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Effects of Colchicine on the Morphology, Yield Components and Correlation of the M2 Variant Population of Rd.43 Rice Varieties

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ABSTRACT

Background: The initial objective of the RD.43 rice project was to induce polyploid rice to improve yield components and tolerance to adverse environmental conditions. During the study, several RD.43 variant rice plants emerged. These plants presented several interesting traits.

Methods: The working group collected M1 RD.43 variant rice plants (M2 variant rice populations) to study their morphology, yield components and trait correlation. The objective of this study was to examine the morphology, stomata, yield components and correlations between different traits of M2 RD.43 variant rice populations.

Result: This study revealed that M2 RD.43 variant rice populations had improved height, number of leaves, leaf width, leaf length, leaf thickness, first shoot diameter, number of shoots and SPAD value compared to the mother plants. Certain M2 RD.43 variant rice populations have higher yield components (number of panicles, total number of seeds, number of full seeds, seed weight, seed width and seed length) than the mother plants. A research found that variant plants have longer stomata than mother plants. Correlation analysis revealed that the number of shoots per plant increased panicles, shriveled seeds, seeds with tails, total number of seeds, number of leaves and leaf length, while full seeds, full seed weight, percentage of pollination and stomatal density decreased.

Key words: Colchicine, Mutagenesis, Mutation, *Oryza sativa* L, Rice.

INTRODUCTION

RD.43 rice is an enhanced variety of rice grown in Thailand. RD. 43 rice was selected from a single cross between the Suphan Buri fragrant rice variety and the Suphan Buri 1 variety at the Suphan Buri Rice Research Center. RD.43 rice has a long and slender grain shape, with few chalky grains. The size of the rice grains is length × width × thickness = 7.5 × 2.1 × 1.8 mm. When cooked, rice is of good quality and is soft, sticky and has a light aroma, similar to Jasmine rice 105. The glycemic index for cooked RD.43 rice is 57.5, which is classified as a food with a moderate to low glycemic index, indicating that this rice is suitable for controlling blood sugar levels. Overall, RD.43 is a healthy rice source for the general public and diabetic patients (Thadamatakul *et al*., 2021). Although RD.43 rice already has many good qualities, further research is expected to verify additional beneficial qualities of RD.43 rice, such as better yield, good adaptation to inappropriate environments and ability to be grown even in arid or saline areas. One technique that helps improve the resistance of rice varieties to inappropriate environments is polyploidy.

Studies on rice have shown that polyploid rice varieties also have improved qualities affecting its yield, such as Huaduo 8 (H8) neo-tetraploid rice and F1 hybrids, which have long panicles, high number of filled grains per plant, high grain yield per plant, high 1000-grain weight and good seed setting (Ghaleb *et al*., 2020). Other studies have also shown that 15 neo-tetraploid rice cultivars similarly have high yield potential (Yu *et al*., 2020). A study of rice polyploidy induction worldwide revealed that the most popular chemical for inducing polyploidy in rice is colchicine (Chen *et al*., 2021).

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Colchicine is a metaphase inhibitor and its mechanism of action involves binding to α-tubulin and β-tubulin dimers, disrupting microtubule assembly during the cell cycle and preventing polar chromosome migration during anaphase, which results in increased polyploidy (Miri, 2020). However, several studies have shown that colchicine can induce not only polyploidy but also mutagenesis (Samadi *et al*., 2021; Cabahug *et al*., 2021).

The initial study of the research team aimed to induce polyploid rice. However, even though the rice treated with colchicine did not turn polyploid, variant and mixoploid plants were generated. These rice plants presented many interesting traits. Therefore, in this study, the research team examined the morphology and yield component of the offspring of M1 RD.43 variant rice plants (M2 variant RD.43 rice population) to determine whether these rice variants have the potential to be developed into varieties with acceptable yield traits or tolerance to unsuitable environmental conditions.

MATERIALS AND METHODS

Rice varieties

RD.43 rice variety from Thailand, Department of Agriculture and RD.43 M2 variants 1-7, 7 populations from the colchicine treatment in the previous experiment. This study was conducted at Sakon Nakhon Rajabhat University, Sakon Nakhon Province, Thailand in 2024.

M2 RD.43 variant rice populations

M2 RD.43 variant rice populations are the offspring of M1 RD.43 variant rice plants that were induced by mutagenesis using 0.1% colchicine for 6 hours as a mutagen. Each M2 RD.43 variant rice population was obtained from 6 M1 RD.43 variant rice plants.

