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Characterization of M8 Wheat Mutant Adaptability to Low Land

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Abstract

The wheat requirement in Indonesia is still fulfilled by import, which increases annually. To reduce the import dependence, Indonesia is required to elevate the domestic wheat production appropriate to the Indonesian agroclimatic condition by wheat plant breeding mutation. This study was aimed to characterize several mutant wheat commodities, that are adaptive to lowland condition. The experiment was arranged in a completely randomized block design with 16 observed-wheat genotypes (G). The wheat genotypes used were: 1) (G1) N1 200 2.4.B.6, 2) (G2) N 200 2.3.3, 3) (G3) N 200 2.5.2, (G4) N 350 3.6.2, (G5) N 350 3.7.1, (G6) N 300 3.6.1, (G7) N 350 3.1.3, (G8) N 250 3.7.1, (G9) M 200 1.7.1, (G10) S 300 7.9.1, (G11) S 300 2.1, (G12) D 200, and several comparative varieties, such as (G13) *Guri-3*, (G14) *Selayar*, (G15) *Nias*, and (G16) *Dewata*. The results obtained that the lowland-adapted M8 wheat mutant with high productivity level was found in N 200 2.4.B.6 (2.75 $t.ha^{-1}$), N 200 2.3.3 (2.69 $t.ha^{-1}$), and D 350 3.6.2 (2.35 $t.ha^{-1}$). Characters with the highest heritability level were number of tillers, number of productive tillers, seed weight per panicle, and production. Meanwhile, characters, that were correlated with production, were plant height, number of tillers, number of productive tillers, harvesting age, seed-filling period, number of spikelets per panicle, percentage of empty florets, number of seeds per panicle, and seed weight per panicle

Keywords: characteristics, lowland, wheat

A. Introduction

Wheat (*Triticum aestivum* L.) is an important food commodity in the world and the second most important food, after rice, both as a caloriandor proteomic source. The protein level in wheat is 13% and the carbohydrate level is 69% (Suriani & Farid, 2014). Wheat is required as the main ingredient for wheat flour in Indonesia, which continues to increase along with the wheat flour needs (Silahturrohmah, S., Roviq, M., & Barunawati, N., 2019). The wheat import tends to fluctuate annually due to high demand and a growing number of inhabitants. The wheat requirement in Indonesia has massively been obtained from the import activity, whereas 11.43 million tons in 2017, 10.09 million tons in 2018, 10.69 million tons in 2019, and 10.29 million tons in 2020 (BPS, 2021). To reduce import dependence, Indonesia needs to improve domestic wheat production.

Domestic wheat production needs to be supported by available wheat varieties appropriate to the agroclimatic condition in Indonesia. Different height levels may affect the whole climate component difference in the following location (Mardi & Wahyu, 2022). Therefore, wheat development prior to the agroclimatic condition in Indonesia is necessary. This development program has also been conducted by the Agricultural Research and Development Center through the multilocation test of wheat plants from India and CIMMYT (International Maize and Wheat Improvement Center) in 2003. Based on the adaptation test, two wheat varieties adaptable to highland/low temperatures in Indonesia were found, namely variety Selayar and Dewata varieties, which were released at the end of 2003 (Talanca & Andayani, 2015). However, wheat plant cultivation in the highlands is uneconomical due to high competition with other horticultural plant commodities. Therefore, wheat plant cultivation in the lowland is necessary to conduct (Wicaksono, F. Y., Nurmala, T., Irwan, A. W., & Putri, A. S. U., 2016). Furthermore, evaluation and genotype selection from the mutated wheat product should be proceeded to obtain high-temperature-adapted wheat, based on the location height.

