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Evaluation of Agronomic Performance and Grain Quality of Bacterial Leaf Blight-Resistant Rice Varieties in Hung Yen Province, Vietnam

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Abstract. The field experiment aimed to evaluate the growth, yield, and grain quality of eight rice varieties with high resistance to bacterial leaf blight (TBR225-New, TBR225ĐK-1, TBR225ĐK-2, Dong A2, TBR19, ĐC16, BC3, and TBR86), compared to the control variety Bac Thom 7 (BT7), during the 2024 spring season in Bac Dong Hung commune, Hung Yen province, Vietnam. The trial was arranged in a randomized complete block design (RCBD) with three replications. Agronomic characteristics varied among the varieties, with plant height ranging from 103.0 cm (TBR86) to 116.6 cm (TBR19), and total growth duration from 120 days (BT7, TBR86) to 126 days (TBR225-New). Grain yields ranged from 4.83 tons ha^{-1} (BT7) to 6.68 tons ha^{-1} (TBR86), with TBR225ĐK-2 (6.38 tons ha^{-1}) and TBR225ĐK-1 (6.20 tons ha^{-1}) also outperforming the control. All improved varieties showed significantly greater resistance to bacterial leaf blight, with lesion areas below 5%, compared to 65.3% in BT7. Milling quality was acceptable, with brown rice rates ranged from 79.0–83.0% and head rice recovery from 75.7–81.9%. These findings suggest that TBR225ĐK-2, TBR225ĐK-1, and TBR86 combine balanced agronomic traits, high yield potential, disease resistance, and acceptable grain quality, making them strong candidates for large-scale adoption in Hung Yen province to improve rice productivity and sustainability.

Keywords: permethrin, behavioural biomonitoring, artificial neural network, early warning system

1 Introduction

Rice (*Oryza sativa* L.) is a staple food crop for more than half of the world's population, supplying essential calories and nutrients, particularly in Asia, where over 90% of global rice production takes place [1, 2]. As the global population is projected to reach approximately 9 billion by 2050, rice production will need to increase by 70–100% to meet future food security demands [3]. Beyond yield, consumers are increasingly concerned with rice quality traits, including aroma, texture, and cooking characteristics [4].

However, rice production faces serious threats from bacterial leaf blight (BLB), caused by *Xanthomonas oryzae* pv. *oryzae*, which is among the most destructive diseases affecting rice in tropical and subtropical regions [5, 6]. BLB is estimated to cause a 10%–20% annual reduction in global rice production [7], and in severe epidemics, losses can reach up to 50% [8]. In Vietnam, BLB is a widespread and damaging disease in many rice-growing areas. Most commercial rice cultivars grown in Vietnam remain highly susceptible to BLB, resulting in annual yield losses of approximately 15%–30% [9].

Although chemical pesticides can suppress the causal pathogen, their excessive use leads to environmental pollution and health risks. Therefore, breeding and deploying rice cultivars with durable resistance to BLB represents a sustainable and eco-friendly strategy for disease management [10]. Nevertheless, the performance of these resistant cultivars regarding growth characteristics and yield potential must be evaluated under local agroecological conditions to ensure their suitability for regional production systems.

In this context, the present study was carried out to compare the growth and yield performance of selected rice varieties with high resistance to bacterial leaf blight in Hung Yen province, Vietnam. The results are expected to provide recommendations for promising varieties that can enhance rice productivity and sustainability in the region.

2 Materials and methods

2.1 Materials

Eight rice varieties developed and selected by ThaiBinh Seeds Group — namely TBR225-New, TBR225ĐK-1, TBR225ĐK-2, Dong A2, TBR19, ĐC16, BC3, and TBR86 — were evaluated in this study. All of these varieties are known for their good resistance to bacterial leaf blight. The traditional rice cultivar Bắc Thơm 7 (BT7) was used as the control. BT7 was chosen because it is one of the most widely cultivated and popular varieties in northern Vietnam, appreciated for its aromatic grains and desirable cooking qualities. However, it is highly susceptible to bacterial leaf blight and exhibits only moderate yield potential. Therefore, BT7 serves as an appropriate reference for assessing the improvements in disease resistance, agronomic performance, and grain quality achieved by the newly developed varieties.

