Evaluation on reproductive and productivity characters of wheat (*Triticum aestivum* L.) genotypes grown in the lowlands

M Farid BDR¹, Nasaruddin¹, M F Anshori¹, and A N J Chaerunnisa²

¹Department of Agronomy, Faculty of Agriculture, Hasanuddin University Jl. Perintis Kemerdekaan KM 10, Makassar 90245.
²Agrotechnology Study Program Students, Faculty of Agriculture, Hasanuddin University Jl. Perintis Kemerdekaan KM 10, Makassar 90245.

E-mail: farid_deni@yahoo.co.id

**Abstract.** The objective of this study is to obtain mutant and convergent wheat breeding lines adapted to lowlands with high productivity and high heritability characters. This research was carried out in Bonto Parang, Tolo Selatan Village, Kelara District, Jeneponto Regency with coordinates 5°24’58.0"S 119°54’58.2"E at 135 m above sea level (asl). This research took place from May to September 2019. This study was arranged with Randomized Complete Block Design with 20 genotypes and 4 control varieties (Dewata, Guri-3, Selayar, and Nias). The study was conducted with 3 replications so that there were 72 experimental units. The results show that adaptive mutant lines and convergent wheat breeding in lowlands with high productivity were shown by genotype N 250 4.6.2 (2.27 t ha⁻¹), S 300 7.9.1 (2.29 t ha⁻¹), S 300 8.3.1 (2.35 t ha⁻¹), N 200 2.5.2 (2.27 t ha⁻¹), S 300 2.1 (2.29 t ha⁻¹), CBF6-110 (2.31 t ha⁻¹), and CBF6-192 (2.37 t ha⁻¹). Characters that have high heritability values were panicle length, the number of spikelets per panicle, seed weight per panicle, the potential yield per plant, and productivity.

1. **Introduction**

Wheat has been used in a large amount for cereal food as a supply of staple food for global citizens. Wheat consumption in Indonesia continued to increase in line with the growing interest in the consumption of processed wheat, such as noodles, bread, and biscuits. Consequently, Indonesia became one of the biggest wheat importing countries in the world. Based on the Global Agricultural Information Network [1], demand for wheat imports from 2018 to 2019 reached 11.15 tons, so it was predicted that wheat demand in 2018 to 2020 would increase by 11.30 tons.

Wheat was a subtropical crop, however, it could be cultivated in Indonesia at high altitude region (> 1000 m above sea level) to obtain growing condition suitable for wheat growth. Wheat plantation in the highlands could yield more than 3.0 t ha⁻¹ [2]. However, competition with other commodities such as horticulture plants is one of factor that limiting the development of wheat in this region in addition to the lack of knowledge on wheat cultivation. To overcome these challenges, the use of the available lowland for wheat development is one of solutions to solve this problem. However, there were several problems such as the lack of wheat varieties for the lowland tropics and the vulnerability of the plant to the stress of high temperatures and drought [3].

Crossing and genetic mutations are common approaches to induce plant diversity. Both approaches could be done in selecting the adaptive wheat plants in the lowlands. In the mutation approach, the
physical mutation, especially gamma-ray radiation, is a common mutagen in inducing the new diversity randomly which previously not exist. Moreover, in the crossings approach, convergent breeding is the famous crossings with assembling genes from many parents in its offspring population, hence this cross also could create a new desired combination [4]. Therefore, both approaches could be applied to develop adaptive varieties in the lowland area.

The mutation study in this research was a follow-up that started from M1 by doing gamma-ray radiation, then development of M2 mutants was carried out by a population diversity study. For M3 until M5 mutants, the selection were carried out by following a concept of shuttle selection breeding. Selection was conducted on varied conditions, the M3 selection was at high-temperature stress, selection of the M4 was in the optimal environment, and selection of the M5 at high-temperature pressure [5]. Finally, in 2018, an evaluation of the M6 generation was carried out in the lowlands and obtained wheat mutant lines that could potentially have high production but could not be reproduced. Whereas for convergent breeding research conducted by Nur [6] obtained genetic diversity of convergent breeding crosses of F3 generation of wheat-based on SSR markers associated with high temperatures.

Based on this description, several selected wheat lines from the approach of mutation and convergent breeding needed to be evaluated under the lowland. This evaluation is predicted to obtain the adaptive lines under the lowland recommended to release as varieties. The objective of the research is to obtain mutant and convergent wheat breeding lines adapted to lowlands with high productivity and high heritability characters.