One of the frequent physical mutagenic activities is gamma-radiation. The mutation induction technique is extremely good for plants without parental sources. According to Witjaksono (2003), the wheat plant in Indonesia is included in the lowest genetic variation, as gaining the new superior character with a hybridization technique is difficult to conduct. The genetic variation increase and improvement can be performed by cross-breeding and genetic mutation induction. The previous study applied several wheat varieties to identify, namely M1 by *300-Gy* gamma-radiation, M2 by determining the population variety, M3 by high-temperature stress selection, M4 by optimal environmental selection, and M5 by high-temperature stress selection (Nur, 2013). Meanwhile, the previous activities of wheat mutant lines to produce a higher production were found in N.350.3.8.9 (2.31 t. ha^{-1}) and N.200.2.4.B.6 (2.66 t. ha^{-1}) (Nasaruddin Farid, Yunus, dan Hari, 2018).

The results assembled varieties need to maintain their genetic purity to get maximum results. Variety identification during the assemblage is necessary to be performed for differing the lines produced by the available variety. However, the variety identification method can only be performed conventionally, more inefficient, time-consuming, complicated observation, and relatively expensive price, if applied in routine testing. Therefore, a cheap and fast way without specific tools should be developed to assist seed purity identification with reliable accuracy. Based on the description above, a further study regarding the characterization of mutant wheat adaptability to lowlands was performed

B. Methodology

This study was conducted in the Experimental Field, Faculty of Agriculture, Hasanuddin University, Tamalanrea Sub-District, Makassar, South Sulawesi at 22.4 m above sea level throughout July-October, 2022. The experiment was arranged in a completely randomized block design with 16 observed-wheat genotypes (G) as the treatments and three replications. Thus, there were 48 trial plots observed in this study. Each plot was represented by five plant samples, thereby 240 samples from the plots were observed in this study. The wheat genotypes used were: 1) (G1) N1 200 2.4.B.6, 2) (G2) N 200 2.3.3, 3) (G3) N 200 2.5.2, (G4) N 350 3.6.2, (G5) N 350 3.7.1, (G6) N 300 3.6.1, (G7) N 350 3.1.3, (G8) N 250 3.7.1, (G9) M 200 1.7.1, (G10) S 300 7.9.1, (G11) S 300 2.1, (G12) D 200, and several comparative varieties, such as (G13) *Guri-3*, (G14) *Selayar*, (G15) *Nias*, and (G16) *Dewata*.

The parameters observed were plant height, number of tillers, number of productive tillers, panicle length, number of spikelets, number of empty spikelets, the weight of seeds per panicle, the weight of 1000 grains, leaf chlorophyll content, number of stomata, and productivity, seed color, growth behavior, number of flag leaves, panicle color, culm length, and bottom husk. Data analysis was performed by analysis of variance with the Least-Significant Different (LSD) test at a 0.05 confidence level. To find out the relationship between the characters, regression and correlation studies were carried out, while the genetic diversity of mutant genotypes was carried out by heritability analysis

C. Result and Discussion

The LSD test results from Table 1 indicate that the N200.2.4.B.6 (g1) obtained the highest plant height (57.00 cm), which was significantly different from the comparative varieties, namely Guri-3 (a) and Selayar (b). Based on the number of tillers, the N 200 2.4.B.6 (g1) also had the most tillers (5.60 tillers) and was significantly different from the comparative varieties, namely Selayar (b), Nias (c), and Dewata (d), while the number of productive tillers showed that the N 200 2.4.B.6 (g1) had the most productive tillers (4.53 tillers) and was significantly different from the comparative varieties, such as *Guri-3* (a) and *Dewata* (d).

Table 1. Plant height, number of tillers, and number of productive tillers in M8 wheat genotypes