2.2 Experimental design

The field experiment was conducted during the spring season of 2024 at the Crop Research Institute of ThaiBinh Seeds, located in Bac Dong Hung commune, Hung Yen province. The experiment followed a Randomized Complete Block Design (RCBD) with three replications. Each plot measured 10 m² (5 m × 2 m), with 40 cm spacing between plots and replications. Transplanting was performed with one seedling per hill, at a spacing of 20 cm × 20 cm, equivalent to a planting density of 25 hills per m². Seedlings were sown on January 29, 2024, and transplanted on February 20, 2024, at 22 days old.

The fertilizer regime was calculated per hectare, including 472 kg of Dau Trau L1 (N–P–K: 17–12–5), 56 kg of Dau Trau L2 (15–4–17), and 54 kg of urea. Fertilizer was applied in three stages: 40% of Dau Trau L1 was applied as a basal dose before transplanting; at the tillering stage, 100% of the urea and 30% of Dau Trau L1 were applied; and ten days later, the remaining 30% of Dau Trau L1 and all of Dau Trau L2 were used. Other cultivation practices were applied uniformly across all treatments. Pest and disease management, including the use of plant protection chemicals, was conducted in accordance with recommendations from the plant protection authorities.

2.3 Sampling parameters

Growth and yield parameters — including plant height, number of leaves, number of tillers, total growth duration, yield components, and theoretical yield — were evaluated in accordance with the Rice Genebank Standards of the International Rice Research Institute [11] and the Vietnamese National Standard TCVN 13381-1:2021 (Ministry of Science and Technology, 2021) [12]. For actual yield assessment, each experimental plot was harvested separately. From each plot, a 1 kg of fresh sample was collected, dried to a moisture content of 14%, and the actual yield was subsequently calculated for each plot.

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Physiological parameters: SPAD values were measured using a handheld SPAD-502 chlorophyll meter (Konica Minolta Sensing Inc., Osaka, Japan) at three positions on fully expanded leaves. The leaf area index (LAI, m² of leaf area per m² of ground area) was calculated using the formula: $LAI = (A_1 \times \text{number of plants per m}^2) / A_2 \times 100$; where A_1 is the total fresh leaf weight of a single plant (g), and A_2 is the fresh weight of 1 dm² of leaves (g). Panicles were separated and oven-dried at 80 °C until a constant weight was achieved to determine dry matter.

Bacterial leaf blight was assessed following the methodologies described by IRRI [11] and TCVN 13381-1:2021 [12].

Grain quality: The percentages of brown rice, milled rice, and head rice; and grain size were determined according to TCVN 7983:2015 [13].

2.4 Statistical analysis

Data processing and statistical analysis were performed using Microsoft Excel (Microsoft Corporation, Redmond, WA, USA) and MINITAB version 16 (Minitab Inc., State College, PA, USA) software. Analysis of variance (one-way ANOVA) was used for analyzing the effects of the experimental factor. The differences between treatments were identified according to Tukey's honest significant difference (HSD) test with $p = 0.05$.

3 Results and discussion

3.1 Agronomical characteristics of rice varieties

The agronomic traits of the eight rice varieties, along with the control (BT7), showed considerable variation (Table 1). Plant height ranged from 103.0 cm (TBR86) to 116.6 cm (TBR19), with TBR19, TBR225ĐK-1, TBR225ĐK-2, ĐC16, TBR225-New, and Dong A2 significantly taller than the control according to Tukey's HSD test ($p < 0.05$). In contrast, BC3, TBR86, and BT7 exhibited relatively shorter plant heights, which may help reduce lodging risk under high-input conditions.

Regarding the number of leaves per hill, values ranged from 12.1 to 13.2. TBR225ĐK-1 recorded the highest number of leaves (13.2 leaves hill^{-1}), which was significantly higher only compared to BC3 (12.1 leaves hill^{-1}). The other varieties did not differ significantly from the control in this parameter.

The number of tillers per hill showed more pronounced differences among varieties. TBR225-New and ĐC16 demonstrated higher tillering capacity (12.5 and 12.2 tillers hill^{-1}, respectively), comparable to the control (12.6 tillers hill^{-1}) and significantly exceeding those of TBR225ĐK-2 (10.2 tillers hill^{-1}), Dong A2 (10.3 tillers hill^{-1}), TBR19 (9.7 tillers hill^{-1}), BC3 (9.4 tillers hill^{-1}), and TBR86 (9.5 tillers hill^{-1}). This higher tillering potential is beneficial for maximizing panicle number, an important yield component.