Morphological study of M2 RD.43 variant rice populations

This study was a CRD experiment that planted M2 RD43 variant rice populations in 3 replications of 15 pots each, with 1 plant per pot, 10 inches in diameter, no holes and filled with 2:1:1 soil:raw rice husk:manure. After planting, 50 kg/rai urea fertilizer was sprayed for 1 month. After that, 30 kg/rai of 15-15-15 fertilizer was applied monthly till harvest. The 2-month-old was sprayed with pesticide. Morphological data were taken three months following planting. This comprised plant height, number of leaves, number of shoots per plant, plant circumference, leaf breadth, leaf length and SPAD values. Plant height was measured from base to its highest point. All enormous, fully spread leaves were counted. The number of shoots per plant was measured by counting each shoot. Measurements of the first shoot's circumference were obtained 5 cm above ground. The plant's first shoot's 3rd-order leaf was measured for leaf width characteristics. The middle and tip of the 3rd leaf of the first shoot from the base were measured for SPAD.

Study of yield component characteristics of M2 RD.43 variant rice populations

When rice was 5 months old, yield components were measured. After studying agro-morphology, yield component characteristics were examined. The number of ears, total seeds, full seeds, atrophied seeds, full seed weight, length and width were investigated. Total ears born on the rice plant were counted. The plant's total and per-plant atrophied seed numbers were calculated. All seeds, including atrophied and full ones, were counted per plant. For the number of full seeds in the plant, only all the complete seeds in the plant were counted. Sorting and weighing just complete seeds on a plant determined full seed weight. After 10 seed length measurements, the average seed length was calculated. After measuring 10 seed widths, the average was calculated.

Study of stomatal characteristics of M2 RD.43 variant rice populations

At 3 months of age, the fourth leaf of the first shoot from each treatment was collected, with 4 replicates per treatment and 10 plants per replicate. The stomatal width was measured at 50 stomata per plant, whereas the stomatal density was counted at 5 areas of each plant. The stomata were made more visible using adhesive by applying a thin layer of adhesive to the abaxial side of the midpoint of the fourth leaf. When the adhesive was dry, it was peeled off and placed on a glass microscope slide for stomatal analyses. Stomatal characteristics were examined using a 40x microscope (Euromex, Netherlands). The stomatal width was measured from the center of the widest stomatal area. The stomatal length is measured from both ends of the stomata. Stomatal density was determined by counting the number of stomata from 5 fields (with a leaf area of 1 mm^2) of each plant visible under the microscope.

Statistical analysis

A completely randomized design was used. There were 8 treatments in the study: RD.43, RD.43-variant1, RD.43-variant2, RD.43-variant3, RD.43-variant4, RD.43-variant5, RD.43-variant6 and RD.43-variant7. Subsequently, wherever the F test was significant, mean comparisons were conducted using DMRT. All analyses were performed *via* the SPSS version 16 package.

Study of the correlation between the morphological characteristics and yield components of RD.43 M2 variant rice varieties

The correlation coefficients were used to describe the relationships among agronomic traits and some phenotypic traits. Correlation analysis between traits was performed *via* the SPSS version 16 software package.

RESULTS AND DISCUSSION

Morphological characteristics of RD.43 rice and the M2 variant population of RD.43 rice

Morphological characteristics for RD.43 rice and M2RD. 43variants were recorded after 3 months of cultivation. Compared to RD.43 rice, M2 RD.43 variant1 rice had more leaves, shoots and first shoot diameter but lower plant height, leaf width, leaf length, leaf thickness and leaf SPAD values. RD.43 M2 variant2 rice had more leaves and shoots than RD.43 rice but lower plant height, leaf width, leaf length, leaf thickness, first shoot diameter and leaf SPAD. RD.43 M2 variant3 rice had more leaves, leaf width, leaf thickness, first shoot diameter and shoot per plant than RD.43 rice,

Table 1: Morphological characteristics of RD.43 M2 variant rice varieties.

