TẠP CHÍ KHOA HỌC
TRƯỜNG ĐẠI HỌC QUY NHƠN

Đánh giá tính kháng nảy mầm trước thu hoạch và bước đầu phân tích đa dạng di truyền của một số giống lúa trồng phổ biến trên địa bàn tỉnh Bình Định dựa vào đặc điểm hình thái

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TÓM TẮT

Nghiên cứu đặc điểm hình thái, nông học, tính kháng nảy mầm trước thu hoạch và đa dạng di truyền của một số giống lúa trồng phổ biến trên địa bàn tỉnh Bình Định có ý nghĩa quan trọng trong việc đánh giá nguồn vật liệu khởi đầu phục vụ công tác chọn, tạo giống lúa mới thích ứng biến đổi khí hậu. Kết quả nghiên cứu trên 09 giống lúa cho thấy, có 1 giống cực ngắn ngày, 5 giống ngắn ngày và 3 giống trung ngày; 3 giống có tỷ lệ nảy mầm trung bình trước thu hoạch > 50% và 3 giống < 15%; các giống lúa nghiên cứu có chiều cao cây dao động từ 94,98 - 110,80 cm, số nhánh hữu hiệu từ 5,48 - 8,07 nhánh, chiều dài lá đòng từ 25,93 - 32,05 cm, chiều rộng lá đòng từ 1,17 - 1,51 cm, chiều dài bông từ 26,53 - 31,98 cm, chiều dài hạt gạo từ 5,91 - 8,41 mm, chiều rộng hạt gạo từ 2,31 - 3,60 mm, tỷ lệ D/R từ 2,15 - 3,32, khối lượng 1.000 hạt từ 19,85 - 24,23 g, số bông hữu hiệu/m^2 từ 279,83 - 351,66 bông, số hạt chắc/bông từ 108,50 - 154,33 hạt/bông, năng suất lý thuyết và năng suất thực thu của các giống dao động lần lượt từ 76,76 - 109,02 và 54,74 - 77,55 tạ/ha. Dựa trên 13 tính trạng kiểu hình, với hệ số tương đồng 0,03 các giống lúa nghiên cứu được phân thành 4 nhóm khác nhau cách biệt về di truyền. Số liệu thu được trong nghiên cứu này cung cấp thông tin tham khảo bước đầu cho các nhà nghiên cứu chọn lọc và cải tiến giống lúa thích ứng biến đổi khí hậu ở Bình Định nói riêng và vùng Duyên hải Nam Trung bộ nói chung.

Từ khóa: *Kháng nảy mầm trước thu hoạch, tỷ lệ nảy mầm, đa dạng di truyền, đặc điểm nông - sinh học.*

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Evaluation of pre-harvest germination resistance and initial analysis of genetic diversity of some popular rice varieties grown in Binh Dinh province based on morphological characteristics

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ABSTRACT

Research on the morphological characteristics, agronomics, pre-harvest germination resistance, and genetic diversity of some popular rice varieties grown in Binh Dinh province is essential in assessing material resources for selecting and developing new rice varieties that can adapt to climate change. The results show that there is one extra short-day variety, five short-day varieties, and three medium-day varieties. Among these three varieties, there is an average pre-harvest germination percentage of over 50%, and three under 15%. The plant height ranged from 94.98 to 110.80 cm, effective tiller number per plant from 5.48 to 8.07, flag leaf length from 25.93 to 32.05 cm, and flag leaf width from 1.17 to 1.51 cm. The panicle length ranged from 26.53 to 31.98 cm, grain length from 5.91 to 8.41 mm, grain width from 2.31 to 3.60 mm, L/W ratio from 2.15 to 3.32, 1000-grain weight from 19.85-24.23 g, number of panicle/m^2 from 279.83 to 351.66, and filled spikelet per panicle from 108.50 to 154.33. The theoretical and actual yield of the varieties ranged from 76.76 - 109.02 and 54.74 - 77.55 quintals/ha, respectively. Based on 13 phenotypic traits, the rice varieties studied were classified into 4 groups of genetic diversity with a coefficient of 0.03. The information obtained from this study is critical for breeding rice varieties that can adapt to climate change in Binh Dinh province in particular and South Central Region in general.

