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Determining the Optimal Wide - Narrow Row Spacing for TBR225 Rice Variety in Vietnam

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ABSTRACT **Original research paper**

This study aimed to evaluate the effects of alternate wide-narrow row spacing on growth, development, pest and disease incidence, and yield of the TBR225 rice variety. Five planting treatments (F1-F5) were tested. Recorded parameters included plant height, accumulated dry matter, tillering ability, pest and disease occurrence, and yield components. Results showed that wider row spacing (F4-F5) significantly increased accumulated dry matter at panicle initiation and heading stages. The maximum tiller number, effective tillers, and proportion of effective tillers of TBR225 were markedly higher in F4-F5 compared with the narrower row treatments. At the same time, the incidence of major pests and diseases (blast, sheath blight, stem borer, leaf folder) was substantially reduced under wider rows, reflecting improved microclimatic conditions in the paddy field. Yield components such as panicles per m², filled grain ratio, and 1000-grain weight remained almost unchanged, whereas grains per panicle and actual yield increased significantly in F4-F5 (6.37-6.42 t ha^{-1}, 8-10% higher than F1). These results confirm that selecting appropriate row spacing is a key agronomic measure to improve growth potential, reduce pest and disease pressure, and increase rice yield. This study provides a scientific basis for recommending cultivation techniques to maximize the production potential of TBR225 rice under actual field conditions.

Keywords: TBR225 rice variety, Growth and development, Yield.

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Introduction

Rice (***Oryza sativa*** L.), a member of the Poaceae family, is one of the most important staple food crops worldwide (Counce et al., 2020; Fageria, 2007). It is cultivated in about 115 countries across nearly all continents except Antarctica (Bouman et al., 2007; Zaman et al., 2000). About 90% of the total rice-growing area is concentrated in Asia, 4.6% in Africa, and 4.7% in the Americas (Maclean et al., 2013). Rice can grow under a wide range of conditions from deepwater paddies and dry lowlands to upland terraces (Connor, 2024). It provides roughly 13% of global protein intake (Juliano, 1994) and plays a pivotal role in food security and agricultural development in Vietnam (Nguyen, 2007).

Planting density and spacing are critical factors affecting rice yield (Bui, 1999). Proper row spacing enhances the photosynthetic efficiency of both individual plants and the canopy by improving light interception, leaf area index, tillering capacity, and pest and disease resistance, thereby increasing yield (Nguyen et al., 1997). Research by Nguyen (2003) on alternate wide-narrow row planting demonstrated that optimal density and spacing limit excessive tillering, reduce non-productive tillers, improve photosynthetic efficiency, and enhance light interception ultimately improving yield potential.

In recent years, alongside the breeding and dissemination of high-yielding rice varieties, developing suitable cultivation practices for each variety has become essential. TBR225, a pure-line rice variety, is widely adopted in northern Vietnam, especially Thanh Hoa Province, due to its adaptability, high yield potential, and stable grain quality. However, to fully exploit its potential, determining appropriate planting distances is crucial. Numerous studies worldwide have confirmed that optimal planting density improves canopy structure, reduces pest pressure, and enhances economic efficiency. Yet, specific studies on alternate wide-narrow row spacing for TBR225 rice in Thanh Hóa remain limited, and no official recommendations exist for farmers. This study therefore aimed to determine the effects of alternate wide-narrow row spacing on growth, development, pest incidence, and yield of the TBR225 rice variety in Thanh Hoa, and to identify optimal spacing for production.

Materials and Methods

Experimental Site and Duration

The experiment was conducted in Thanh Hoa province, Vietnam during the 2025 summer crop season on fields with light clay soil, medium organic matter content, rich in readily available potassium, and medium levels of available nitrogen and phosphorus. Soil pH ranged from 5.5 to 6.0, with a tillage layer 25 - 30 cm thick, good water retention and drainage, suitable for rice cultivation. The experimental area has a typical tropical monsoon climate, favorable for double-cropping rice production.

