physiological measurements of nitrogen uptake and utilization were beyond the scope of the present study, the stable superiority observed under coordinated multi-location evaluation strongly suggests improved nitrogen-use efficiency. Similar observations have been reported by Hirel et al. (2007), who emphasized that genetic variability for nitrogen acquisition, assimilation and remobilization can be effectively exploited to improve productivity under reduced nitrogen availability. Likewise, Xu et al. (2012) highlighted that the development of nitrogen-efficient rice varieties provides an effective strategy for sustaining productivity while minimizing fertilizer inputs.

An important feature of WGL-1488 is its broad adaptability across diverse rice-growing environments. The coordinated AICRIP evaluation demonstrated consistent performance across Zones II, III, VI and VII under low nitrogen conditions, indicating stable genotype × environment interaction. Multi-location testing across contrasting agro-climatic regions is an essential criterion for varietal identification because it provides reliable evidence of yield stability and wide adaptation. The consistent superiority of WGL-1488 across different production environments demonstrates its suitability for cultivation under a broad range of irrigated ecosystems where reduced nitrogen fertilizer application is desirable.

In addition to superior grain yield, WGL-1488 exhibited favourable reactions to several economically important diseases and insect pests. The genotype recorded resistant reactions to bacterial leaf blight, sheath blight, sheath rot and glume discoloration, while showing moderate resistance to brown spot and brown planthopper under coordinated AICRIP screening. The pooled greenhouse and field evaluations further confirmed stable resistance to brown planthopper. The integration of improved nitrogen-use efficiency with multiple disease and insect resistance is particularly advantageous because it contributes to production stability, minimizes yield losses and reduces dependence on chemical plant protection measures. Such a combination of favourable agronomic performance and biotic stress tolerance is highly desirable for the development of climate-resilient and resource-efficient rice varieties.

Grain quality is one of the most important determinants of farmer acceptance, consumer preference and market value. The present study demonstrated that WGL-1488 retained grain quality characteristics comparable with both the recurrent parent MTU 1121 and the donor parent Swarna. The variety exhibited desirable hulling recovery, milling recovery, head rice recovery, intermediate amylose content, acceptable alkali spreading value and favourable gel consistency. These results indicate that improvement for low nitrogen adaptation was achieved without compromising grain quality. Maintenance of desirable grain quality during varietal improvement is essential because successful adoption of newly developed rice varieties depends on the combined expression of high productivity and consumer-preferred grain characteristics (Juliano, 1985; Cruz and Khush, 2000).

The present findings also highlight the practical significance of WGL-1488 for sustainable rice production. Nitrogen fertilizer constitutes a major component of cultivation costs in irrigated rice systems, and excessive nitrogen application contributes to greenhouse gas emissions, deterioration of soil health and contamination of water resources (Good and Beatty, 2011). Therefore, varieties capable of maintaining high grain yield under reduced nitrogen application provide an effective approach for improving fertilizer-use efficiency while minimizing environmental impacts. Recent studies have similarly emphasized that improving nitrogen-use efficiency through genetic enhancement is an important component of climate-resilient and environmentally sustainable rice production systems (Hu et al., 2023; Liu et al., 2022).

Overall, the coordinated multi-location evaluation clearly demonstrated that WGL-1488 successfully combines superior grain yield under reduced nitrogen application with broad adaptation, favourable reactions to major diseases and insect pests, and desirable grain quality. These characteristics make WGL-1488 a promising low nitrogen stress-tolerant rice culture for irrigated ecosystems. Its adoption has the potential to reduce nitrogen fertilizer requirements, lower cultivation costs, improve nitrogen-use efficiency and contribute to environmentally sustainable rice production. Therefore, WGL-1488 represents a valuable genetic resource for future rice breeding programmes aimed at developing high-yielding and resource-efficient rice varieties.

CONCLUSION

WGL-1488 (IET 30261), developed through backcross breeding using MTU 1121 and Swarna, demonstrated superior grain yield under low nitrogen conditions along with broad adaptability, resistance to major diseases, moderate resistance to brown planthopper, and desirable grain quality. The rice culture consistently outperformed the standard checks under both 0% and 50% recommended nitrogen levels across multi-location AICRIP trials, indicating its potential for sustainable rice production with reduced nitrogen fertilizer inputs. Therefore, WGL-1488 is a promising cultivar for improving nitrogen-use efficiency and productivity in irrigated rice ecosystems.

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