Keywords: *Pre-harvest sprouting, germination percentages, genetic diversity, agronomic characters.*

1. INTRODUCTION

Rice (*Oryza sativa* L.) is an important cereal that feeds more than 50% of the world's population. Therefore, rice has made significant contributions to the global food security strategy. According to the Food and Agriculture Organization of the United Nations (FAO, 2021), there are approximately 144 countries growing rice, distributed across all continents, with a total area of 164.19 million ha, an average yield of 4.61 tons/ha, and a production of 756.74 million tons.[1]

Asia has 140.46 million ha of rice land, accounting for 85.54% of the total global area. Of these, 69.21 million ha (49.27%) are regularly threatened by natural disasters, with 36.72 million ha entirely depending on rainwater (rainfed rice), 19.15 million ha being dry land (upland rice), and 13.34 million ha prone to flooding. As a result, nearly 20% of the area is

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severely flooded. Rice yield in disaster-affected areas is only 0.8 - 1.7 tons/ha, which is 20 - 40% of rice yield in non-disaster-affected areas.[1]

Pre-harvest sprouting (PHS) is a phenomenon in which seeds germinate on the plant directly before harvest. PHS is associated with early hibernation break and usually occurs in conditions of high air humidity or prolonged rainfall, greatly affecting yield and grain quality.[2,3] This is a very common phenomenon in higher plants; PHS has been observed in nearly 100 species of flowering plants (belonging to 40 genera and 23 different families).[4,5] PHS, in particular, is found on many crops and in most parts of the world, including rice.[6]

Many studies on rice have shown that the seed dormancy mechanism is closely related to the water loss process that occurs during the grain's ripening stage, and that the amount of carbohydrate accumulated is proportional to the amount of water lost in seed development. However, because of unseasonal rains or continuous, prolonged rainy weather accompanied by high temperatures near harvest, conditions have been created for stored carbohydrates to "store" water, thereby breaking the process of seed dormancy through changes in hormones (particularly ABA and GA), which causes the embryo to develop inside the seed coat while it is still on the plant.[7]

The study of genetic diversity based on morphological and agronomic traits is a classic method that is still widely used today because it does not require expensive equipment or complex experimental arrangements while still ensuring certain efficiency, allowing researchers to distinguish varieties quickly in the field. Therefore, assessing the agro-biological characteristics and genetic diversity of rice varieties based on phenotype will assist breeders in selecting rice varieties with many desirable traits for use as a source of starting material for the breeding of rice varieties with high resistance to PHS.[8-13]

Rice is the most important food crop in Vietnam, feeding 100% of the population. According to the General Statistics Office, the rice-cultivated area was 7.24 million ha in 2021, with an average yield of 6.06 tons/ha, a production of 43.85 million tons, and an export of 6.2 million tons, which was approximately $3.2 billion. Thus, after more than 30 years of renovation, Vietnam has made significant strides in rice production while also ensuring national food security.[14]

Currently, global climate change is caused by the earth's warming, resulting in hot weather, high temperatures, storms, floods, and droughts occuring on a continuous and increasing basis. The World Meteorological Organization predicts that Asia will be the most affected by climate change over the next 50 years, and Vietnam is one of the five worst-affected countries.[15] Furthermore, because Vietnam is located in the sub-equatorial tropics, with steep terrain and a long coastline, tropical depressions, storms, and floods are common. As a result, rice production and cultivation in Vietnam has faced numerous challenges, including global climate change, sea level rise, saline intrusion, drought, and flooding. Prolonged rainfall and high humidity during the harvest season will cause early germination on pre-harvest flower, seriously affecting rice yield and quality and causing significant economic losses. According to Hu Weimin, the phenomenon of PHS reduces conventional rice yield by 6%, hybrid rice yield by 20%, and causes a loss of billions of US dollars each year.[16]

In recent years, many provinces in Central Vietnam have been directly affected by abnormal and extreme weather phenomena that cause continuous and long-term heavy rains, causing hundreds of ha of rice to fall in flooded fields, which leads to the germination of rice seeds on the spikelet, causing heavy yield and quality losses and reducing the economic value of the rice grain by 20-50%. According to the Commanding Committee for Disaster Prevention and Search and Rescue, in 2019, over 4.000 ha of rice fields

in Quang Binh, over 100 ha in Quang Tri, and over 5.000 ha in Thua Thien – Hue province were submerged and damaged. More than 3.000 ha of rice land in Binh Dinh were completely submerged in water.

Central Vietnam was the region which suffered the heaviest consequences caused by floods and rains in 2020, with more than 49.93 ha of rice and crops being damaged. Recent heavy and prolonged rains in 2021 destroyed nearly 3.000 ha of rice during winter-spring crop in Quang Binh and over 5.000 ha in Ha Tinh, providing clear evidence of unseasonal rainy weather, which has a negative impact on rice production and cultivation. Therefore, the evaluation of "Evaluation of pre-harvest germination resistance and initial analysis of genetic diversity of some popular rice varieties grown in Binh Dinh province based on morphological characteristics" is one of the positive and feasible solutions, which helps breeders to select, improve, and create new rice varieties with good PHS resistance, high yield, and good quality, contributing to reducing potential risks and promoting rice production in the Central provinces in particular, and Vietnam in general in the near future.