Research Material

The rice variety used was the TBR225 inbred line, provided by Thai Binh Seed Company.

Experimental Design

The experiment was arranged in a Randomized Complete Block Design (RCBD) with five row-spacing treatments (F1 to F5) and three replications (Nguyen & Pham 2005). Each treatment occupied an area of 20 m², with the following specific layouts:

- F1 (control): Equal row spacing of 18 cm; plant spacing of 18 cm.
- F2: Alternating wide (24 cm) and narrow (18 cm) rows; plant spacing of 18 cm.
- F3: Alternating wide (30 cm) and narrow (18 cm) rows; plant spacing of 18 cm.
- F4: Alternating wide (36 cm) and narrow (18 cm) rows; plant spacing of 18 cm.
- F5: Alternating wide (44 cm) and narrow (18 cm) rows; plant spacing of 18 cm.

Seedlings were transplanted at 10 days old, with 2-3 seedlings per hill. Crop management followed the standard practice for the pure-line rice variety TBR225.

Measurement of plant height: Plant height was measured from the ground surface to the tip of the tallest leaf or panicle (cm). In each plot, three random points were selected and five plants per point were measured.

Determination of dry matter: Five plants per sampling point were collected at each observation period. Plant parts were separated into roots, stems, green leaves, and panicles (if present). All plant parts were oven-dried at 80 °C to constant weight to determine dry matter.

Determination of tillering ability: Tillering was observed at the tillering stage. In each plot, three random points were selected, and at each point five representative plants were sampled. Recorded indicators included:

Maximum tillers: total number of tillers (productive and non-productive) per plant at the peak tillering stage.

Effective tillers: tillers bearing panicles at the heading stage, directly determining yield.

Effective tiller ratio (%): calculated as the proportion of effective tillers to the maximum tillers per plant.

Yield components and yield determination:

Number of effective panicles per m²: counted at the physiological maturity stage as panicles bearing at least 10 filled grains per plot.

Number of filled grains per panicle: counted on five randomly selected panicles per plot, then averaged.

1000grain weight: measured using 1000 fully filled grains at 14% moisture using an analytical balance.

Grain yield: each plot was harvested at full maturity. Grains were sun-dried to 14% moisture and weighed. Yield was converted to tons per hectare.

Assessment of pest and disease incidence: Surveys were conducted periodically at the main growth stages (recovery, tillering, panicle initiation, heading, and milky/dough stage). In each plot, five fixed points were selected in an X-pattern. At each point, 10 hills were observed (50 hills per plot). Each hill was scored, and an average score was calculated for the entire plot.

Data analysis: All experiments were independently replicated three times. Results were expressed as mean ± standard deviation (SD). Data were processed and analyzed by ANOVA using IRRISTAT 5.0 software.

Research Results and Discussion

Effect of wide-narrow row planting patterns on plant height of TBR225 rice variety

Table 1. Effect of wide-narrow row planting patterns on plant height of TBR225 rice variety

Unit: cm

Treatment	Rooting	Tillering	Panicle Initiation	Heading	Dough Stage
F1	31.36^{a} ± 0.36	55.51^{a} ± 1.02	78.65^{a} ± 1.26	95.76^{a} ± 1.72	116.25^{a} ± 1.67
F2	31.45^{a} ± 0.21	54.92^{a} ± 0.39	78.45^{a} ± 0.65	95.18^{a} ± 0.72	115.44^{a} ± 1.03
F3	31.49^{a} ± 0.33	54.37^{a} ± 0.30	78.41^{a} ± 1.43	94.42^{a} ± 0.90	115.32^{a} ± 1.61
F4	31.14^{a} ± 0.39	54.25^{a} ± 0.55	77.54^{a} ± 0.47	94.57^{a} ± 1.28	115.42^{a} ± 1.01
F5	31.52^{a} ± 0.38	54.36^{a} ± 1.01	77.85^{a} ± 1.53	94.45^{a} ± 1.04	115.26^{a} ± 1.07
LSD	*0.55*	*1.47*	*1.44*	*2.26*	*2.40*
CV	*0.90*	*1.40*	*1.00*	*1.30*	*1.10*