Genotypes	Plant height	Number of tillers	Number of productive tillers
(g1) N 200 2.4.B.6	57.00 **ab**	5.60 **bcd**	4.53 **ad**
(g2) N 200 2.3.3	47.70	4.60 d	3.93 d
(g3) N 200 2.5.2	42.43	2.73	2.27
(g4) N 350 3.6.2	48.93	4.20 d	3.67
(g5) N 350 3.7.1	48.93	2.67	2.40
(g6) N 300 3.6.1	46.47	2.40	2.13
(g7) N 350 3.1.3	49.00	2.67	2.13
(g8) N 250 3.7.1	48.47	1.87	1.67
(g9) M 200 1.7.1	48.97	3.53	3.00
(g10) S 300 7.9.1	50.70	2.53	2.00
(g11) S 300 2.1	48.03	3.00	2.60
(g12) D 200	45.33	2.80	2.07
(g13) Guri-3 (a)	50.00	5.07	3.93
(g14) Selayar (b)	46.87	4.53	4.27
(g15) Nias (c)	55.40	4.27	4.20
(g16) Dewata (d)	53.73	3.40	3.27
NP LSD 5%	6.28	0.58	0.49

Note: Numbers followed by the same letter in the column (abcd) indicate a highly significant difference from the comparative varieties of *Guri-3* (a), Selayar (b), Nias (c), and Dewata (d), based on the LSD test level = 0.05

The number of productive tillers was affected by an environmental factor, namely air temperature, whereas higher air temperature tended to inhibit the number of productive tiller growth. This condition followed Andriani & Isnaini (2011), that the number of tillers depended on the variety and environmental conditions. Each tiller has the potential to produce one panicle. The number of tillers importantly contributes to the harvesting product. This condition was similar to Rachmadani, S., Damanhuri, D., & Soetopo, L. (2017), that the number of tillers could directly affect the product per plant as part of the selection criteria to gain a highly potential wheat genotype. The higher number of productive tillers, the more seed produced in the plants.

Based on the LSD test results from Table 2, the N 350 3.1.3 (g7) obtained the fastest flowering day (43.33 DAP) and was significantly different from the comparative varieties, namely Guri-3 (a) and Selayar (b), while seed-filling rate showed that the N 200 2.4.B.6 (g1) obtained the fastest seed filling (27.47 days) and was significantly different from the comparative varieties, namely Guri-3 (a), Selayar (b), and Dewata (d). The flowering day in the wheat plant can also be affected by the environment, mainly temperature. High temperatures can accelerate the flowering process. Wheat planted in lowland flowers faster than in highland (<400 asl). This condition was caused by the lowland environmental condition is more supportive for wheat growth, based on the temperature, humidity, and sunlight level. Wahyu, Y., Samosir, A. P., & Budiarti, S. G (2013) performed a study on wheat and stated that the flowering day of wheat in the lowland was about 43-70 DAP. A faster harvesting day was thought due to temperature stress in the lowland. Besides environmental conditions, the factor of land height can also affect the flowering day and harvesting period. Wahyu *et al* (2013) stated that extremely high air temperatures could affect the harvesting period in several wheat varieties in the low-elevated area.

Table 2. Flowering Day, Harvesting Period, and Seed Filling Rate in M8 wheat genotypes

Genotype	Flowering Day		Harvesting Period		Seed Filling Rate	
(g1) N 200 2.4.B.6	44.80		72.93	**ab**	27.47	**abd**
(g2) N 200 2.3.3	46.47		73.93	ab	28.13	ab
(g3) N 200 2.5.2	46.73		77.67		30.93	
(g4) N 350 3.6.2	47.67		77.20		29.53	a
(g5) N 350 3.7.1	46.87		76.93		30.07	a
(g6) N 300 3.6.1	46.33		78.33		32.00	
(g7) N 350 3.1.3	43.33	**ab**	75.80	a	32.80	
(g8) N 250 3.7.1	43.60	b	73.07	ab	29.47	a
(g9) M 200 1.7.1	44.20		77.13		32.93	
(g10) S 300 7.9.1	47.87		76.93		29.07	a
(g11) S 300 2.1	47.93		79.93		32.00	
(g12) D 200	47.07		78.80		31.73	
(g13) Guri-3 (a)	46.47		79.53		33.07	
(g14) Selayar (b)	46.80		78.07		31.27	
(g15) Nias (c)	44.80		74.87		30.07	
(g16) Dewata (d)	44.47		75.33		30.87	
NP LSD 5%	**2.96**		3.51		2.97	

