Evaluation of Growth and Productivity of Different Rice Varieties Growing in Vietnam

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Abstract

ability to accurately identify key growth stages is critical for proper rice management, Since management practices are directly tied to plant developmental processes, a sound understanding of rice growth is essential for effective cultivation. This study was conducted to evaluate the growth and yield performance of seven rice varieties (BT, CUDH1, NU986, ST25, TBR225, TX111, and VNR20) during different growth stages (Root establishment and Greening up, Tillering, Panicle initiation, Flowering, and Dough stage) in Thanh Hoa province, Vietnam. Results indicated that CUDH1 and TX111 exhibited superior performance, with greater plant height, higher leaf area index (LAI) throughout most growth stages, and enhanced dry matter accumulation. These characteristics reflect strong photosynthetic capacity and robust growth potential, ultimately leading to the highest recorded yields: CUDH1 (8.25 t ha^{-1}) and TX111 (8.02 t ha^{-1}). The NU986 (7.73 t ha^{-1}) and BT (7.32 t ha^{-1}) also achieved relatively good yields, though improvements in cultivation techniques are recommended to fully exploit their potential. Conversely, ST25 (6.97 t ha^{-1}), VNR20 (7.05 t ha^{-1}), and TBR225 (7.18 t ha^{-1}) exhibited lower plant height and dry matter accumulation, thus making them more suitable for high-quality rice production or areas prone to lodging. the conclusion, varietal selection tailored to specific production goals and local ecological conditions is a critical factor in improving the efficiency and sustainability of rice production systems.

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Introduction

Rice (*Oryza sativa* L.), a member of the Poaceae family and is one of the leading food crops in the world (Beighley, 2010). It is cultivated in approximately 115 countries across all continents except Antarctica (Bouman, 2007). Nearly 90% of global rice cultivation occurs in Asia, with 4.6% in Africa and 4.7% in the Americas (Bandumula, 2018; Jabran *et al*., 2015; Ullah *et al*., 2018). Rice is adaptable to diverse agroecological conditions, from deep-flooded paddies to arid plains and upland sloped terrains (Prabhu *et al*., 2021). Globally, it contributes around 13% of total protein intake (Maclean *et al*., 2013) and plays a vital role in food security and agricultural economic development, particularly in Vietnam (Trong *et al.,* 2022).

The growth and development of rice plants are closely linked to grain yield. If the plant is not healthy during any growth stage, its development and productivity can be significantly limited (Counce *et al.,* 2000). Therefore, the ability to accurately identify key growth stages is critical for proper rice management. Since management practices are directly tied to plant developmental processes, a sound understanding of rice growth is essential for effective cultivation (Defoer *et al.,* 2009).

In the face of climate change, increasingly complex pest and disease pressures, and rising demands for both yield and grain quality, it is essential to select, evaluate, and identify rice varieties that demonstrate strong growth, high resistance, and stable productivity. Regional adaptation trials and variety screening efforts must prioritize not only yield performance, but also quality traits, pest and disease resistance, and market suitability. Accordingly, a number of studies have been conducted to develop and introduce new rice varieties for sustainable agricultural production (Hai *et al*., 2019; Huong *et al*., 2022; Nhi and Phu, 2017; Dong *et al.,* 2020; Hu *et al*., 2019; Nagarajan *et al*., 2024).

Recent reviews emphasize that Vietnam possesses a rich rice germplasm base, and that varietal improvement plays a decisive role in enhancing productivity and resilience in different cropping systems (Khanh *et al.,* 2021). Studies on production efficiency further indicate that both the choice of varieties and the cropping season significantly affect economic outcomes in rice farming, with spring rice showing marked variability depending on cultivar selection (Ho *et al.,* 2023). Moreover, climate change vulnerability assessments in Thanh Hoa province highlight that rice cultivation in this region remains highly sensitive to environmental stresses, underlining the importance of selecting and testing suitable varieties that can adapt to local conditions (Huong *et al.,* 2024). These findings provide a solid basis for conducting experimental trials to evaluate the performance of promising rice cultivars in the agro-ecological context of Vietnam.