The plant height of rice variety TBR225 increased gradually from the recovery stage to the milky/dough stage across all row-spacing treatments (Table 1). At the recovery stage, mean plant height ranged from 31.14 to 31.52 cm, with no statistically significant differences among treatments ($LSD_{0.05}$ = 0.55 cm). From the tillering to panicle initiation stages, plant height increased to 54.25 - 55.51 cm and 77.54 - 78.65 cm, respectively, but still showed no significant differences among treatments. At the heading and milky/dough stages, plant height reached 94.42 - 95.76 cm and 115.26 - 116.25 cm, respectively, maintaining non-significant differences ($p > 0.05$). The low coefficient of variation (CV = 0.9 - 1.4%) indicates that the data were stable and reliable.

Overall, TBR225 plant height tended to increase under the alternate wide–narrow row spacing, particularly from panicle initiation to the milky/dough stage. This trend is consistent with the "shade-avoidance" mechanism, whereby narrower spacing increases population density and canopy coverage, activating the phytochrome system and stimulating stem and leaf elongation (Dong et al., 2022). Although F1 had the highest planting density, mean differences compared with other treatments remained below the LSD threshold, suggesting that TBR225 plant height under these experimental conditions was relatively insensitive to density variation at the tested levels. This finding aligns with several studies on local varieties reporting stable plant height, whereas other studies have noted that plant density more strongly affects the number of tillers, panicle density per m², and yield rather than individual plant height.

Effect of wide-narrow row planting patterns on accumulated dry matter

Table 2. Effect of wide-narrow row planting patterns on accumulated dry matter of TBR225 rice variety

Unit: g/m²

Treatment	Rooting	Tillering	Panicle Initiation	Heading	Dough Stage
CT1	0.34^{a} ± 0.04	1.12^{a} ± 0.24	14.32^{c} ± 0.11	23.55^{c} ± 0.38	30.57^{a} ± 1.23
CT2	0.35^{a} ± 0.02	1.15^{a} ± 0.16	15.51^{b} ± 0.33	23.89^{bc} ± 0.24	30.78^{a} ± 1.01
CT3	0.39^{a} ± 0.02	1.26^{a} ± 0.31	16.62^{a} ± 0.45	24.47^{ab} ± 0.34	31.26^{a} ± 0.82
CT4	0.42^{a} ± 0.06	1.44^{a} ± 0.14	16.68^{a} ± 0.48	25.05^{a} ± 0.35	32.12^{a} ± 1.71
CT5	0.46^{a} ± 0.04	1.57^{a} ± 0.35	17.12^{a} ± 0.53	25.14^{a} ± 0.19	32.16^{a} ± 0.87
LSD	*0.82*	*0.72*	*0.52*	*0.76*	*2.22*
CV	*11.10*	*3.30*	*1.70*	*1.70*	*3.80*

The accumulated dry matter of rice variety TBR225 varied across the alternate wide–narrow row spacing treatments at different growth stages (Table 3). At the recovery stage, dry matter ranged from 0.34 g/m² (F1) to 0.46 g/m² (F5), with no statistically significant differences among treatments ("a," $LSD_{0.05}$ = 0.82 g/m²). At the tillering stage, dry matter increased to 1.12 - 1.57 g/m² but still showed no significant differences (all "a").