2. MATERIALS AND METHODS

2.1. Experimental materials

The experiment was carried out on nine rice varieties that are commonly grown in Binh Dinh province to assess their morphological, agronomic, and PHS resistance (Table 1).

Table 1. The origin of experimental rice varieties.

No.	Variety	Origin
1	OM18	Cuu Long Delta Rice Research Institute's Department of Biotechnology
2	BDR999	Agricultural Science Institute for Southern Coastal Central
3	BDR17	
4	DV108	Originated from China and selected by ThaiBinh Seed Group
5	KD18	
6	Dai thom rang	
7	VNR20	Vietnam National Seed Group
8	Thien uu 8	
9	Dai thom 8	Southern Seed Corporation

2.2. Experimental methods

The experiment was carried out in accordance with National Regulations QCVN 01-55: 2011/BNNPTNT and QCVN 01-65: 2011/ BNNPTNT,[17] with the following modifications:

- The study was conducted in the Winter-Spring crop 2021 - 2022 at My Duc commune, Phu My district, Binh Dinh province.

- The experiment was set up in a randomized complete block design (RCBD) with three replications.

- The area of the experimental plot is 10 m^2 (2 m x 5 m); the distance between experimental plots within the same replicate is 40 cm, and the distance between replicates is 40 cm.

- Planting density: 20 x 10 cm (row spacing: 20 cm, tree spacing: 10 cm), 50 plants/m^2.

- Seasonal and experimental farming methods and techniques are used in accordance with the current rice cultivation process in the area and are overseen by the Departments of Agriculture and Rural Development of Binh Dinh province and Phu My district.

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2.3. Indicators and measures

Evaluation of PHS resistance: The PHS resistance of nine rice varieties was tested using the method of Nguyen *et al*.,[18] which is based on the seeds germination rate with minor modification. One hundred seeds from each plant harvested at 40 and 50 days after flowering were placed on doubled sheets of WhatmanNo. 1 filter paper in a 9 cm Petri dish; 10 ml of sterile water was added, and dishes were incubated at 30°C in darkness for 7 days. Tests were performed in triplicate. Seeds with coleoptiles that extended more than 2 mm were considered germinated. The germination percentage (%) is calculated as the number of germinated seeds divided by the total number of filled seeds x100 (%).[18]

- Morphological and agronomic characteristics of rice varieties were assessed in accordance with National Regulations QCVN 01-55: 2011/BNNPTNT and QCVN 01-65: 2011/BNNPTNT.

+ Growth time (days): The number of days from sowing to seed maturity (85% of seeds on panicles were ripen);

+ Flag leaf length (cm): Distance from the base to the tip of the leaf;

+ Flag leaf width (mm): Distance of the widest section of the leaf;

+ Panicle length (cm): The average distance from the panicle neck to the panicle tip of the panicles of three replicates;

+ Plant height (cm): Distance from soil surface to tip of the tallest panicle (awns ex-cluded);

+ Rice grain size: For each replicate, the length and width of the kernels of randomly selected 20 grains of rice were measured with a Baker E-02 (Japan), and the average value was used;

+ Grain shape: The ratio of length and width (L/W);

+ Number of panicle/m^2: Determined from three representative square meter regions that were randomly sampled from each plot;

+ Number of filled spikelet/panicle: The total number of filled spikelets/panicle was counted from 10 random clusters for each experimental plot;

+ Filled spikelet ratio (%): The percentage (%) of filled spikelets per panicle;

+ 1000-grain weight (g): 1000 well-developed whole grains of the three replicates were weighed, then the average value was used;

+ Theoretical yield (quintals/ha) = (Number of panicle/m^2) x (Number of filled spikelet/ panicle) x 1000-grain weight x 10^{-4};

+ Actual yield (quintals/ha) = Area harvested should not be less than 5 m^2/plot (at least two border rows should be discarded). Report yield in kg/ha on rough (paddy) rice at 14% moisture.

- Genetic diversity of rice varieties studied based on phenotype: The results of the traits evaluation and actual yield in the field of the studied rice varieties were used to build the similarity matrix. These matrices represent the genetic close relationship between the analyzed samples. The NTSYSpc 2.11a software converts data on genetic correlation between samples in the form of a matrix into a tree graph (also known as an evolutionary tree), and samples with coefficients are classified into a group.

2.4. Methods of data processing

The obtained data were biologically processed using Statistix software version 8.0, and the diversity of rice varieties based on phenotype was analyzed using the UPGMA method in NTSYS pc 2.11a software. Differences in mean values was compared using the LSD test at a significance level of 0.05.