Materials and Methods

The study was conducted during the spring seasons of 2025 on double-crop rice cultivation land in Thanh Hoa Province, Vietnam (19°48′ North, 105°46′ East). Climatic conditions during the experiment were favorable for rice cultivation. The average daily temperature during the cropping season ranged between 20°C and 30°C. These conditions fell within the optimal temperature range for rice growth and grain development (Hussain *et al.,* 2019). The region also experienced moderate and well-distributed rainfall. The experiment was carried out on 7 rice varieties, as presented in Table 1.

Table 1. Information about the varieties of experiment

No.	Variety	Origin	Growth characteristics and grain yield
1	BT	Corporation Jointly produced by North Central Seed Company and Thanh Hoa Center for Scientific and Technical Research and Application	Medium plant height, strong stem, fairly resistant to lodging. Grain yield: 6-7 t ha^{-1}.
2	CUDH1	Selected by Western China - Sichuan Seed Company	Medium height, strong stem, fairly resistant to bacterial leaf blight and blast. Grain yield: 7.5-8.5 t ha^{-1}.
3	NU986	Imported from China	Medium plant height, strong stem, fairly resistant to lodging and pests/diseases. Grain yield: 7.0-9.0 t ha^{-1}.
4	ST25	Selected by Soc Trang Rice Research Institute	Medium height, strong stem, fairly resistant to lodging, moderate resistance to pests and diseases. Grain yield: 6.0-7.0 t ha^{-1}.
5	TBR225	Selected by Thai Binh Seed	Medium height, strong stem, fairly resistant to bacterial leaf blight and blast. Grain yield: 6.5-8.0 t ha^{-1}.

6	TX111	Hybrid rice variety between the High-Tech Agriculture Co., Ltd., Sichuan Agricultural University (China), and Thai Binh Seed Corporation	Medium height, strong stem, fairly resistant to bacterial leaf blight and sheath blight. Grain yield: 7.0-8.0 t ha^{-1}.
7	VNR20	Selected by Vietnam National Seed Group Joint Stock Company	Short to medium height, strong stem, fairly resistant to pests and diseases. Grain yield: 6.5-7.5 t ha^{-1}.

Experimental Design: The experiment consisted of seven treatments arranged in a randomized complete block design (RCBD) with three replications. Each plot measured 20 m^2. The planting density was 35-36 hills m^{-2}, with 2-3 seedlings per hill. Rice seedlings transplanted to the field were 18-20 days, with an average height of 12-15 cm and 3-4 fully expanded leaves. The seedlings were healthy, free from visible pests and diseases, and possessed a well-developed root system to ensure successful establishment after transplanting. Rice was sown on 27 December 2024, transplanted on 12 January 2025, and harvested on 25 May 2025.

Technical Practices: Fertilizer application per hectare included 80 kg Urea, 90 kg Super Phosphate, and 100 kg Potassium Chloride. Application schedule: Urea: 100% Super Phosphate + 40% nitrogen + 20% Potassium Chloride. Top dressing: applied in two stages: One at tillers stage: 50% Urea + 30% Potassium Chloride; Second at 20 days before heading stage: remaining Urea and Potassium Chloride.

Plant Height (cm): Plant height was measured at growth stages (Root establishment and greening up, Tillering, Panicle initiation, Flowering, and Dough stage) from five randomly selected plant in each plot (Trong *et al*., 2022).

Leaf Area Index (LAI: m² leaf area per m² ground area): Leaf area was measured using a CI-202 leaf area meter. LAI was calculated using the formula:

$$LAI = \frac{Total\ leaf\ area\ per\ unit\ ground\ area}{Ground\ area}$$

Dry Matter Accumulation: Five plants were sampled at each observation stage (Root establishment and greening up, Tillering, Panicle initiation, Flowering, and Dough stage). Plant parts (roots, stems, green leaves, and panicles if present) were separated and dried at 105°C until constant weight to determine dry matter accumulation (Trong *et al*., 2022).