Note: Numbers followed by the same letter in the column (abcd) indicate a highly significant different from the comparative varieties of *Guri-3* (a), *Selayar* (b), *Nias* (c), and *Dewata* (d), based on the LSD test level = 0.05

The LSD test results from Table 3 present that the N 250 3.7.1 (g8) obtained the highest panicle length (8.47 cm) and was significantly different from the comparative varieties of *Guri-3* (a), *Selayar* (b), and *Dewata* (d). The number of spikelets per panicle data presents that the N 200 2.4.B.6 (g1) has the highest value and (13.20 spikelets) and was significantly different from the comparative varieties of Guri-3 (a) and Nias (c). Furthermore, the number of seeds per panicle data indicates that the N 200 2.4.B.6 (g1) had the highest value (28.13 seeds) and was significantly different from the comparative varieties.

Panicle length is a product component that has a direct connection to the number of spikelets. Based on Kirby (2002), the longer panicle found, the more spikelets formed as a potential of a greater number of seeds produced. The panicle length also showed an interaction after the temperature stress treatment (Syuryawati, Rahmi YA, Zubachtirodim, 2007).

Table 3. Panicle Length, Number of Spikelets per panicle, and number of seeds per panicle in M8 Wheat genotypes.

Genotype	Panicle Length		Number of Spikelets per Panicle		Number Of Seeds Per Panicle	
(g1) N 200 2.4.B.6	8.40	ad	13.20	**ac**	28.13	**abcd**
(g2) N 200 2.3.3	8.23	d	12.60	a	24.90	abd
(g3) N 200 2.5.2	7.60		12.00		23.80	a
(g4) N 350 3.6.2	8.00		13.00	ac	24.80	ab
(g5) N 350 3.7.1	8.03		12.87	ac	22.07	
(g6) N 300 3.6.1	7.50		11.80		23.33	a
(g7) N 350 3.1.3	8.33	ad	12.13		20.33	
(g8) N 250 3.7.1	8.47	**abd**	12.60	a	23.40	a
(g9) M 200 1.7.1	7.93		12.27		21.27	
(g10) S 300 7.9.1	8.10		12.53		20.13	
(g11) S 300 2.1	7.80		11.80		18.03	
(g12) D 200	7.77		12.00		20.87	
(g13) Guri-3 (a)	7.83		11.67		19.60	
(g14) Selayar (b)	7.93		12.33		20.13	
(g15) Nias (c)	8.03		11.73		21.87	
(g16) Dewata (d)	7.69		13.13		21.13	

NP LSD 5%	0.49	0.88	3.70

Note: Numbers followed by the same letter in the column (abcd) indicate a highly significant difference from the comparative varieties of *Guri-3* (a), Selayar (b), Nias (c), and Dewata (d), based on the LSD test level = 0.05

The LSD results in Table 4 present that the N 200 2.4.B.6 (g1) obtained the greatest number of seeds per panicle (28.88 seeds) and was significantly different from the comparative varieties of Guri-3 (a), Selayar (b), and Dewata (d). The seed weight per panicle data indicates that the N 200 2.4.B.6 (g1) obtained the highest weight (0.79 g), as also found in the weight of 1000 seeds (28.84 g), which was significantly different from all comparative varieties, while the production value showed that the N 200 2.4.B.6 (g1) was the most productive variety (2,75 $t.ha^{-1}$) and significantly different from all comparative varieties. Commonly, one spikelet per wheat panicle has three florets, each of which is filled with one wheat seed. Therefore, the greater number of spikelets, the greater number of florets formed. This condition was similar to Wahyu *et al.* (2013), who stated that a greater number of empty florets per panicle represents a lower number of seeds produced per panicle.