3. RESULTS AND DISCUSSION

3.1. Pre-harvest germination resistance of rice varieties studied

The PHS resistance of rice varieties was assessed using the germination percentages of rice seeds at 45 and 50 days after the flowering. The lower the germination percentages were, the higher PHS

resistance was, and vice versa. Table 2 shows the germination percentages of rice varieties at 45 and 50 days after flowering. After 7 days of experimentation, three varieties that had low pre-harvest germination percentages (< 15%) were Thien uu 8 (11.56%), Dai thom 8 (12.36%), and Dai thom rang (12.79%). These are varieties with high PHS resistance. Three varieties which had average pre-harvest germination percentages (> 50%) were BDR999 (50.81%), KD18 (55.63%), and DV108 (60.43%). The resistance to PHS of these varieties need to be improved. This result is also the same with the recent research findings of Pham Quoc Trung *et al*., (2021), who found that many varieties of rice commonly cultivated in North and Central Vietnam have high pre-harvest germination percentages (> 50%) after 10 days of testing.[19]

Table 2. The percentages of germination of rice varieties at 45 and 50 days after the flowering.

Variety	Germination percentages (%)		
	45 day	50 day	Average
OM18	45.00	48.59	46.80
KD18	48.50	62.76	55.63
BDR999	42.84	58.77	50.81
DV108	58.37	62.48	60.43
BDR17	17.89	21.54	19.72
VNR20	35.43	48.97	42.20
Thien uu 8	10.54	12.55	11.55
Dai thom 8	11.50	13.21	12.36
Dai thom rang	12.58	13.00	12.79

However, after drying the rice varieties at 50°C for 7 days, the germination percentages of most of the varieties were > 90%. The results showed that all varieties, including Thien uu 8 (95.12%), Dai thom 8 (90.49%), and Dai thom rang (90, 25%), had their dormant state broken during heat treatment (Table 3).

Table 3. The percentages of germination of dried rice varieties at 45 and 50 days after the flowering.

Variety	Germination percentages (%)		
	45 days	50 days	Average
OM18	97.32	99.76	98.54
KD18	100	99.64	99.82
BDR999	95.82	99.87	97.85
DV108	97.21	100	98.61
BDR17	92.32	98.13	95.23
VNR20	94.35	99.16	96.76
Thien uu 8	90.24	100	95.12
Dai thom 8	88.27	92.71	90.49
Dai thom rang	82.87	97.63	90.25

3.2. Some morphological and agronomic characteristics of the rice varieties studied

The growing time (GT) of rice varieties is a genetic trait that is affected by environmental factors. Rice varieties are classified as follows by GT according to National Standard TCVN 13381-1:2021/BKHCN: Extra short-day (< 100 days), short-day (100 - 115 days), medium-day (116 - 130 days), and long-term (> 130 days). Table 4 shows the results of grouping rice varieties studied according to GT.

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Table 4. The groups of rice varieties based on growth time.

Trait group	The number of varieties	Varieties	Ratio (%)*
Extra short-day (< 100 days)	1	BĐR999	11.11
Short-day (100-115 days)	5	OM18, KD18, DV108, BDR17, VNR20	55.56
Medium-day (116-130 days)	3	Thien uu 8, Dai thom 8, Dai thom rang	33.33
Long-term (> 130 days)	0		0

Note*: *Percentage of total 9 varieties*

There is one extra short-term variety (11.11%), five short-term varieties (55.56%), three medium-day varieties (33.33%), and no long-term varieties. Thus, the GT of the studied rice varieties was relatively diverse, with the majority of them falling into the short and midium-day groups. The results of grouping according to GT are similar to the subgroup of commonly grown rice varieties in the Northwest (short and medium-day varieties) in Doan Thi Thuy Linh's previous report, and this is also a valuable trait in selecting and developing new rice varieties.[9]

The plant height, the effective tiller number per plant, the flag leaf length, the flag leaf width, the panicle length, the grain length, the grain width, L/W ratio, 1000-grain weight, the number of panicle/m^2, and other basic characteristics of rice plants are frequently used to evaluate the morphological differences of rice varieties, making it easier to group rice varieties in the field. Table 5 shows the findings of the study on the traits of the aforementioned rice varieties.

Table 5. The morphological characteristics of the rice varieties studied.