Panicle Density (panicles m^{-2}): The number of panicles with at least 10 filled grains was counted in the sample plants at maturity and converted to panicles per square meter.

Number of Filled Grains per Panicle: The number of filled grains per panicle was counted from five sample plants in each plot and averaged.

Grain Weight (g): 1000 grain weight was weighed at 14% moisture content. The average weight was recorded.

Grain Yield (t ha^{-1}): Entire plots were harvested. Grains were dried to 14% moisture content, weighed, and converted to tons per hectare.

Data Analysis: Results were expressed as mean values ± standard deviation (SD). Collected data were analyzed by analysis of variance (ANOVA) using IRRISTAT version 5.0, and treatment means were compared using the least significant difference (LSD) test at the 5% probability level.

Results and Discussion

Plant height (cm)

Plant height is a key morphological indicator reflecting the growth and development capacity of rice varieties under specific ecological conditions. As shown in Figure 1, from the seedling establishment to the tillering stage, all rice varieties exhibited a slight increase in height. Among them, CUDH1 had the greatest height 22.33 cm, while VNR20 had the lowest 20.35 cm. The differences between varieties at this stage were minor, indicating relatively uniform early growth.

From the panicle initiation to heading stages, plant height increased significantly in all varieties, consistent with the findings of Linh *et al.* (2023). The CUDH1 variety stood out with a height of 90.49 cm at the panicle initiation stage and 95.64 cm at heading. In contrast, TBR225 and VNR20 showed comparatively shorter plant heights during this period.

At the soft dough stage, all varieties reached their maximum height. CUDH1 was again the tallest 121.56 cm, followed by ST25 (120.53 cm), with TBR225 being the shortest 93.42 cm. This clearly illustrates distinct varietal differences in biomass accumulation and vertical growth toward the end of the crop cycle.

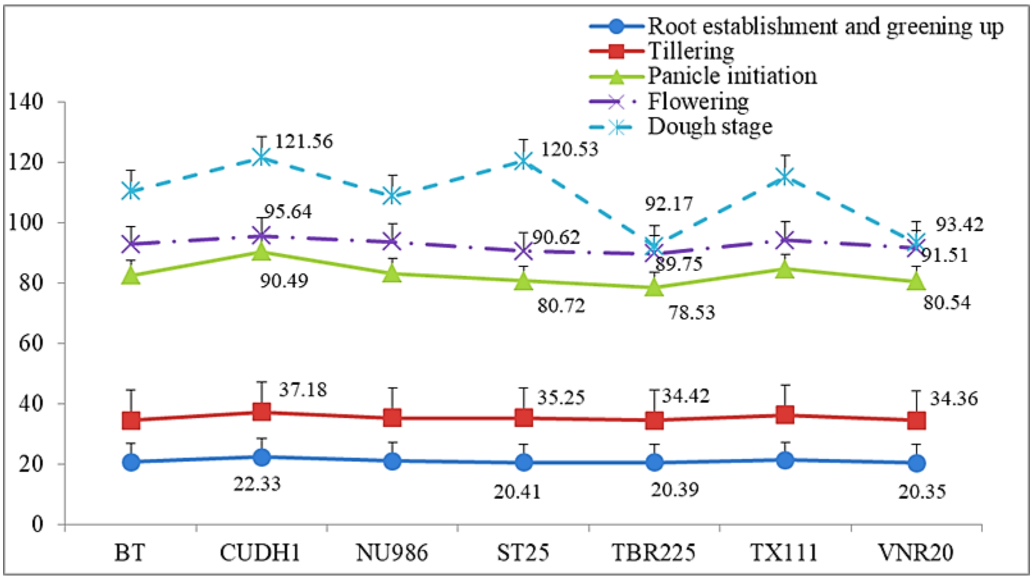

Figure 1. Plant height of rice varieties at different growth stages

The general trend observed was a gradual increase in plant height across growth stages, with the most rapid elongation occurring between the tillering and panicle initiation stages. It was during this period that significant statistical differences in plant height began to emerge, especially at the soft dough stage. ST25 and CUDH1 exhibited significantly greater heights compared to VNR20, a difference that was statistically meaningful. The group of medium-to-short varieties included VNR20 and TBR225.