The increased number and percentage of empty florets in the lowlands was caused by the drought or no rainy weather during the seed filling period, followed by the increased temperature that caused the pollen development failure and seed production inhibition. The number of empty florets affects directly the decreased seed weight per panicle and wheat production per grove. The percentage of empty florets in the lowest value is quite tolerable, following Nur (2013), who mentioned that the genotype selection with low empty floret level should be performed to obtain a highly temperature-tolerant genotype in lowland cultivation.

Table 4. Number of Empty Florets, Weight per Panicle, Weight of 1000 seeds, and Production of M8 Wheat Genotypes

Genotype	Number of Empty Florets (%)		Seed weight per Panicle (g)		Weight of 1000 Seeds (g)		Production (ton. ha^{-1})	
(g1) N 200 2.4.B.6	28.88	**abcd**	0.79	**abcd**	28.84	**d**	2.75	**abcd**
(g2) N 200 2.3.3	34.13	abd	0.73	abcd	28.18	d	2.69	abcd
(g3) N 200 2.5.2	33.92	abd	0.66	abcd	25.24		1.22	
(g4) N 350 3.6.2	36.48	bd	0.73	abcd	24.88		2.35	abcd
(g5) N 350 3.7.1	42.86		0.59	abc	26.41		1.21	
(g6) N 300 3.6.1	33.62	abd	0.78	abcd	22.29		1.43	
(g7) N 350 3.1.3	44.09		0.50		28.81	d	0.87	
(g8) N 250 3.7.1	37.94		0.53	a	22.44		0.74	
(g9) M 200 1.7.1	42.12		0.61	abc	25.00		1.62	a
(g10) S 300 7.9.1	46.22		0.52	a	27.73	d	0.82	
(g11) S 300 2.1	48.96		0.35		27.56	d	0.83	
(g12) D 200	42.05		0.57	ab	27.47	d	0.98	
(g13) Guri-3 (a)	43.80		0.42		27.67		1.24	
(g14) Selayar (b)	45.47		0.46		26.65		1.74	
(g15) Nias (c)	37.96		0.49		28.63		1.82	
(g16) Dewata (d)	46.32		0.54		22.57		1.45	
NP LSD 5%	1.65		0.10		3.88		0.34	

Note: Numbers followed by the same letter in the column (abcd) indicate a highly significant different from the comparative varieties of *Guri-3* (a), *Selayar* (b), *Nias* (c), and *Dewata* (d), based on the LSD test level = 0.05

In Table 5, the highest heritability level is presented from the number of productive tillers' character (91.28%). Heritability level depends on the genotype and environment variance. Heritability is a variance proportion caused by the genetic factors against the phenotype variance. Heritability level is one of the genetic parameters considered for character selection (Wirnas, D., I. Widodo, Sobir, Trikoesoemaningtyas, D. Sopandie , 2006; Suharsono & Jusuf, 2009; Sungkono Trikoesoemaningtyas, D. Wirnas, D. Sopandie, 2009; Syukur M., S. Sujiprihati, A. Siregar, 2010; Yunianti R., S. Sastrosumarjo, S. Sujiprihati, M.Surahman, S.H. Hidayat, 2010; Barmawi *et al.*, 2013). Based on the highest heritability level, characters that can be considered as selection characters to choose the best family are the number of tillers, number of productive tillers, seed weight per panicle, and production.

Correlation denotes the amount of relationship occupied in the observed parameters. The correlation coefficient analysis results from Table 6 indicate the correlation of productivity character with other characters. This condition means that plant height, number of tillers, number of productive tillers, chlorophyll index, harvesting period, seed-filling period, number of spikelets per panicle, percentage of empty florets, production per grove, number of seeds per panicle, seed weight per panicle are significantly correlated with the production, as each of which has the correlation values of 0.39, 0.75, 0.78, 0.56, -0.33, -0.37, 0.33, -0.53, 0.99, 0.58, and 0.62, respectively.

Table 5. Heritability Level in M8 Wheat mutants.