By the panicle initiation stage, clear differences emerged: F1 recorded the lowest dry matter (14.32 g/m²), F2 was intermediate (15.51 g/m²), while F3 - F5 were highest (16.62 - 17.12 g/m²) ($LSD_{0.05}$ = 0.52 g/m²). At heading, dry matter continued to increase, with F4 and F5 reaching 25.05 - 25.14 g/m², 1.5 g/m² (6.3%) higher than F1, a statistically significant difference ($LSD_{0.05}$ = 0.76 g/m²). At the milky/dough stage, dry matter ranged from 30.57 to 32.16 g/m²; F4 - F5 were 1.6 g/m² (5.2%) higher than F1, although this difference was not significant ($LSD_{0.05}$ = 2.22 g/m²).

These results show that in the early stages (recovery and tillering), dry matter accumulation did not differ significantly among treatments because plants had only recently recovered and total biomass was still low. From panicle initiation onward, treatments with wider row spacing (F4-F5) accumulated more dry matter than the narrow-row treatments (F1-F3). This may be explained by greater per-plant availability of space, light, nutrients, and water under wider spacing, which leads to increased leaf area, higher photosynthetic intensity, and greater assimilate accumulation. Plants in wider spacing also tend to develop stronger root systems and larger panicles, contributing to higher dry matter accumulation per plant.

This trend aligns with previous findings. Li et al. (2015) and Singh et al. (2019) reported that wider row spacing increased individual leaf area and pre-heading dry matter accumulation, thereby improving canopy structure and grain yield. Pham et al. (2020) also found that rice planted at lower density in the Red River Delta accumulated more dry matter per plant than rice planted at higher density.

However, it should be noted that as planting density decreases, total dry matter per unit area may not increase if the reduction in plant number per m² exceeds the increase in per-plant dry matter. Therefore, recommendations for wider row spacing should be accompanied by monitoring of effective tillers, panicles per m², and final yield to evaluate the true benefits.

In summary, wider row spacing (F4-F5) increased dry matter accumulation of the TBR225 rice variety at key growth stages (panicle initiation and heading), supporting the "resource competition" hypothesis and aligning with findings from previous studies.

Effect of wide-narrow row planting patterns on tillering ability

Table 3. Effect of wide-narrow row planting patterns on tillering ability of TBR225 rice variety

Treatment	Maximum number of tillers (tillers/plant)	Number of effective tillers (tillers/plant)	Percentage of effective tillers (%)
F1	$8.72^{b} \pm 0.13$	$6.42^{c} \pm 0.17$	77.06
F2	$8.75^{b} \pm 0.18$	$6.51^{c} \pm 0.19$	77.83
F3	$8.92^{ab} \pm 0.12$	$6.72^{bc} \pm 0.43$	78.70
F4	$9.15^{ab} \pm 0.44$	$7.25^{ab} \pm 0.32$	79.23
F5	$9.37^{a} \pm 0.26$	$7.52^{a} \pm 0.46$	80.26
LSD	*0.54*	*0.62*	-
CV	*3.20*	*4.80*	-

Tillering ability is an important factor influencing canopy development and rice yield. Results presented in Table 3 show differences among treatments in maximum tiller number, effective tiller number, and effective tiller ratio.

The tillering ability of rice variety TBR225 was clearly affected by the alternate wide–narrow row spacing treatments (Table 3). Maximum tiller number ranged from 8.72 to 9.37 tillers/plant; F5 achieved the highest value (9.37 tillers/plant), 0.65 tillers/plant (7.5%) higher than F1, with a statistically significant difference compared with F1-F2 ($LSD_{0.05}$ = 0.54). CT3 - CT4 were intermediate.

Effective tiller number ranged from 6.42 to 7.52 tillers/plant; F5 again achieved the highest value, significantly higher than F1-F3 ($LSD_{0.05}$ = 0.62). F4 also produced significantly more effective tillers than F1-F2. The effective tiller ratio increased gradually from 77.06% (F1) to 80.26% (F5). Thus, wider row spacing enhanced maximum tiller number, effective tiller number, and effective tiller ratio of TBR225.