Total growth duration among the varieties was generally similar, ranging from 120 to 126 days. TBR86 and BT7 exhibited the shortest growth duration (120 days), which could be advantageous for multiple-cropping systems. Conversely, TBR225-New had the longest growth period (126 days), which may allow for a longer grain-filling period and potentially higher yield if climatic conditions are favorable.

These results suggest that the newly developed TBR lines (TBR225-New, TBR225ĐK-1, TBR225ĐK-2) and ĐC16 possess favorable plant height, leaf number, and tillering capacity, providing a promising agronomic basis for improved yield potential and disease resistance.

Table 1. Agronomical traits of rice varieties

Variety	Plant height (cm)	Number of leaves (hill^{-1})	Number of tiller (hill^{-1})	Total growth duration (days)
TBR225-New	105.7^{b}	12.8^{ab}	12.5^{ab}	126
TBR225ĐK-1	112.5^{a}	13.2^{a}	12.1^{b}	125
TBR225ĐK-2	113.0^{a}	12.6^{ab}	10.2^{c}	125
Dong A2	103.6^{b}	12.4^{ab}	10.3^{c}	125
TBR19	116.6^{a}	12.5^{ab}	9.7^{c}	122
ĐC16	113.2^{a}	12.9^{ab}	12.2^{ab}	124
BC3	103.4^{bc}	12.1^{b}	9.4^{d}	122
TBR86	103.0^{bc}	12.7^{ab}	9.5^{c}	120
BT7 (Control)	103.8^{c}	12.8^{ab}	12.6^{a}	120

Values within a column followed by the different letter indicate significant differences at 0.05 level by Tukey's HSD test.

3.2 Physiological parameters of rice varieties

The SPAD index, which reflects relative chlorophyll content and thus photosynthetic capacity, varied significantly among varieties and growth stages (Table 2). During the tillering stage, TBR19 exhibited the highest SPAD value (40.5), significantly exceeding the other varieties ($p < 0.05$), whereas TBR225ĐK-1 and TBR225ĐK-2 recorded the lowest values (35.2 and 35.4, respectively). This suggests that TBR19 may have superior leaf greenness and photosynthetic activity during early development.

Table 2. SPAD values across growth stages

Variety	Tillering stage	Heading stage	Milk stage	Dough stage
TBR225-New	37.1^{b}	41.5^{b}	34.7^{bc}	29.9^{a}
TBR225ĐK-1	35.2^{c}	42.6^{ab}	35.7^{ab}	28.9^{ab}
TBR225ĐK-2	35.4^{c}	43.1^{ab}	30.9^{d}	29.0^{ab}
Dong A2	36.3^{bc}	43.5^{a}	37.4^{a}	29.0^{ab}
TBR19	40.5^{a}	43.5^{a}	34.7^{bc}	27.9^{b}
ĐC16	36.6^{bc}	41.8^{ab}	30.5^{d}	25.2^{c}
BC3	36.4^{bc}	42.2^{ab}	34.5^{bc}	25.7^{c}
TBR86	37.1^{b}	43.3^{ab}	32.7^{cd}	25.2^{c}
BT7 (Control)	36.5^{bc}	42.8^{ab}	27.6^{e}	22.1^{d}

Values within a column followed by the different letter indicate significant differences at 0.05 level by Tukey's HSD test.

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At the heading stage, SPAD values generally increased compared to tillering stage, with Dong A2 and TBR19 reaching the highest values (43.5). These higher chlorophyll indices at heading stage could be advantageous for sustaining photosynthesis to support panicle development. However, these values were only significantly higher than that of TBR225-New (41.5).

In the milk stage, most varieties showed a decline in SPAD values, ranging from 30.5 (ĐC16) to 37.4 (Dong A2). Dong A2 maintained the highest SPAD value, indicating a potential advantage in chlorophyll retention, which may promote better grain filling. In contrast, BT7 (control) showed a relatively low SPAD value (27.6), suggesting more rapid leaf senescence compared to the improved varieties.