Variety	Plant height (cm)	Effective tiller number/ plant	Flag leaf length (cm)	Flag leaf width (cm)	Panicle length (cm)	Grain length (mm)	Grain width (mm)	D/R ratio	1000-grain weight (g)
OM18	100.15^{b}	6.66^{bc}	27.05^{b}	1.23^{a}	28.48^{b}	8.41^{h}	2.69^{d}	3.11^{f}	23.68^{e}
KD18	101.98^{e}	6.33^{b}	25.93^{a}	1.17^{a}	26.53^{a}	5.91^{a}	2.59^{c}	2.28^{c}	19.85^{a}
BDR999	100.66^{c}	8.05^{d}	27.03^{b}	1.38^{b}	30.51^{cd}	6.90^{b}	3.20^{f}	2.15^{a}	25.15^{f}
DV108	94.98^{a}	6.83^{bc}	29.93^{e}	1.25^{a}	31.98^{g}	7.46^{c}	2.60^{c}	2.87^{f}	20.34^{b}
BDR17	110.01^{f}	5.48^{a}	27.53^{c}	1.27^{a}	28.46^{b}	7.80^{e}	3.35^{g}	2.33^{d}	22.45^{d}
VNR20	101.16^{d}	6.50^{bc}	29.15^{d}	1.41^{bc}	30.56^{cd}	8.07^{g}	3.60^{h}	2.24^{b}	23.89^{e}
Thien uu 8	110.80^{g}	8.07^{d}	32.05^{h}	1.46^{bc}	31.26^{f}	7.92^{f}	2.97^{e}	2.66^{e}	20.68^{c}
Dai thom 8	100.33^{b}	6.33^{b}	31.05^{f}	1.38^{b}	30.91^{ef}	7.70^{d}	2.31^{a}	3.32^{g}	25.23^{f}
Dai thom rang	101.30^{d}	7.33^{bc}	31.55^{g}	1.51^{c}	30.33^{c}	7.49^{c}	2.40^{b}	3.11^{f}	23.66^{e}
CV(%)	***4.63***	***14.85***	***7.04***	***10.59***	***5.58***	***9.31***	***14.81***	***15.82***	***7.56***
LSD 0.05	***0.29***	***0.84***	***0.21***	***0.35***	***0.44***	***0.03***	***0.01***	***0.02***	***0.25***

Note: a,b,c… indicates a statistically significant difference at the 0.05 level; CV: Coefficient variance; LSD: Least significant difference.

The plant height of rice varieties ranged from 94.98 cm (DV108) to 110.80 cm (Thien uu 8), with the effective tiller number per plant ranged from 5.48 to 8.07. The results show that, there was one variety (DV108, accounting for 11.11%) of the semi-dwarf type with a plant height of less than 100 cm, and eight varieties (88.89%) of the medium typewith a plant height ranged between 100 and 120 cm, indicating that the varieties have good lodging resistance. The evaluation of the number of effective tiller/plant of the varieties revealed that there were seven varieties (77.78%) of medium panicle level and two varieties (Thien uu 8 and BDR999) of high panicle level (Table 6).

Table 6. The groups of rice varieties based on the plant height and the effective tiller number/plant.

Trait group	The number of varieties	Ratio (%)*
Plant height (cm)		
< 100 cm (semi-dwarf)	1 (DV108)	11.11
100-120 cm (medium)	8	88.89
> 120 cm (height)	0	0
Effective tiller number/plant		
< 5 tiller (less)	0	0
5-8 tiller (medium)	7	77.78
> 8 tiller (much)	2	22.22

Note*: *Percentage of total 9 varieties*

The flag leaf length of the varieties ranged from 25.93 cm (KD18) to 32.05 cm (Thien uu 8) and flag leaf width from 1.17 - 1.51 cm. None of the varieties had narrow leaves (flag leaf width < 0.8 cm) (Table 5). Panicle length is an important factor because it is a genetic trait that determines variety. Scientists frequently seek ways to increase panicle length in breeding because this is the primary economic indicator of rice. The panicle length of the varieties ranged from 26.53 cm (KD18) to 31.98 cm (DV108). There are six varieties (66.67%) with medium panicles (26 - 30 cm) and three (33.33%) with long panicles (> 30 cm).

Table 7. The groups of rice varieties based on the grain size and shape.

Trait group	The number of varieties	Ratio (%)*
Grain length (mm)		
Extra short (< 4.50 mm)	0	0
Short (4.51 - 5.50 mm)	0	0
Medium (5.51 - 6.50 mm)	1	11.11
Long (6.51 - 7.50 mm)	3	33.33
Extra long (> 7.50 mm)	5	55.56
Grain width (mm)		
Narrow (< 2.5 mm)	2	22.22
Medium (2.5 - 3.0 mm)	4	44.45
Width (> 3.0 mm)	3	33.33
Grain shape (L/W)		
Round (< 1,5)	0	0
Semi-round (1.5 - 1.99)	0	0
Semi-slender (2 - 2.49)	4	44.45
Slender (2.5 - 2.99)	2	22.22
Long slender (≥ 3,0)	3	33.33