No	Characters	Heritability	Classification
1	Plant height	37.90	Medium
2	Number of Tillers	90.48	High
3	Number of Productive tillers	91.28	High
4	Flowering day	28.99	Medium
5	Harvesting Period	41.83	Medium
6	Seed filling rate	36.49	Medium
7	Length of Panicle	37.51	Medium
8	Number of Spikelets per Panicle	37.46	Medium
9	Number of Seeds per Panicle	48.67	Medium
10	Percentage of Empty Florets	48.40	Medium
11	Weight Seeds per Panicle	82.12	High
12	Weight of 1000 Seeds	37.59	Medium
13	Production	90.67	High

Note: $0 < h^2 \leq 20$ (low), $21 < h^2 \leq 50$ (medium), $50 < h^2 \leq 100$ (high)

Correlation analysis is an overview of the kinship level between one character to the others, but the value of correlation cannot explain the causal relationship of the kinship level among characters. Therefore, the role of cross-print analysis is important to elaborate the correlation coefficient. The results of the cross-print analysis can describe how significant the direct and indirect effects of a character to the main character (Rohaeni & Permadi, 2012). The use of correlation analysis and cross-print analysis in determining the selection character has also been performed in many studies, including Milligan SB, Gravois KA, Bischoff KP, Martin FA. (1990), Akhmadi (2016), Anshori (2019), Fadhli, Farid M, Rafiuddin, Effendi R, Azrai M, Anshori MF (2020), Farid BDR M, Nasaruddin, Anshori MF, Chaerunnisa ANJ (2020), and Farid M, Nasaruddin, Musa Y, Ridwan I, Anshori MF. (2021).

Table 6. Correlation analysis

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	**1.00**	0.41 **	0.47**	-0.24*	-0.34**	-0.22tn	0.35**	0.34**	-0.12tn	0.26*	0.07tn	0.18tn	0.39**
2		**1.00**	0.93**	-0.01tn	-0.08tn	-0.12tn	0.12tn	0.09tn	-0.23tn	0.23*	0.14tn	0.30*	0.75**
3			**1.00**	-0.01tn	-0.15tn	-0.16tn	0.10tn	0.15tn	-0.17tn	0.20tn	0.12tn	0.24*	0.78**
4				**1.00**	0.57**	-0.15tn	-0.24*	0.05tn	0.22tn	-0.23tn	-0.02tn	0.00tn	-0.02tn
5					**1.00**	0.53**	-0.42**	-0.31*	0.40**	-0.45**	-0.32*	-0.05tn	-0.33**
6						**1.00**	-0.20tn	-0.44**	0.38**	-0.53**	-0.38**	-0.07tn	-0.37**
7							**1.00**	0.26*	-0.08tn	0.15tn	0.03tn	0.19tn	0.20tn
8								**1.00**	0.08tn	0.31*	0.34**	-0.06tn	0.33**
9									**1.00**	-0.88**	-0.67**	0.12tn	-0.53**
10										**1.00**	0.71**	-0.13tn	0.58**
11											**1.00**	-0.12tn	0.62**
12												**1.00**	0.10tn
13													**1.00**

Description :

1. Plant height
2. Number of Tillers
3. Number of Productive Tillers
4. Flowering day
5. Harvesting Period
6. Seed Filling
7. Penicle Lenght
8. Number of Spikelets
9. Number of seeds per panicle
10. Number of Empty Florets
11. Weight per Panicle
12. Weight of 1000 seeds
13. Production

D. Conclusion

The results showed that the genotypes of M8 wheat mutants in lowland obtained the highest production in the N 200 2.4.B.6 (2.75 t. ha-1), N 200 2.3.3 (2.69 t.ha^{-1}) and N 350 3.6.2 (2.35 t.ha^{-1}). Characters that had high heritability level in M8 wheat mutant were number of tillers, number of productive tillers, weight seeds per panicle, and production. Furthermore, characters that were highly correlated with production were plant height, number of tillers, number of productive tillers, harvesting period, seed filling period, number of spikelets per panicle, percentage of empty florets, number of seeds per panicle, and seed weight per panicle.

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