At the dough stage, a further decrease in SPAD values was observed across all varieties, reflecting the natural senescence process. Dong A2 and the TBR225 lines maintained higher SPAD values (approximately 29.0), while BT7 dropped to the lowest level (22.1), which was significantly lower than all other varieties. This prolonged chlorophyll retention at the dough stage may contribute to extended grain filling, thus improving yield and grain quality.

The SPAD measurements across growth stages highlighted the superior chlorophyll retention of Dong A2 and the TBR225 lines, particularly during the grain-filling period. This prolonged photosynthetic activity may complement their favorable agronomic traits described earlier, contributing to stable yield formation and potentially enhanced grain quality compared to the control variety BT7.

Table 3. Leaf area index across growth stages (Unit: $m^2\ m^{-2}$)

Variety	Tillering stage	Heading stage	Milk stage	Dough stage
TBR225-New	4.52^{a}	6.82^{a}	5.74^{a}	4.64^{a}
TBR225ĐK-1	3.64^{d}	5.75^{c}	5.27^{d}	3.83^{c}
TBR225ĐK-2	3.68^{d}	6.26^{b}	5.37^{cd}	4.26^{b}
Dong A2	3.46^{e}	6.41^{b}	5.48^{bc}	4.40^{b}
TBR19	3.75^{cd}	5.67^{c}	5.56^{b}	3.66^{d}
ĐC16	3.85^{c}	6.79^{a}	4.81^{e}	3.37^{e}
BC3	3.87^{c}	5.80^{c}	5.43^{bc}	3.61^{d}
TBR86	4.30^{b}	6.34^{b}	5.58^{b}	3.91^{c}
BT7 (Control)	4.61^{a}	5.50^{d}	3.62^{f}	2.21^{f}

Values within a column followed by the different letter indicate significant differences at 0.05 level by Tukey's HSD test.

The leaf area index (LAI), a critical indicator of canopy development and photosynthetic potential, varied significantly among the tested rice varieties and across growth stages (Table 3). During the tillering stage, TBR225-New and the control (BT7) exhibited the highest LAI values (4.52 and 4.61 $m^2\ m^{-2}$, respectively), significantly exceeding the other varieties ($p < 0.05$). TBR86 also demonstrated a relatively high LAI (4.30 $m^2\ m^{-2}$), while Dong A2 recorded the lowest LAI

(3.46 $m^2 m^{-2}$), indicating comparatively weaker early canopy development.

At the heading stage, LAI generally increased in all varieties, reaching peak values. TBR225-New and ĐC16 achieved the highest LAI (6.82 and 6.79 $m^2 m^{-2}$, respectively), suggesting robust canopy expansion to support panicle formation. Other varieties, including TBR225ĐK-2, Dong A2, and TBR86, also maintained comparatively high LAI values, whereas BT7 had the lowest LAI (5.50 $m^2 m^{-2}$), which may limit its source capacity for subsequent grain filling.

During the milk stage, a gradual decline in LAI was observed across most varieties due to leaf senescence. TBR225-New continued to maintain the highest LAI (5.74 $m^2 m^{-2}$), followed closely by TBR86 (5.58 $m^2 m^{-2}$) and TBR19 (5.56 $m^2 m^{-2}$), all significantly higher than BT7 (3.62 $m^2 m^{-2}$). This suggests delayed leaf aging and a potentially greater assimilate supply during early grain filling.

At the dough stage, LAI continued to decrease in all varieties, reflecting advancing senescence. TBR225-New still retained the highest LAI (4.64 $m^2 m^{-2}$), while Dong A2 (4.40 $m^2 m^{-2}$) and TBR225ĐK-2 (4.26 $m^2 m^{-2}$) also preserved relatively high canopy cover. In contrast, BT7 declined sharply to 2.21 $m^2 m^{-2}$, which was significantly lower than the improved varieties. The steep decline in LAI observed in BT7 may be attributed to its rapid leaf senescence and the absence of prolonged canopy activity. Traditional varieties like BT7 often show earlier chlorophyll degradation, resulting in a shorter photosynthetic duration during the grain-filling period. This physiological limitation reduces the plant's capacity to supply assimilates to developing grains, ultimately lowering yield potential [14, 15]. In contrast, improved lines such as TBR225-New and TBR225ĐK-2 maintained higher LAI during later growth stages, indicating delayed senescence and extended photosynthetic activity. While this study did not investigate stay-green traits at the genetic level, the observed canopy retention is consistent with morphological expressions typically associated with stay-green behavior [16].