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1000-grain weight (g)		
Extra low (< 20 g)	1	11.11
Low (20 - 24 g)	6	66.67
Medium (25 - 29 g)	2	22.22
High (30 - 35 g)	0	0
Extra high (> 35g)	0	0

Note*: *Percentage of total 9 varieties*

The grain size and grain weight are typical parameters of rice varieties that are controlled by genes and less affected by environmental factors. As a result, they are important characteristics used to group varieties. The classification of grain size and weight characteristics according to the IRRI (2002) (Tables 5 and 7) shows that, in terms of rice grain length, there are five varieties of extra long grain (55.56%), three varieties of long grains (33.33%), and only one variety of medium grain (11.11%). In terms of 1000-grain weight, there is one variety with a extra low 1000-grain weight (11.11%), six varieties with a low 1000-grain weight (66.67%) and two varieties with a medium 1000-grain weight (22.22%).

The number of panicle/m^2 and the number of filled spikelet/panicle are critical factors in determining rice yield. In this study, the number of panicle/m^2 of the rice varieties ranged from 279.83 (VNR20) to 351.66 (Thien uu 8), and the number of filled spikelet/panicle ranged from 108.50 (BDR17) to 154.33 (KD18) (Table 8).

3.3. The yield and yield components of the rice varieties studied

Yield is a synthetic factor of a variety; it is the result of rice plants' growth, development, accumulation, and synthesis of organic matter. Table 8 shows the yield and yield components of the rice varieties.

Table 8. Yield components of rice varieties.

Variety	No. Panicle/ m^2	No. Filled spikelet/ panicle	Filled spikelet ratio (%)	1000-grain weight (g)	Theoretical yield (quintals/ ha)	Actual yield (quintals/ ha)
OM18	305.16^{d}	121.17^{b}	14.81^{f}	23.68^{e}	87.56^{c}	59.38^{c}
KD18	310.00^{e}	133.50^{d}	17.07^{h}	19.85^{a}	82.15^{b}	56.98^{b}
BDR999	288.33^{b}	132.00^{d}	13.92^{e}	25.15^{f}	91.92^{d}	65.83^{e}
DV108	291.83^{c}	154.33^{g}	15.46^{g}	20.34^{b}	91.61^{c}	63.22^{d}
BDR17	315.16^{f}	108.50^{a}	17.52^{i}	22.45^{d}	76.76^{a}	54.74^{a}
VNR20	279.83^{a}	152.66^{g}	10.27^{b}	23.89^{e}	102.07^{f}	72.83^{f}
Thien uu 8	351.66^{h}	128.83^{c}	9.48^{a}	20.68^{c}	93.69^{e}	74.63^{g}
Dai thom 8	310.50^{e}	144.33^{f}	10.56^{c}	25.23^{f}	108.60^{g}	76.90^{h}
Dai thom rang	329.50^{g}	139.83^{e}	12.83^{d}	23.66^{e}	109.02^{h}	77.55^{i}
CV(%)	***6.77***	***10.45***	***19.74***	***7.56***	***10.97***	***12.58***
$LSD_{0.05}$	***1.38***	***1.87***	***1.25***	***0.25***	***0.03***	***0.27***

Note: *a,b,c… indicates a statistically significant difference at the 0.05 level; CV: Coefficient variance; LSD: Least significant difference.*

Table 8 shows that the theoretical yield and actual yield of the varieties ranged from 76.76 - 109.02 and 54.74 - 77.55 quintals/ha, respectively. The variety with the highest theoretical yield and actual yield was Dai thom rang (109.02 and 77.55 quintals/ha), followed by Dai thom 8 (108.60 and 76.90 quintals/ha), and the variety with the lowest theoretical yield and actual yield was BDR17 (76.76 and 54.74 quintals/ha).

3.4. Evaluation of genetic diversity of the rice varieties through phenotype

Genetic diversity can be assessed using either phenotype (morphological traits) or genotype (using molecular markers), in which the phenotype is expressed as a result of the interaction between genotype and environment. The study of genetic diversity based on morphological and agronomic traits is a classic method that is still widely used today because it does not require expensive equipment, the experimental setup is not complicated, and certain efficiency is guaranteed. The analysis of rice variety diversity was based on 13 traits: the average pre-harvest germination percentages, GT, the plant height, the effective tiller number/plant, the length and width of flag leaves, the panicle length, the grain length and grain width, the grain shape (L/W), the number of panicles/m^2, 1000-grain weight, and the actual yields. The data were analyzed using the UPGMA method in NTSYS pc 2.11a software and modeled as a tree diagram, as shown in Figure 1.