Varieties	Plant height (cm)	Number of leaves	Leaf width (cm)	Leaf length (cm)	Leaf thickness (mm)	First shoot diameter (mm)	Number of shoot	SPAD
RD.43	100.62±0.51 ^{b}	45.30±1.21 ^{d}	1.17±0.08 $^{a-c}$	41.34±3.56	0.47±0.03 ^{b}	5.14±0.30	9.70±0.46 ^{d}	33.63±2.71 ^{a}
RD.43-variant1	96.14±1.52 $^{b-c}$	46.60±7.22 ^{d}	1.08±0.07 $^{b-c}$	40.69±2.31	0.42±0.04 ^{b}	5.19±0.67	11.00±0.72 ^{c}	27.00±2.21 ^{b}
RD.43-variant2	95.09±0.31 $^{b-c}$	58.83±4.88 $^{a-b}$	1.08±0.05 $^{b-c}$	41.28±3.12	0.41±0.02 $^{b-c}$	5.00±0.26	13.10±1.14 ^{b}	20.23±1.31 ^{c}
RD.43-variant3	92.36±1.55 ^{c}	63.47±2.80 ^{a}	1.19±0.04 $^{a-c}$	38.36±2.55	0.58±0.04 ^{a}	5.55±0.12	14.03±0.70 ^{b}	27.99±2.52 ^{b}
RD.43-variant4	96.15±1.02 $^{b-c}$	47.83±4.62 $^{c-d}$	1.06±0.03 ^{c}	41.15±1.98	0.42±0.06 ^{b}	5.25±0.30	11.53±0.85 ^{c}	29.56±1.49 $^{a-b}$
RD.43-variant5	93.42±1.30 $^{b-c}$	33.96±9.76 ^{e}	1.16±0.06 $^{a-c}$	40.16±2.38	0.36±0.01 $^{c-d}$	5.30±0.73	12.77±0.57 ^{b}	30.31±3.23 $^{a-b}$
RD.43-variant6	107.61±10.72 ^{a}	56.94±5.89 $^{a-c}$	1.30±0.06 ^{a}	43.91±4.03	0.33±0.01 ^{d}	5.08±0.44	15.71±1.15 ^{a}	29.22±3.58 $^{a-b}$
RD.43-variant7	100.03±1.36 ^{b}	50.50±4.33 $^{b-d}$	1.21±0.13 $^{a-b}$	46.07±4.81	0.33±0.02 ^{d}	5.41±0.48	13.97±0.64 ^{b}	31.15±1.13 $^{a-b}$
F-test	**	**	*	ns	**	ns	**	**
% CV.	3.99	10.32	6.10	7.83	9.58	8.10	5.33	8.96

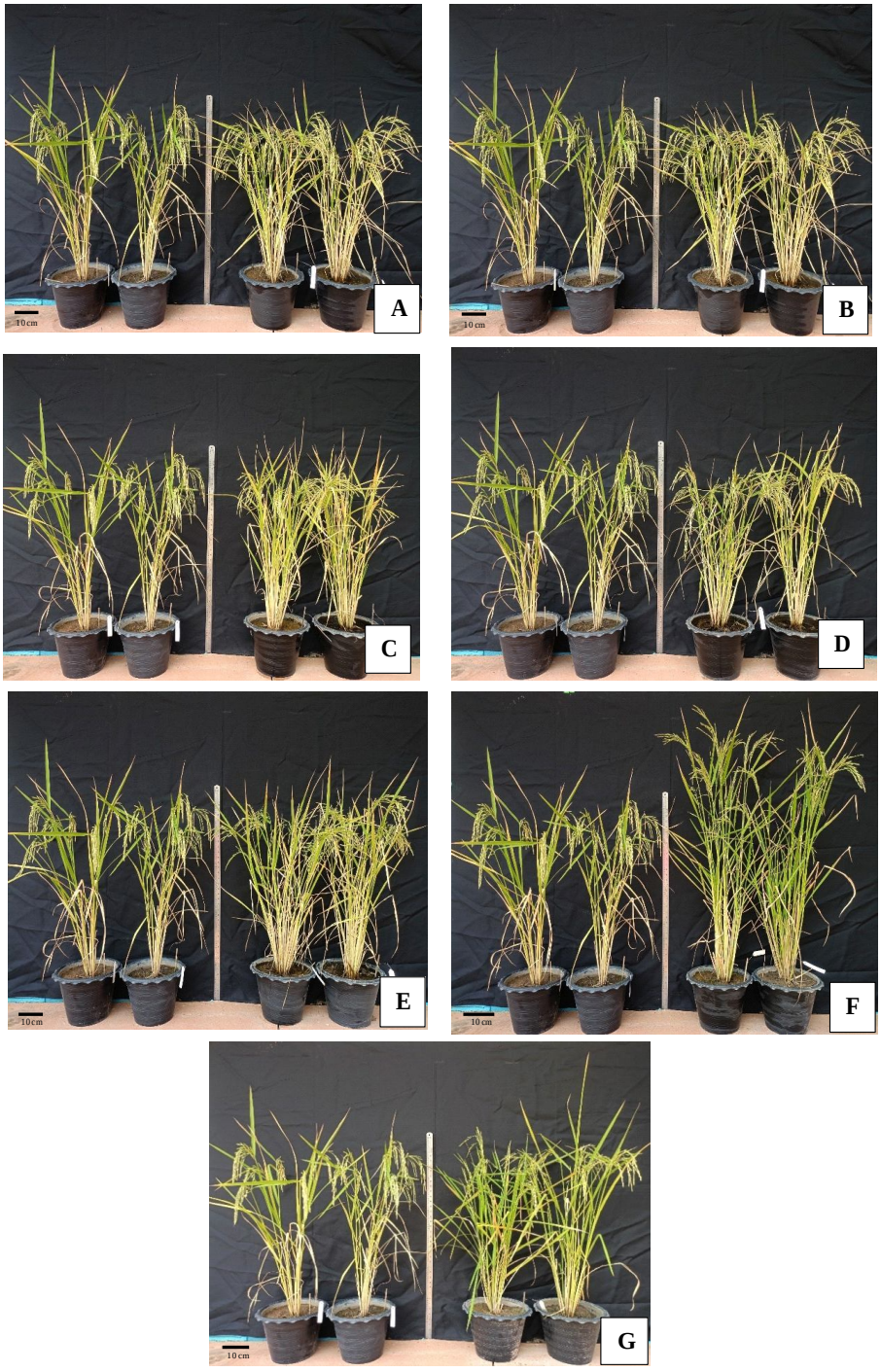
Different superscripts in each column indicate significant (p<0.05) differences; ns = non-significant; ** = highly significant (p<0.01); * = significant (p<0.05); ± standard deviation.