Our findings align with previous research showing that rice genotypes with higher LAI at maturity often exhibit better yield performance under both optimal and stress conditions [17]. Therefore, the superior LAI retention in the improved varieties may represent an important physiological advantage contributing to their enhanced productivity relative to the control.

The accumulation of dry matter in panicles is a key indicator of assimilate partitioning efficiency and sink strength. At the heading stage, TBR225-New recorded the highest panicle dry weight (11.8 g $hill^{-1}$), significantly exceeding that of the control BT7 (7.0 g $hill^{-1}$, $p < 0.05$). BC3 and TBR86 also exhibited relatively high values (11.3 g $hill^{-1}$ each), indicating good initial assimilate allocation to the panicle. In contrast, ĐC16, TBR19, and TBR225ĐK-2 showed more moderate dry weights ranging from 9.7 to 9.8 g $hill^{-1}$ (Table 4).

During the milk stage, panicle dry weight increased in all varieties, reflecting continued assimilate translocation. The highest values were observed in ĐC16 (18.2 g $hill^{-1}$) and TBR19 (18.0 g $hill^{-1}$), both significantly greater than that of BT7 (14.5 g $hill^{-1}$, $p < 0.05$). TBR225ĐK-1 and TBR225-New also maintained elevated panicle dry weights (17.7 and 17.2 g $hill^{-1}$, respectively), demonstrating effective grain-filling.

At the dough stage, dry weight accumulation continued to rise in most varieties, reaching maximum levels. Dong A2 achieved the highest panicle dry weight (26.2 g $hill^{-1}$), although this was not significantly different from other

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improved varieties, except for BT7 (20.5 g $hill^{-1}$), which remained substantially lower.

Improved varieties such as TBR225-New and TBR225ĐK-1, which maintained relatively high SPAD and LAI values during the milk and dough stages, also showed greater panicle dry matter accumulation. This suggests that sustained chlorophyll content and canopy coverage during grain filling may enhance photosynthetic capacity and promote more effective assimilate translocation to the developing panicle. These findings are in agreement with previous research. Liao et al. [18] demonstrated that, in indica hybrid rice, dynamic changes in SPAD and LAI during grain filling were closely linked to yield-related traits. Similarly, Gawdiya et al. [19] reported strong positive correlations between SPAD, LAI, and above-ground dry matter at maturity in lowland rice, underscoring the importance of these physiological indicators in improving grain yield.

Table 4. Dry weight accumulation in panicles (Unit: g $hill^{-1}$)

Variety	Heading stage	Milk stage	Dough stage
TBR225-New	11.8^{a}	17.2^{ab}	24.7^{a}
TBR225ĐK-1	10.6^{abc}	17.7^{a}	25.5^{a}
TBR225ĐK-2	9.8^{c}	16.9^{ab}	26.0^{a}
Dong A2	10.2^{bc}	17.2^{ab}	26.2^{a}
TBR19	9.7^{c}	18.0^{a}	24.1^{a}
ĐC16	9.7^{c}	18.2^{a}	24.2^{a}
BC3	11.3^{ab}	15.7^{bc}	24.2^{a}
TBR86	11.3^{ab}	16.8^{ab}	24.5^{a}
BT7 (Control)	7.0^{d}	14.5^{c}	20.5^{b}

Values within a column followed by the different letter indicate significant differences at 0.05 level by Tukey's HSD test.

3.3 Grain yield and yield components of rice varieties

The grain yield and yield components of the tested rice varieties varied markedly (Table 5). The number of panicles per square meter ranged from 249.2 (BC3) to 330.4 (BT7). Although BT7 produced the highest panicle density, its yield was not the best, suggesting that a higher panicle count alone does not guarantee high productivity if other yield components are insufficient. TBR86 also showed a relatively high panicle number (310.8), while TBR225-New and TBR225ĐK-2 maintained moderate panicle densities (268.8 and 271.6, respectively), providing a suitable sink size for grain production.