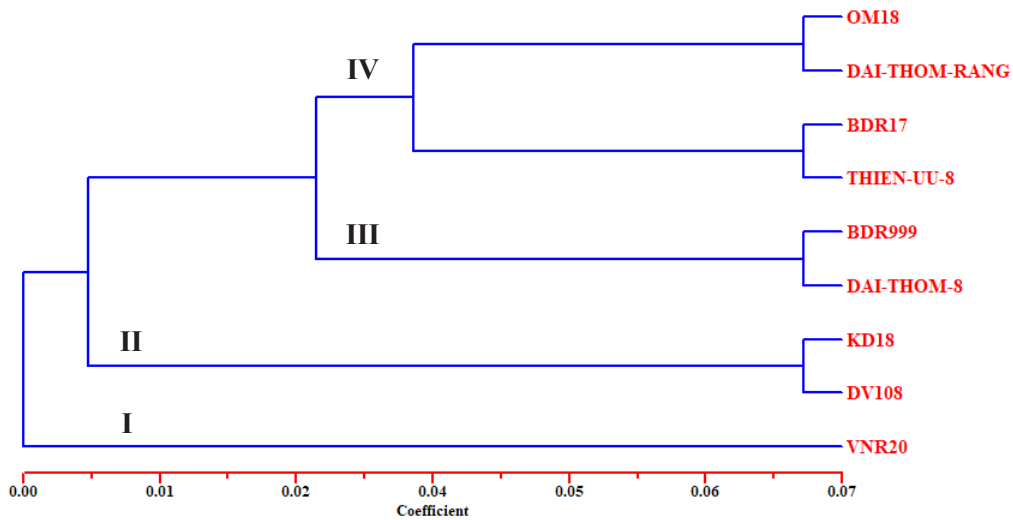

Figure 1. The genetic correlation of the rice varieties studied is depicted as a tree diagram.

The genetic grouping results of nine rice varieties studied revealed that if the coefficient is 0.03, they are classified into four genetic groups (Figure 1), which is then combined with three PHS groups (Tables 1) and four GT groups (Table 4). The results show that Group I contains only one variety (VNR20), which has a distant relation with the other varieties, and GT belongs to the short-day group with moderate resistance to PHS; Group II contains KD18 and DV108, both of which have short-day GT and low resistance to PHS; Group III contains Dai thom 8 (with medium-day GT and high resistance to PHS) and BDR999 (with extra short-day GT and low resistance to PHS); Group IV includes OM18, BDR17 (with short-day GT and moderate resistance to PHS) and Thien uu 8, Dai thom rang (with medium-day GT and high resistance to PHS). As a result, aromatic rice varieties frequently have longer GT and are highly resistant to PHS. This result also serves as the foundation for the research team to conduct additional studies on the relationship between aromaticity, GT, and PHS.

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4. CONCLUSION

The preliminary assessment of pre-harvest germination percentages revealed that there are three varieties with average pre-harvest germination percentages > 50% and three varieties with mean pre-harvest germination percentages < 15%.

The evaluation of some agro-biological characteristics shows that there are one extra short-day variety, five short-day varieties and three medium-day varieties; one variety is semi-dwarf and eight varieties have medium height; seven varieties with medium number of panicles and two varieties with high number of panicles; most varieties have medium length and width of flag leaves; six varieties with medium panicles and three varieties with long panicles; five varieties with extra long grains, three varieties with long grains and one with medium grains.

In terms of yield and yield components of the rice varieties, the number of panicle/m^2 ranged from 279.83 - 351.66, the number of filled spikelet/panicle from 108.50 - 154.33, and the 1000-grain weight from 19.85 - 24.23 g; the theoretical yield and the actual yield of the varieties were from 76.76 - 109.02 and 54.74 - 77.55 quintals/ha, respectively.

The rice varieties studied are classified into four genetic groups based on the coefficient of 0.03. Combined with three PHS groups and four GT groups, it is revealed that Group I contains only one variety with short-day GT and moderate resistance to PHS; Group II contains two varieties with short-day GT and low resistance to PHS; Group III contains one variety with medium-day GT and high resistance to PHS and one with extra short-day GT and low resistance to PHS; and Group IV contains two varieties with short-day GT and moderate resistance to PHS and two varieties with medium-day GT and high resistance to PHS.

REFERENCES

1. FAOSTAT. International agricultural statistics, [DB/OL],<http://faostat.fao.org/default.aspx.>, accessed on 12 May 2022.

2. H. Nonogaki J. M. Barrero, C. Li. Editorial: Seed dormancy, germination, and pre-harvest sprouting, *Frontiers in Plant Science*, **2018**, *9,* 1783.