These results indicate that planting at wider spacing allowed TBR225 to produce more tillers and achieve a higher proportion of effective tillers. This may be explained by reduced competition for light, nutrients, and space under wider spacing, which enables each plant to develop a stronger root system and produce more tillers. In addition, lower plant density improves light penetration into the canopy, which enhances photosynthesis at the lower leaf layers, supports the growth of young tillers, and increases the proportion of effective tillers. In contrast, high-density planting increases competition and suppresses the development of young tillers into productive ones.

This trend aligns with previous findings. Pham et al. (2020) reported that lower planting density increased tiller number and the proportion of effective tillers compared with higher density. Singh et al. (2019), Li et al. (2015), Dong et al (2021) also demonstrated that wider row spacing improved effective tiller number and canopy structure, leading to higher panicle production.

However, if plant density is too low, the total number of effective tillers per m² may decrease despite higher per-plant tillering. Therefore, the choice of optimal spacing should balance individual plant performance with population-level yield potential.

In summary, wider planting spacing increased maximum and effective tiller numbers and improved the proportion of effective tillers, thereby contributing to higher panicle density. These findings are consistent with previous domestic and international research.

Effect of wide-narrow row planting patterns on pest and disease incidence

Table 4. Effect of wide-narrow row planting patterns on pest and disease incidence of TBR225 rice variety

Unit: score

Treatment	Rice blast	Sheath blight	Bacterial leaf blight	Stem borer	Leaf folder	Brown planthopper
F1	2	3	2	1	1	0
F2	1	2	1	1	1	0
F3	1	2	1	0	1	0
F4	1	1	0	0	0	0
F5	0	1	0	0	0	0

Table 4 shows the incidence of six major pests and diseasesblast, sheath blight, bacterial leaf blight, stem borer, leaf folder, and brown planthopperon seven rice varieties, evaluated on a qualitative scale (0: no incidence; 1: low incidence; 2: moderate incidence).

For TBR225, the incidence of pests and diseases varied markedly among the alternate wide-narrow row spacing treatments (Table 4). In the narrow-row treatments (F1–F3), blast scores ranged from 1 to 2; sheath blight 2–3; bacterial leaf blight 1–2; stem borer and leaf folder 0–1; brown planthopper was almost absent.

In contrast, the wider-row treatments (F4 - F5) showed markedly lower pest and disease levels. Specifically, F4 recorded a score of 1 for blast and 1 for sheath blight, with no bacterial leaf blight, stem borer, leaf folder, or brown planthopper. F5 recorded no blast (0), sheath blight 1, and no other pests or diseases.

Thus, wider row spacing (F4-F5) greatly reduced pest and disease pressure compared with narrow row spacing (F1-F3). This suggests that planting at wider spacing substantially improved the rice field microclimate, thereby reducing pest and disease incidence. Wider spacing creates a more open canopy, lowers humidity within the field, and restricts favorable conditions for leaf diseases (blast, sheath blight, bacterial blight). Increased light penetration down to the base of the plants further suppresses fungal spore development and pest populations that hide in dense foliage. Moreover, with lower plant density, there is less “host material” per unit area, slowing the spread of pathogens and insects.

This trend is consistent with previous research. Pham et al. (2020) found that lower planting density reduced the incidence of blast and sheath blight compared with denser planting. Singh et al. (2019) also reported that wider row spacing decreased pest populations in rice fields in India. Li et al. (2015) emphasized that a more open canopy is a key factor in disease suppression in high-yielding rice systems.

However, overly low planting density can leave more bare soil, which may encourage weed growth and attract insect species migrating from field borders. Therefore, recommendations on optimal row spacing should consider both pest/disease pressure and weed competition.

In summary, wider row spacing (F4–F5) markedly reduced pest and disease incidence in TBR225 rice due to improved field microclimate and lower host density. These findings align with previous domestic and international research.