Table 5. Grain yield and yield components of rice varieties

Variety	Number of panicles (per m^2)	Number of filled grains (per panicle)	Percentage of unfilled grains (%)	1000 grain weight (g)	Grain yield (tons ha^{-1})
TBR225-New	268.8^{c}	110.7^{b}	27.1^{a}	24.2^{bc}	6.02^{c}
TBR225ĐK-1	254.8^{cd}	120.1^{a}	19.3^{c}	23.3^{c}	6.20^{b}
TBR225ĐK-2	271.6^{c}	108.9^{b}	22.6^{b}	25.4^{b}	6.38^{b}
Dong A2	252.0^{cd}	107.7^{b}	23.0^{b}	25.7^{b}	6.14^{bc}
TBR19	252.0^{cd}	103.1^{c}	8.9^{f}	27.7^{a}	6.03^{c}
ĐC16	252.0^{cd}	111.4^{b}	12.0^{e}	23.3^{bc}	5.56^{d}
BC3	249.2^{d}	110.5^{b}	16.0^{d}	25.3^{b}	6.08^{c}
TBR86	310.8^{b}	118.5^{a}	12.0^{e}	20.9^{d}	6.68^{a}
BT7 (Control)	330.4^{a}	84.3^{d}	4.7^{g}	19.6^{d}	4.83^{e}

Values within a column followed by the different letter indicate significant differences at 0.05 level by Tukey's HSD test.

The number of filled grains per panicle varied significantly among varieties, from 84.3 grains in BT7 to 120.1 grains in TBR225ĐK-1. Varieties such as TBR225ĐK-1, TBR86, TBR225-New, ĐC16, and BC3 consistently recorded high filled grain numbers (>110 grains per panicle), demonstrating superior sink potential compared to the control. This improvement is likely linked to their higher tillering capacity, greater LAI, and better panicle dry matter accumulation discussed in earlier sections.

The percentage of unfilled grains, which in this study reflects the proportion of spikelets that failed to develop into fully filled grains, ranged from as low as 4.7% in BT7 to as high as 27.1% in TBR225-New. Although BT7 exhibited a low proportion of unfilled grains and a high panicle number per unit area, it had a low number of filled grains per panicle, suggesting limited yield potential. In contrast, improved varieties such as TBR225ĐK-1, ĐC16, BC3, and TBR86 showed moderate unfilled grain percentages (12–19%), indicating a better balance between sink size and grain-filling efficiency. The relatively high unfilled grain percentage observed in TBR225-New (27.1%) implies that its grain-filling process may still require optimization, despite its promising panicle characteristics.

The 1000-grain weight also contributed greatly to final yield differences. TBR19 recorded the highest grain weight (27.7 g), while BT7 had the lowest (19.6 g). Several varieties, including TBR225-New, TBR225ĐK-1, TBR225ĐK-2, Dong A2, ĐC16, and BC3, maintained 1000-grain weights between 23–25 g, which, combined with higher filled grain numbers, supported yield stability.

Finally, grain yield across varieties ranged from 4.83 tons ha^{-1} (BT7) to 6.68 tons ha^{-1} (TBR86). The relatively poor yield performance of BT7, despite its high panicle number and low sterility, can be attributed to its small grain weight and low filled grain count. In contrast, TBR86 achieved the highest yield, benefiting from a combination of high filled grain number, acceptable grain weight, moderate sterility, and good source capacity as

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evidenced by its high SPAD values, stable LAI, and consistent panicle dry weight accumulation throughout the reproductive stages. TBR225ĐK-2 and TBR225ĐK-1 also reached promising yields (6.38 tons ha^{-1} and 6.20 tons ha^{-1}, respectively), attributable to their high filled grain numbers, reasonable grain-filling rates, and balanced source–sink relationships.

The results confirmed that achieving high rice yield depends on a coordinated balance of a sufficient number of productive panicles, high spikelet density with good grain-filling efficiency, adequate grain weight, and maintained source capacity for assimilate translocation during reproductive stages. Improved lines such as TBR86 and TBR225ĐK-2 successfully integrated these traits, demonstrating clear superiority over the control BT7.

3.4 Resistance of rice varieties to bacterial leaf blight

Although the eight improved rice varieties in this study were previously reported as resistant to BLB, their resistance was confirmed under experimental conditions (Table 6). All eight showed the lowest disease score (1) with lesion areas below 5%, while the susceptible control BT7 scored 9 with a lesion area of 65.3%, demonstrating high vulnerability.