These variations in plant height over time reflect both the genetic makeup and adaptive growth capacities of each variety (Hu, *et al*. 2019). CUDH1, ST25, and TX111 demonstrated high biomass potential and may be suitable for farming systems favoring tall rice varieties. Conversely, varieties such as VNR20 and TBR225 are better suited for low-plant-type cultivation systems, where lodging resistance is a priority.

Leaf area index (m^2 leaf area per m^2 ground area)

Figure 2 presents the LAI of seven rice varieties at five key growth stages: seedling establishment, tillering, panicle initiation, heading, and soft dough. During the seedling establishment stage, LAI values ranged from VNR20 (0.45) to CUDH1 (0.72). At the tillering stage, the highest LAI was recorded in CUDH1 (1.45), while the lowest was in TBR225 (1.04).

During the panicle initiation stage, the highest LAI values were observed in CUDH1 (5.69) and TX111 (5.58), whereas VNR20 had the lowest 4.39. This trend continued at the heading stage, with CUDH1 and TX111 maintaining their high LAI 5.78 and 5.76, respectively, and VNR20 again shows the lowest 4.82. At the soft dough stage, CUDH1 still led with an LAI of 5.08, while TBR225 had the lowest 4.28.

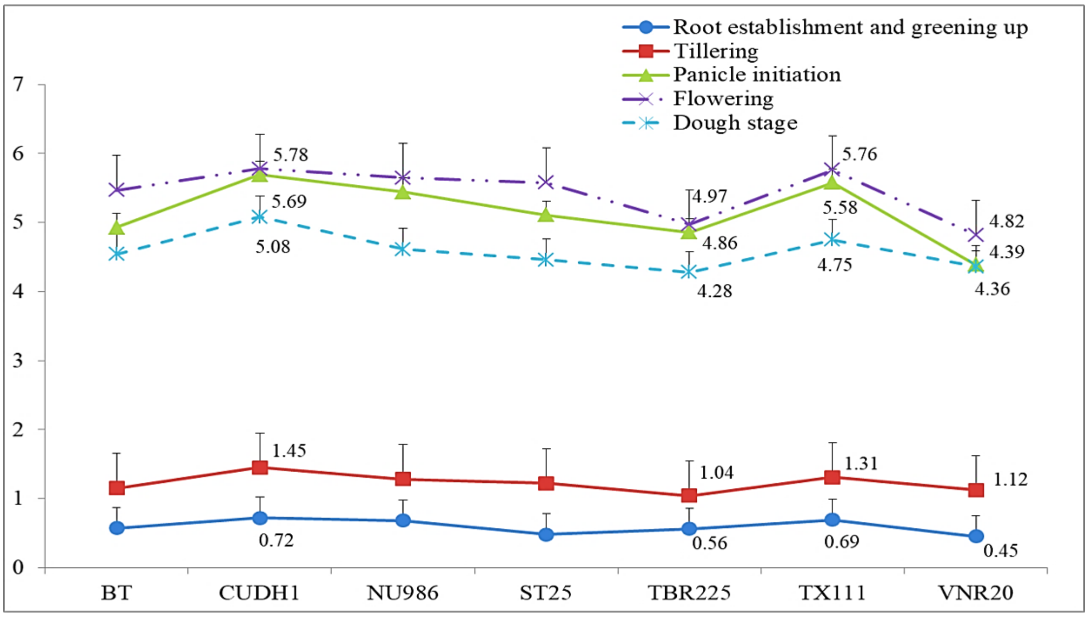

Figure 2. LAI of rice varieties at different growth stages

The results indicate that all varieties showed a general trend of increasing LAI from the seedling stage to heading, followed by a slight decrease at the soft dough stage. This reflects a normal physiological pattern, as the leaf canopy reaches its maximum expansion at heading before beginning to senesce. Among the varieties, CUDH1 and TX111 demonstrated the strongest leaf growth potential, with significantly higher LAI values across most stages-indicating enhanced photosynthetic capacity, which may positively contribute to final yield.