but lower plant height, leaf length and leaf SPAD. RD.43 M2 variant4 rice has more leaves, first shoot diameter and shoot number than RD.43 but lower plant height, leaf width, length, thickness and SPAD. RD.43 M2 variant5 rice exhibited higher first shoot diameter and shoot number per plant but lower plant height, leaf number, width, length, thickness and SPAD than RD43 rice. RD.43 M2 variant6 rice had higher plant height, number of leaves, leaf width, leaf length and number of shoots than RD.43 rice, but lower leaf thickness, first shoot diameter and leaf SPAD. RD.43 M2 variant7 rice showed higher leaf number, width, length, first shoot diameter and number of shoots per plant than RD.4 Thrice but lower plant height, leaf thickness and leaf SPAD (Fig 1, Table 1). Previous studies of the effects of colchicine in M1 generation in several plant species (Surson *et al*., 2018; Surson *et al*., 2024a; Surson *et al*., 2024b; Surson *et al*., 2024c; Surson *et al*., 2025) found that colchicine also altered the morphological characteristics of these plants, some of which were beneficial and improved the yield component of those plants. This study examined the morphological characteristics, yield components, stomatal morphology and correlations of various rice variant traits to determine the potential of colchicine-mutated RD.43 variant rice for selection and breeding for environmental resistance and yield improvement. The study examined characteristics including height, yield and awn seed production in mutant RD.43 M1 variant rice plants. Seeds were then collected and segregated (M2 RD.43 variant population). To find associations, morphological, yield and stomatal variables were evaluated. The morphological characteristics of RD.43 M2 rice in each group were inconsistent or showed significant differences, indicating that the population was dispersed in the M2 generation. The study found differences among the different RD.43 M2 populations (RD.43 M2 1-7), indicating that colchicine affected different maternal plants in the maternal plant (RD.43 M1) at different gene loci. Colchicine caused chromosome aberrations (Khah *et al*., 2022; Barman *et al*., 2021) and molecular DNA changes (El-Nashar and Ammar, 2016; Zeinullina *et al*., 2023). These alterations considerably affected rice morphology in this study.

Characteristics of the yield components of the rice variety RD.43 and the M2 variant plant populations of the rice variety RD.43