The result is consistent with earlier studies reporting that BT7 is highly susceptible to BLB in the absence of effective resistance genes. Phuong et al. [9] demonstrated that the elite cultivar TBR225, which shares genetic background with BT7, showed marked improvement in disease resistance when the promoter region of the susceptibility gene OsSWEET14 was edited. Similarly, Ngoc et al. [20] found that conventional BT7 was severely infected, whereas BT7-derived lines carrying resistance genes such as xa5 and Xa7 exhibited low disease scores and maintained favorable agronomic traits. These findings support the observed high lesion severity in BT7 in our experiment and suggest that the improved lines owe their resistance to effective genetic modifications inherited from molecular breeding programs.

Table 6. Bacterial leaf blight resistance of rice varieties

Variety	Disease score	Lesion area (%)
TBR225-New	1	4.4
TBR225ĐK-1	1	3.5
TBR225ĐK-2	1	3.0
Dong A2	1	2.7
TBR19	1	3.5
ĐC16	1	3.3
BC3	1	4.6
TBR86	1	3.3
BT7 (Control)	9	65.3

This strong resistance is crucial for maintaining yield stability. Despite its high panicle number and low sterility, BT7's severe disease infection likely contributed to its lowest grain yield. In contrast, the improved varieties combined effective bacterial leaf blight resistance with favorable yield traits (high filled grain numbers, reasonable grain weight), ensuring better assimilate translocation and superior yield performance. These results reinforce the value of using disease-resistant varieties to achieve stable and high rice yields under field conditions.

3.5 Grain quality of rice varieties

Milling yield is one of the most important criteria for evaluating rice quality, especially from a marketing perspective. The ultimate objective of the milling process is to improve appearance and palatability while minimizing loss of nutritional value and grain weight [21]. The proportion of the various grain components differs depending on genotype, environmental factors, and milling conditions [22].

Table 7. Grain quality of rice varieties

Variety	Brown rice rate (%)	Milled rice rate (%)	Head rice rate (%)	Grain length (mm)	Length/width ratio
TBR225-New	81.3	70.1	80.9	6.57	3.08
TBR225ĐK-1	80.1	71.1	80.2	6.70	3.41
TBR225ĐK-2	80.0	70.7	79.3	7.13	3.57
Dong A2	80.5	70.7	79.2	7.15	3.41
TBR19	83.0	70.0	81.9	6.60	2.96
ĐC16	81.0	72.0	75.7	6.97	3.48
BC3	82.0	72.0	79.3	6.70	3.00
TBR86	82.2	71.4	79.2	5.59	2.58
BT7 (Control)	79.0	72.1	80.6	5.42	2.58

In our study, the rice varieties generally showed similar brown rice recovery, milled rice recovery, and head rice yield compared to the control variety. The brown rice recovery ranged from 79.0% (BT7) to 83.0% (TBR19). The milled rice recovery ranged from 70.0% (TBR19) to 72.1% (BT7). The head rice yield ranged from 75.7% (ĐC16) to 81.9% (TBR19) (Table 7).

Rice is consumed primarily as whole grains, so grain size is one of the key factors in quality assessment. In general, a length-to-width (L/W) ratio ranging from 2.5 to 3.0, with grain length exceeding 6 mm, is widely accepted [23]. The length of milled grains among the studied rice varieties was classified into two groups: the long-grain group (grain length > 6.6 mm), which included TBR225ĐK-1, TBR225ĐK-2, Dong A2, TBR19, ĐC16, and BC3; and the medium-grain group (grain length from 5.51–6.59 mm), comprising the remaining varieties. Regarding the L/W ratio, TBR225-New, TBR225ĐK-1, TBR225ĐK-2, Dong A2, ĐC16, and BC3, with L/W ratios greater than 3, were classified as slender-grain types, while the remaining varieties with L/W ratios between 2.5 and 3.0 were classified as medium-grain types (Table 7).

4 Conclusion

Improved rice lines such as TBR225ĐK-2, TBR225ĐK-1, and TBR86 demonstrated favorable agronomic traits, superior physiological performance, and strong resistance to bacterial leaf blight. These advantages contributed to higher yields (6.2–6.7 tons ha^{-1}) compared to the susceptible control BT7 (4.8 tons ha^{-1}). Their grain quality also met market standards. These results indicate that the selected lines are suitable for cultivation in Hung Yen province and have potential to improve local rice productivity. Further multi-location trials are recommended to confirm their adaptability.

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