3. M. V. Rodrıguez, J. M. Barrero, F. Corbineau, F. Gubler, R. L. Benech-Arnold. Dormancy in cereals (not too much, not so little): about the mechanisms behind this trait, *Seed Science Research*, **2015**, *25*(2), 99-119.

4. M. Q. Yao, W. W. Chen, J. H. Kong, X. L. Zhang, N. N. Shi, S. L. Zhong, P. Ma, P. Gallusci, S. Jackson, Y. L. Liu, Y. G. Hong. Methyltransferase1 and ripening modulate vivipary during tomato fruit development, *Plant Physiol*, **2020**, *183*, 1883-1897.

5. A. Ali, J. Cao, H. Jiang, C. Chang, H-P. Zhang, S. W. Sheikh, L. Shah, C. Ma. Unraveling molecular and genetic studies of wheat (*Triticum aestivum* L.) resistance against factors causing pre-harvest sprouting, *Agronomy*, **2019**, *9*(3), 117.

6. S. Nakamura. Grain dormancy genes responsible for preventing pre-harvest sprouting in barley and wheat, *Breeding Science*, **2018**, *68*, 295-304.

7. S. K. Nelson, T. Ariizumi and C. M. Steber. Biology in the dry seed: Transcriptome changes associated with dry seed dormancy and dormancy loss in the Arabidopsis GA-insensitive sleepy1-2 mutant, *Frontiers in Plant Science*, **2017***, 8*, 2158.

8. V. T. T. Hien. Genetic variation of rice (*Oryza sativa* L.) Accessions based on morphological characteristics, *Journal of Science and Development*, **2012**, *10*(16), 844-852.

9. D. T. T. Linh, N. V. Khoa. *Genetic diversity of native rice (Oryza sativa L.) in northwest basedon morphological characteristics,* The 5th National Scientific Conference on Ecology and Biological Resources, 2013.

10. P. T. T. Ha, D. T. Khang, P. T. Tuyen, L. T. Minh, T. N. Minh, N. T. Lang, B. C. Buu. T. D. X. Minh. Correlation among agro-morphological variation and genetic diversity of rice (*Oryza sativa* L.) under drought stress, *International Letters of Natural Sciences,* **2016**, *58*, 42-53.

11. T. T. H. Hai, D. T. Thuy, D. T. Long, H. H. Tran, N. M. Tuan. Genetic diversity based on morphological characteristics of Ngoc Linh Ginseng (Panax Vietnamensis Ha Et Grushv.) at Nam Tra My, Quang Nam*, Hue University Journal of Science: Natural Science*, **2018**, *127*(1), 203-210.

12. N. V. Tam, N. T. Nga, T. V. Vuong, P. T. Hien, T. N. Thanh, N. T. Huong, V. D. Hoa. Evaluating the genetic diversity and phenotypic correlationof giant crinum lily lines (*Crinum asiaticum* L.), *Vietnam Science & Technology*, **2019**, *61*(12), 36-40.

13. N. T. Q. Trang, D. T. Long, H. T. K. Hong. *Genetic diversity based on morphological characteristics of Lotus (Nelumbo Nucifera Gaernt.) Thua Thien Hue province*, The National Biotechnology Conference, 2021.

14. GSO. General Statistics Office of Vietnam, <https://www.gso.gov.vn/so-lieu-thong-ke/>, accessed on 19 October 2022.

15. WMO. World Meteorological Organization, <https://public.wmo.int/en>, accessed on 6 August 2022.

16. W. M. Hu, C. X. He & H. Ma. Genetic effects of pre-harvest sprouting in hybrid rice *(Oryza sativa* L.*)*, *Chinese Journal of Rice Science*, **2003**, *3*, 76–79 (In Chinese with English abstract).

17. Ministry of Agriculture and Rural Development. *National technical regulation on testing for value of cultivation and use of rice* (National Regulations QCVN 01-55 and 01-65: 2011/ BNNPTNT), 2011.

18. T. L. N. Nguyen, C. L. Zhou, T. Y. Zhang, J. F. Yu, R. Miao, Y. S. Huang, X. J. Zhu, W. H. Song, X. Liu, C. L. Mou, J. Lan, S. J. Liu, Y. L. Tian, Z. G. Zhao, L. Jiang and J. M. Wan. Identification of QTL for seed dormancy from weedy rice and its application to elite rice cultivar 'Ninggeng 4', *Molecular Breeding*, **2019**, *39*, 123.

19. N. Q. Trung, H. M. Chinh, C. D. Ha, N. T. Hong, D. T. Thuy, L. T. Hien, V. M. Thiet. Vietnam may conduct research on early germination resistance in rice in response to climate change, *Vietnam Journal of Science, Technology and Engineering*, **2021**, *3*, 4-7.