In contrast, VNR20 and TBR225 exhibited relatively lower LAI values, reflecting weaker leaf area development potential. High LAI during panicle initiation and heading stages supports increased photosynthesis and dry matter accumulation for grain formation. However, excessively high LAI can cause self-shading and inefficient nutrient usage. Therefore, CUDH1's high but reasonably declining LAI at the soft dough stage suggests a good balance between vegetative and reproductive growth.

The varieties showed distinct differences in LAI at each growth stage. CUDH1 and TX111 stood out with consistently high LAI, indicating high growth vigor and yield potential. Selecting varieties with an appropriate LAI profile suited to cultivation goals and local ecological conditions is crucial for sustainable rice production.

Dry matter accumulation (g m^{-2})

Dry matter refers to the organic substances synthesized by the plant through nutrient uptake and photosynthesis. The plant’s ability to accumulate dry matter and translocate assimilates from vegetative organs to reproductive structures forms the physiological foundation for grain yield formation (Fu *et al.*, 2024). Thus, dry matter accumulation is an important physiological parameter that reflects photosynthetic capacity, assimilate accumulation, and metabolic activity throughout the plant's growth cycle (Linh *et al.*, 2023).

The results show a general upward trend in dry matter accumulation across all rice varieties over successive growth stages, indicating increasingly vigorous photosynthesis and biomass accumulation over time (Figure 3).

At the early stage (seedling establishment), dry matter accumulation ranged from VNR20 (0.35) to CUDH1 (0.60). At this stage, dry matter accumulation was relatively low due to the plants still recovering from transplanting, limited leaf area development, and consequently reduced photosynthetic activity. However, varieties such as CUDH1 and TX111 demonstrated earlier dry matter accumulation, suggesting superior early growth potential.

At the tillering stage, dry matter accumulation increased significantly across all varieties. CUDH1 (1.65) and TX111 (1.55) remained dominant, indicating robust development of leaf and stem structures, laying the foundation for high yield potential.

During the panicle initiation to heading stages, rice plants entered their most vigorous growth phase. At this point, biomass accumulation peaked, driven by active photosynthesis and enhanced assimilate translocation. A marked increase in dry matter was observed in all varieties, especially in CUDH1 (increasing from 23.95 to 33.98), followed by TX111 and NU986. This suggests that these varieties possess strong capabilities in both biomass accumulation and effective mobilization of assimilates during the yield-determining period.