The yield components of RD.43 rice and RD.43 M2 variant1 rice showed that the latter had more panicles, full seeds, withered seeds, awn seeds, total seeds, weight of full seeds and seed length. Alternative RD.43 M2 variant1 rice had a smaller seed width and set % than RD.43 rice. RD.43 M2 variant2 rice had more panicles, withered seeds, awn seeds, total seeds, seed width and seed length than RD.43 rice, but fewer full seeds, weight of full seeds and percentage of seed set. RD.43 variant3 rice had more panicles, withered seeds, awn seeds, total seeds, seed width and seed length than RD.43 rice, but fewer full seeds, weight of full seeds

and percentage of seed set. RD.43 M2 variant4 rice had more panicles, withered seeds, awn seeds and total seeds/ plants than RD.43 rice, but fewer full seeds, weight of full seeds, seed width, seed length and percentage of seed set. RD.43 M2 variant5 rice had more panicles, withered seeds, awn seeds and total seeds than RD. 43 rice, but fewer full seeds, weight of full seeds, seed width, seed length and percentage of seed set. RD.43 M2 variant6 rice had more panicles, withered seeds, awn seeds and total seeds than RD.43 rice, but fewer full seeds, weight of full seeds, width, length and percentage of seed set. RD.43 M2 variant7 rice had more panicles, withered seeds, awn



(A; RD.43 M2 Variant1, B: RD.43 M2 Variant2, C: RD.43 M2 Variant3, D: RD.43 M2 Variant4, E: RD.43 M2 Variant5, F: RD.43 M2 Variant6, G: RD.43 M2 Variant7).

Fig 1: Rice plants: left is normal plant and right is RD.43 variant plant .

Table 2: Yield component of RD.43 M2 variant rice varieties.

Varieties	Number of panicles/plant	Number of full seed/plant	Number of withered seed/plant	Number of awn seed/plant	Number of total seed	Weight of full seed(g)	Seed width (cm)	Seed length (cm)	Percentage of seed set(%)
RD.43	9.87±0.49 ^{d}	526.32±59.87 $^{a-b}$	680.47±55.35 ^{c}	0.00±0.00 ^{c}	1189.60±15.54 ^{c}	13.52±3.17 ^{a}	0.26±0.01	1.03±0.01	44.21±4.51 ^{a}
RD.43-variant1	13.57±0.91 ^{b}	554.00±73.52 ^{a}	987.43±64.21 ^{b}	15.47±1.97 $^{a-b}$	1551.67±114.90 $^{a-b}$	14.03±0.61 ^{a}	0.26±0.00	1.05±0.01	35.64±2.73 ^{b}
RD.43-variant2	14.73±1.33 $^{a-b}$	465.83±85.74 $^{a-b}$	1263.97±136.72 ^{a}	17.45±3.29 $^{a-b}$	1743.10±211.96 ^{a}	12.21±1.76 ^{a}	0.27±0.00	1.05±0.01	26.60±2.24 ^{c}
RD.43-variant3	15.04±0.95 ^{a}	455.94±111.09 $^{a-b}$	1116.35±17.42 $^{a-b}$	22.42±2.42 $^{a-b}$	1602.04±148.29 $^{a-b}$	12.11±2.37 ^{a}	0.27±0.01	1.05±0.01	28.20±4.34 ^{c}
RD.43-variant4	11.97±0.12 ^{c}	432.16±47.17 $^{a-b}$	974.27±29.98 ^{b}	10.92±3.23 $^{b-c}$	1399.03±26.21 $^{b-c}$	12.19±1.29 ^{a}	0.26±0.00	1.00±0.00	30.85±2.82 $^{b-c}$
RD.43-variant5	15.84±1.18 ^{a}	240.29±102.74 ^{d}	1255.00±49.76 ^{a}	28.29±8.12 ^{a}	1523.70±132.42 $^{a-b}$	7.47±3.44 ^{b}	0.26±0.01	0.99±0.00	15.47±5.77 ^{d}
RD.43-variant6	16.07±1.01 ^{a}	298.16±34.62 $^{c-d}$	1272.89±189.38 ^{a}	28.53±17.73 ^{a}	1599.14±218.43 $^{a-b}$	7.47±0.54 ^{b}	0.26±0.01	0.99±0.02	18.75±2.07 ^{d}
RD.43-variant7	13.33±0.41 $^{b-c}$	409.04±23.81 $^{b-c}$	1015.43±149.23 ^{b}	14.17±2.54 ^{b}	1436.24±171.88 ^{b}	11.19±0.57 ^{a}	0.26±0.01	1.34±0.54	28.62±1.78 ^{c}
F-test	**	**	**	**	**	**	ns	ns	**
% CV.	5.71	16.24	8.85	41.24	8.05	14.71	2.11	14.16	12.87

Different superscripts in each column indicate significant (p<0.05) differences; ns = non-significant; ** = highly significant (p<0.01); * = significant (p<0.05); ± standard deviation