Effect of wide-narrow row planting patterns on yield and yield components of TBR225 rice variety

Table 5. Effect of wide-narrow row planting patterns on yield components and yield of TBR225 rice variety

Treatment	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}
F1	249.42^{a} ± 2.32	147.26^{c} ± 1.92	80.57^{a} ± 0.57	22.57^{a} ± 0.55	5.85^{b} ± 0.25
F2	249.49^{a} ± 3.02	148.72^{bc} ± 2.21	80.63^{a} ± 0.43	22.54^{a} ± 0.48	5.97^{b} ± 0.12
F3	250.39^{a} ± 2.52	149.36^{bc} ± 2.47	80.58^{a} ± 0.89	22.64^{a} ± 0.42	6.12^{ab} ± 0.24
F4	251.23^{a} ± 1.25	151.12^{ab} ± 1.04	81.42^{a} ± 0.50	22.69^{a} ± 0.58	6.37^{ab} ± 0.23
F5	251.36^{a} ± 1.34	153.47^{a} ± 2.45	81.55^{a} ± 0.91	22.71^{a} ± 0.35	6.42^{a} ± 0.13
LSD	*4.62*	*3.11*	*1.33*	*0.86*	*0.41*
CV	*1.10*	*1.10*	*0.90*	*2.20*	*3.60*

The yield components and actual grain yield of TBR225 varied among the alternate wide-narrow row spacing treatments (Table 5). The number of panicles per m² ranged from 249.42 to 251.36 panicles/m², with no statistically significant differences among treatments ($LSD_{0.05}$ = 4.62). The number of grains per panicle increased from 147.26

grains/panicle (F1) to 153.47 grains/panicle (F5). F5 had the highest value, significantly different from F1 and F2 ($LSD_{0.05}$ = 3.11). The percentage of filled grains ranged from 80.57% to 81.55%, and the 1,000grain weight remained stable at 22.54-22.71 g, with no significant differences ($LSD_{0.05}$ = 1.33 and 0.86, respectively).

Actual grain yield increased from 5.85 t/ha (F1) to 6.42 t/ha (F5); F5 had the highest yield and differed significantly from F1 ($LSD_{0.05}$ = 0.41). F3 and F4 showed intermediate values. Thus, wider row spacing increased the number of grains per panicle and actual grain yield, while the number of panicles/m^2, percentage of filled grains, and 1,000grain weight did not change significantly.

These results indicate that the yield components of TBR225 were affected differently by row spacing. Wider row spacing provided each rice hill with better access to nutrients and light, enhancing photosynthesis and dry matter accumulation, which in turn increased the number of spikelets per panicle. In contrast, the percentage of filled grains and 1,000-grain weight remained relatively stable, which reflects their genetic control and lower sensitivity to planting density under non-stress conditions.

Although the number of panicles per m^2 remained unchanged, the increase in grains per panicle raised the total number of filled grains per m^2, and, combined with a stable filling rate, thereby resulted in higher grain yield. This trend aligns with previous findings. Pham et al. (2020) reported that appropriate transplanting spacing increased grains per panicle and rice yield in the Red River Delta. Singh et al. (2019)and Dong et al (2023) noted that wider row spacing improved individual plant growth conditions, enhanced photosynthetic efficiency, and increased grain yield. Li et al. (2021) also demonstrated that suitable row spacing increased the number of effective grains and yield in intensive rice systems.

Conclusion

The results of this study demonstrate that alternate wide–narrow row spacing significantly affected growth parameters, dry matter accumulation, tillering ability, pest and disease incidence, and grain yield of the TBR225 rice variety. Among the tested treatments, wider row spacing (F3–F5) created more favorable conditions for plant growth and development, including greater dry matter accumulation, higher numbers of effective tillers, markedly lower pest and disease incidence, and increased grains per panicle as well as higher actual grain yield.

These findings indicate that selecting an appropriate row spacing is an important agronomic practice for improving rice production efficiency. This study also provides a scientific basis for further research and recommendations on optimizing planting density and field management to maximize the yield potential of TBR225 rice.

Competing Interests

The authors declare that they have no conflicts of interest regarding the publication of this article.

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