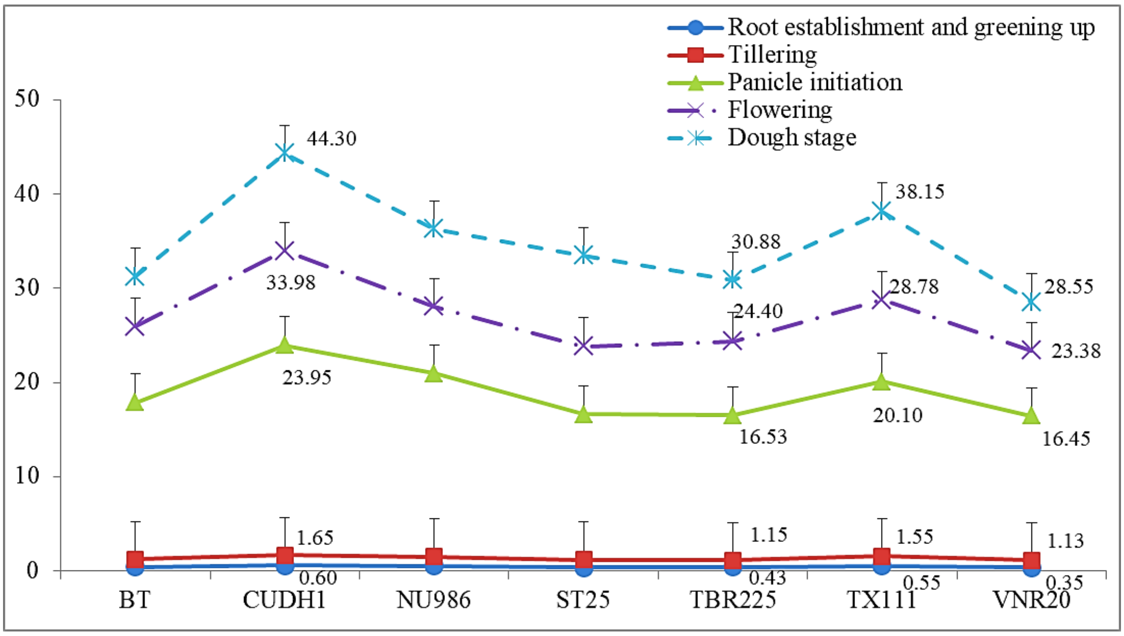

Figure 3. Accumulated dry matter of rice varieties at different growth stages

At the soft dough stage, all rice varieties reached their peak in dry matter accumulation. CUDH1 exhibited the highest dry matter content (44.30), indicating excellent assimilate translocation and accumulation into the grain. This was followed by TX111 (38.15) and NU986 (36.30), which also showed strong biomass accumulation and efficient nutrient remobilization into the grains, playing a decisive role in their yield potential. In contrast, varieties such as VNR20 and TBR225 had lower dry matter accumulation at this stage, with 28.55 and 30.88, respectively, suggesting weaker photosynthetic capacity and assimilate translocation during the grain-filling phase.

The differences in dry matter accumulation among the rice varieties were statistically significant at the 5% level across various growth stages, including seedling establishment, tillering, panicle initiation, heading, and soft dough. Varieties such as CUDH1, NU986, and TX111, which demonstrated high rates and levels of dry matter accumulation throughout the growth cycle, are considered promising candidates for high-yield rice production.

Yield and yield components

Table 2 shows that the rice varieties differed significantly at the 5% level in terms of key yield components and grain yield.

The number of panicles per square meter ranged from ST25 (237.74) to CUDH1 (260.12). Varieties such as BT, NU986, CUDH1, and TX111 had significantly higher panicle numbers than

ST25, reflecting their more effective tiller differentiation and productive tillering capacity.

The number of filled grains per panicle varied from VNR20 (155.36) to CUDH1 (167.17). Among these, CUDH1 and TX111 had the highest values, indicating superior flowering and grain-setting abilities. This finding is consistent with Fageria (2007), who emphasized that the number of panicles per square meter and filled grains per panicle are the most critical yield components in upland rice. Similarly, Beighley (2010); Saini *et al.* (2023). highlighted that grain yield is influenced by the number of panicles per unit area, average grains per panicle, and average grain weight.