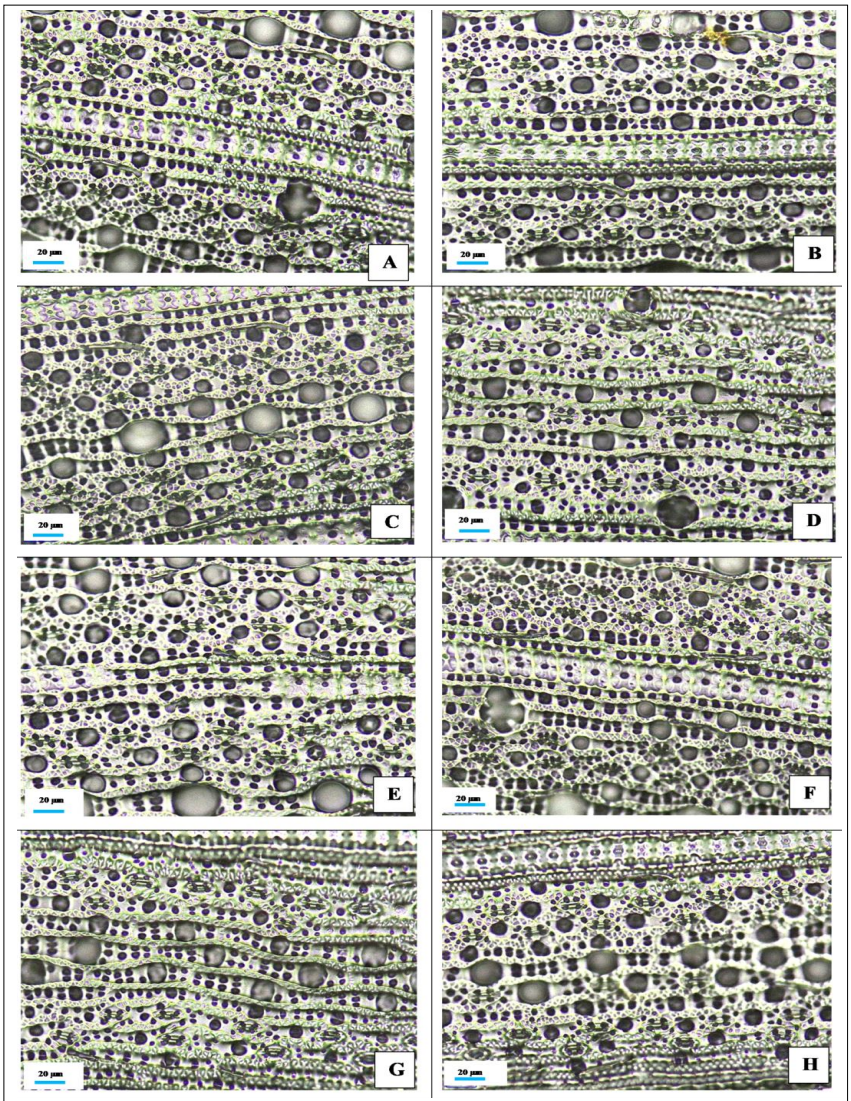
seeds, total seeds and seed length than RD.43, but fewer full seeds, weight of full seeds, width and percentage of seed set (Table 2). The investigation began by selecting mutated M1 RD.43 variant rice plants based on yield and awn seed incidence in the M1 generation. Later, the M2 RD.43 variant population seeds were collected and sorted and yield components were compared. The examination of yield components of M2 RD.43 variant rice in each group showed that each plant had inconsistent or considerable variability, suggesting that the population had distributed in the M2 generation. The study also observed variations between each M2 RD.43 variant population (M2RD.43 variant1-7), suggesting that colchicine affected each mother plant differently. Colchicine may induce mutations at different gene loci in different maternal plants (M1 RD.43 variant plant). Colchicine caused chromosome aberration (Khah *et al*., 2022; Barman *et al*., 2021) and molecular DNA changes (El-Nashar and Ammar, 2016; Zeinullina *et al*., 2023) in several experimental studies. These alterations considerably altered rice morphology and yield in this study. Since the M2 RD.43 variation 7 population was generated from a tall mother plant (M1 RD.43 variant 7) and had awns in almost all seed, there were both tall and short rice plants in the M2 generation. In addition, the M2 generation (from the same mother plant) had plants with many, few and no awned seeds, indicating that the RD.43 variation exhibited diverse phenotypes. Induced polyploidy in rice produces tetraploid plants with awn seeds (Song *et al*., 2014). This study found that colchicine induced rice plants to develop awn seeds without chromosomal duplication or polyploidy using flow cytometry. The presence of awn seeds alone should not indicate polyploidy or be used to select tetraploid plants. In rice types without awn, awn seeds can suggest mutagenesis (Table 2).

Stomatal characteristics of rice variety RD.43 and M2 variant plant populations of rice variety RD.43

RD.43 and RD.43 M2 variant stomatal characteristics comparison, the RD.43 M2 variants had similar stomatal width, length and density. This may be because the rice variety RD.43 and the RD.43 M2 variant had the same chromosomal numbers, therefore no stomatal changes were found. Many investigations showed that polyploid plants have bigger stomata than diploid plants (Mo *et al*., 2020; Khan, 2023). Some investigations found that colchicine increased stomata (Moghbel *et al*., 2015) (Table 3, Fig 2).

Characteristics of correlations of rice variety RD.43 and M2 variant plant populations of rice variety RD.43

A study of RD.43 rice treated with colchicine revealed that the number of panicles was related to the number of full seeds, withered seeds, awn seeds, total seeds, weight of full seeds, seed set percentage and rice shoots. As panicles increased, the number of full seeds, weight of full seeds and percentage of seed set decreased whereas withered seeds, awn seeds, total seeds and rice shoots



(A) RD.43 M2 Variant1 (B), RD.43 M2 Variant2 (C), RD.43 M2 Variant3 (D), RD.43 M2 Variant4 (E), RD.43 M2 Variant5 (F), RD.43 M2 Variant6 (G), RD.43 M2 Variant7 (H).

Fig 2: Stomata of normal rice plants RD.43.

Table 3: Stomatal characteristics of RD.43 M2 variant rice varieties.

Varieties	Stomata width (μm)	Stomata length (μm)	Stomata density (mm^{-2})
RD.43	11.13±0.27	21.44±0.40	460.94±28.67
RD.43-variant1	10.87±0.36	22.04±0.59	431.65±14.37
RD.43-variant2	11.46±0.32	21.77±0.66	472.73±21.87
RD.43-variant3	11.58±0.43	22.09±0.12	454.88±25.04
RD.43-variant4	12.11±0.76	22.62±0.87	469.70±14.67
RD.43-variant5	11.21±0.16	23.22±2.99	466.33±12.71
RD.43-variant6	11.48±0.29	22.88±2.53	442.09±28.26
RD.43-variant7	12.48±1.43	21.57±0.27	470.71±30.65
F-test	ns	ns	ns
% CV.	5.50	6.60	5.02

Different superscripts in each column indicate significant (p<0.05) differences; ns = Non-significant; ** = Highly significant (p<0.01); * = Significant (p<0.05); ± standard deviation.

Table 4: Correlation table of morphological characteristics and yield components of RD.43 rice variety treated with colchicine.

	NP	NFS	NWS	NAS	NTS	WFS	SW	SL	PSS	PH	NL	LW	LL	LT	FSD	NS	SPAD
NP	1	-0.416*	0.909**	0.805**	0.794**	-0.474*	0.043	-0.087	-0.765**	0.010	0.289	0.384	0.016	-0.207	0.094	0.786**	-0.344
NFS	-0.416*	1	-0.452*	-0.508*	0.081	0.912**	0.122	0.080	0.873**	-0.043	0.302	-0.214	0.013	0.398	-0.023	-0.451*	-0.229
NWS	0.909**	-0.452*	1	0.708**	0.849**	-0.439*	-0.032	-0.119	-0.811**	0.063	0.260	0.244	0.134	-0.269	0.041	0.729**	-0.501*
NAS	0.805**	-0.508*	0.708**	1	0.523**	-0.459*	-0.027	-0.149	-0.714**	-0.138	0.222	0.378	0.021	-0.169	-0.009	0.675**	-0.120
NTS	0.794**	0.081	0.849**	0.523**	1	0.028	0.053	-0.083	-0.398	0.028	0.480*	0.180	0.152	-0.066	0.054	0.572**	-0.669**
WFS	-0.474*	0.912**	-.0439*	-0.459*	0.028	1	0.083	0.081	0.818**	-0.162	0.221	-0.362	-0.073	0.385	-0.157	-0.480*	-0.267
SW	0.043	0.122	-0.032	-0.027	0.053	0.083	1	0.307	0.063	-0.426*	0.211	-0.059	-0.196	0.175	-0.047	0.050	-0.325
SL	-0.087	0.080	-0.119	-0.149	-0.083	0.081	0.307	1	0.093	0.051	0.016	-0.051	0.277	-0.073	0.368	0.060	0.123
PSS	-0.765**	0.873**	-0.811**	-0.714**	-0.398	0.818**	0.063	0.093	1	0.020	0.059	-0.234	-0.010	0.380	-0.080	-0.685**	0.122
PH	0.010	-0.043	0.063	-0.138	0.028	-0.162	-0.426*	0.051	0.020	1	0.086	0.413*	0.587**	-0.403	-0.018	0.184	0.144
NL	0.289	0.302	0.260	0.222	0.480*	0.221	0.211	0.016	0.059	0.086	1	0.346	0.112	0.352	0.049	0.521**	-0.345
LW	0.384	-0.214	0.244	0.378	0.180	-0.362	-0.059	-0.051	-0.234	0.413*	0.346	1	0.455*	-0.185	0.141	0.602**	0.341
LL	0.016	0.013	0.134	0.021	0.152	-0.073	-0.196	0.277	-0.010	0.587**	0.112	0.455*	1	-0.460*	0.093	0.202	0.044
LT	-0.207	0.398	-0.269	-0.169	-0.066	0.385	0.175	-0.073	0.380	-0.403	0.352	-0.185	-0.460*	1	0.266	-0.280	-0.026
FSD	0.094	-0.023	0.041	-0.009	0.054	-0.157	-0.047	0.368	-0.080	-0.018	0.049	0.141	0.093	0.266	1	0.148	0.325
NS	0.786**	-0.451*	0.729**	0.675**	0.572**	-0.480*	0.050	0.060	-.0685**	0.184	0.521**	0.602**	0.202	-0.280	0.148	1	-0.133
SPAD	-0.344	-0.229	-0.501*	-0.120	-0.669**	-0.267	-0.325	0.123	0.122	0.144	-0.345	0.341	0.044	-0.026	0.325	-0.133	1