Table 2. Grain yield and its components for rice varieties

Plant varieties	Number of panicles per square meter (panicles)	Number of grains per panicle (grains)	Percentage of filled grains (%)	Weight of 1000 grains (g)	Grain yield t ha^{-1}
BT	256.44^{ab} ± 4.42	165.35^{ab} ± 0.88	81.57^{a} ± 1.68	21.72^{b} ± 0.59	7.32^{bc} ± 0.23
CUDH1	260.12^{a} ± 2.66	167.17^{a} ± 1.76	81.43^{a} ± 1.31	23.92^{a} ± 0.69	8.25^{a} ± 0.49
NU986	257.15^{ab} ± 2.19	164.51^{ab} ± 3.22	80.13^{a} ± 0.66	23.34^{a} ± 0.72	7.73^{ab} ± 0.42
ST25	237.74^{d} ± 2.52	162.42^{bc} ± 2.53	80.13^{a} ± 1.18	23.15^{a} ± 0.55	6.97^{c} ± 0.22
TBR225	253.56^{b} ± 2.23	159.54^{c} ± 2.78	81.35^{a} ± 0.49	22.65^{ab} ± 1.39	7.18^{c} ± 0.37
TX111	257.63^{ab} ± 1.96	166.67^{a} ± 1.58	80.56^{a} ± 1.09	23.62^{a} ± 1.27	8.02^{a} ± 0.46
VNR20	245.52^{c} ± 2.49	155.36^{d} ± 1.70	80.87^{a} ± 0.60	23.42^{a} ± 0.17	7.05^{c} ± 0.12
$LSD_{0.05}$	4.00	3.10	1.98	1.35	0.45
CV	0.90	1.10	1.40	3.30	3.30

The proportion of filled grains among the varieties was relatively consistent, ranging from 80.13% to 81.57%. BT recorded the highest filled grain ratio (81.57%), indicating efficient pollination and grain filling. The 1000 grain weight, ranged from 21.72 g (BT) to 24.02 g (TX111). The CUDH1 variety produced the heaviest grains. When combined with a high number of panicles and grains per panicle, this significantly contributed to its superior yield. In contrast, BT had the lowest 1000 grain weight; although it had high filled grain ratio and number of grains per panicle, its grain weight could potentially affect market quality.

Both theoretical and grain yield showed statistically significant differences among the varieties. CUDH1 achieved the highest grain yield (8.25 t ha^{-1}), followed by TX111 (8.02 t ha^{-1}), and NU986 (7.73 t ha^{-1}). These varieties demonstrated a balanced combination of key yield components. In contrast, ST25 and TBR225 showed lower actual yields (6.97 and 7.18 t ha^{-1}), despite having relatively good filled grain ratios, suggesting limitations potentially due to fewer panicles per square meter or lower grain weight.

Overall, the rice varieties CUDH1 and TX111 demonstrated superior performance in terms of yield and yield components, making them strong candidates for large-scale production. Varieties such as BT and NU986 may have their yield potential further improved through refined cultivation practices or continued breeding selection. ST25, while lower in yield, may be more suitable for premium-quality rice production rather than maximum yield objectives.

Conclusions

The results of the study showed that plant height increased progressively across growth stages, with the most rapid elongation occurring from tillering to panicle initiation. CUDH1 and ST25 exhibited the greatest heights, indicating high biomass potential, while VNR20 and TBR225 remained shorter, belonging to the medium-short group suitable for lodging-resistant cultivation systems. TX111 also displayed a tall plant stature, similar to varieties favored in high-biomass farming systems. Among the tested varieties, CUDH consistently outperformed others in terms of dry matter accumulation, leaf area index, yield components, and grain yield across all developmental stages, followed by TX111. These two varieties showed the highest grain yields (8.25 and 8.02 t ha^{-1}, respectively), indicating strong potential for large-scale cultivation under the ecological conditions of the study area.

Varieties such as NU986 and BT demonstrated promising yield potential and could be further optimized through improved cultivation practices. Meanwhile, ST25 and VNR20, although having relatively lower yields, may be more suitable for quality rice production systems rather than yield-focused approaches. Overall, varietal selection tailored to specific production goals and local ecological conditions is a critical factor in improving the efficiency and sustainability of rice production systems.

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Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

Funding Declaration

No funding was allocated for this article.

Author Contribution

Le Van Trong conceived the idea and designed the experiments. Le Van Trong and Ha Thi Phuong conducted the experiments. Le Van Trong and Le Thi Huyen analyzed the research data. Le Van Trong and Le Thi Huyen wrote the manuscript. All authors read and agree to the submission of the manuscript to the journal.

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