** = Highly significant (p<0.01); * = Significant (p<0.05); NP = Number of panicles/plant, NFS = Number of full seeds/plant, NWS = Number of withered seeds/plant, NAS = Number of awn seeds/plant, NTS = The number of total seeds/plant, WFS = The weight of full seed /plant, SW = Seed width, SL = seed length, PSS = Percentage of seed set, PH = Plant height, NL = Number of leaves, LW = Leaf width, LL = Leaf length, LT = Leaf thickness, FSD = First shoot diameter, NS = Number of shoot, SPAD = SPAD value.

increased. Full seed number was related to panicles, withered seeds, awn seeds, weight, seed set % and shoots. Increasing the number of full seeds lowered panicles, withered seeds, awn seeds and shoots, as did the weight of full seeds per plant, but improved seed set. The number of panicles, full seeds, awn seeds, total seeds, full seed weight, seed set %, shoots and SPAD value affected the number of withered seeds. As the number of withered seeds increased full seeds, full seed weight, seed set % and SPAD value decreased. However, as withered seeds increased, so did panicles, awn seeds, total seeds and shoots. The number of awn seeds was related to panicles, full seeds, withered seeds, total seeds, full seed weight, seed set % and shoots. As awn seeds increased, full seeds, full seed weight and seed set % decreased. Panicles, withered seeds, total seeds and shoots increased. Correlation studies of various traits revealed several interesting traits, such as the rice trait that had numerous awn seeds, which increased panicles, withered seeds, total seeds and shoots but decreased full seeds, full seed weight and seed set. The number of shoots increased the number of panicles, withered seeds, awn seeds, leaves, leaf width and leaf length, but decreased the number of full seeds, full seed weight, percentage of seed set, *etc* (Table 4). However, correlation studies between morphological traits and yield component characteristics are scarce and poorly documented (Taratima *et al*., 2020; Gaafar, 2017; Chen, 2021).

CONCLUSION

After selecting RD.43 M1 variant rice plants with mutations in height, yield and awn seed occurrence, the M2 generation populations were generated. Morphology, yield components and stomatal variability in each M2 population from the same M1 plant showed inconsistency. The distribution of M2 generation offspring from the mutated M1 mother plant caused this variation. Colchicine's actions on each M1 mother plant's chromosomes, DNA molecules and genes at different locations caused population differences in RD.43 M2 variants. Some rice features were discovered to be connected to yield, therefore these associations can be utilized to select high-yielding plants.

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Disclaimers

The opinions and findings articulated in this article are exclusively those of the writers and do not always reflect the perspectives of their connected institutions. The writers bear responsibility for the truth and completeness of the material presented; nevertheless, they disclaim all duty for direct or indirect damages arising from the use of this content.

Conflict of interest

The authors declare that there are no conflicts of interest.

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