2. Materials and methods

This research was conducted in Bonto Parang, Tolo Selatan Village, Kelara District, Jeneponto Regency with coordinates 5°24'58.0"S 119°54'58.2"E at 135 meters above sea level (masl). This research took the date from May to September 2019. The tools used were tractors, hoes, sickles, gauges, rulers, markers, plot boards, marker boards, treatment boards, spraying equipment, analytical scales, manual scales, seed moisture meters, office stationery. Meanwhile, the materials used were 20 genotype wheat seeds, four control varieties (Dewata, Guri-3, Selayar, and Nias), Urea fertilizer (CH4N2O), SP36 (P2O5), NPK, furadan 3G Confidor, Gramaxone herbicide, Decis insecticide, label, the string of raffia, plastic picks, sample bags, and sacks.

The trial was set using a randomized complete block design (RCBD) with treatments consisting of 20 genotypes of wheat mutants and convergent breeding, as well as 4 control varieties (Dewata, Guri-3, Selayar, and Nias). Data obtained from observations were analysed with analysis of variant (ANOVA) using Microsoft Excel. If there is significant effect of the treatment then a further significance difference tests were carried out with Least Significance Difference (LSD) test at level of 5%.

Analysis of the heritability was conducted using the results of variance analysis for one location in one season. The additive linear model used to analyze the estimated heritability of observational data for each character was genetic and phenotypic (table 1).

| Sources of Diversity | Degree of freedom | Sum of Squares (SS) | Means Squared (MS) | Means Squared (MS) |
|----------------------|-------------------|---------------------|--------------------|--------------------|
| Replication          | r-1               | SSr                 | Msr                | δ2r + δ2g          |
| Genotype             | g-1               | SSg                 | MSg                | δ2e + δ2g          |
| Error                | (r-1)(g-1)        | SSE                 | MSE                | δ2e                |

Notes replication (r), genotype (g), environment (e), variety of replication (δ2r), variety of genotypes (δ2g), and variety of environments (δ2e)

Where, δ2e = KTe.
\[ K_Tg = \delta^2 e + k \delta^2 g, \text{ so as } \delta^2 g = (K_Tg - K_{T_e})/k. \]
\[ \delta^2 p = \delta^2 e + \delta^2 g \]

Heritability and criterion values were calculated using the following formula:
\[ h^2_{bs} = (\sigma^2 g)/(\sigma^2 p) \times 100\% \]
\[ h^2_{bs} = \text{heritability in a broad sense} \]
\[ K_Tg = \text{middle squared genotype} \]
\[ K_{T_e} = \text{middle square of the environment} \]
\[ \delta^2 g = \text{variety of genotypes} \]
\[ \delta^2 e = \text{variety of environments} \]
\[ \delta^2 p = \text{variety of phenotypes} \]

3. Results

3.1 Analysis on productivity of wheat grown in lowland

Analysis of variance shows that panicle length, number of spikelet and grain weight per panicle, potential yield and productivity of the wheat were significantly varied between genotypes and control varieties. Table 2 shows the average values of these parameter compared to the control varieties.

| Genotype | Panicle length (cm) | Number of Spikelets per panicle (spikelets) | Grain Weight Per Panicle (g) | The potential yield per plant (g) | Productivity (t ha\(^{-1}\)) |
|----------|---------------------|---------------------------------------------|----------------------------|---------------------------------|-----------------------------|
| G1 (N 200 2.2.3) | 7.94 | 14.11 | 0.71 | 3.31 | 1.85 |
| G2 (N 250 4.6.2) | 8.11 | 15.00\(^c\) | 0.97 | 5.50\(^c\) | 2.27\(^{cd}\) |
| G3 (D 200) | 7.94 | 14.89 | 0.89 | 5.34\(^c\) | 2.11\(^c\) |
| G4 (S 300 7.9.1) | 8.22 | 16.04\(^{acd}\) | 1.00 | 5.97\(^c\) | 2.29\(^{cd}\) |
| G5 (N 350 3.7.1) | 7.94 | 14.11 | 0.71 | 4.32 | 2.07\(^c\) |
| G6 (M 200 1.7.1) | 7.89 | 16.33\(^{acd}\) | 1.07\(^{ed}\) | 6.08\(^{ed}\) | 2.13\(^c\) |
| G7 (N 350 3.1.3) | 8.93\(^c\) | 16.33\(^{acd}\) | 1.07\(^{ed}\) | 6.08\(^{ed}\) | 2.13\(^c\) |
| G8 (N 300 3.6.1) | 7.89 | 14.11 | 0.46 | 2.50 | 2.00 |
| G9 (S 300 8.3.1) | 7.89 | 13.00 | 0.84 | 4.84\(^c\) | 2.35\(^{cd}\) |
| G10 (N 200 2.4.B.6) | 8.06 | 14.44 | 0.69 | 3.30 | 2.12\(^c\) |
| G11 (N 200 2.5.2) | 8.50 | 15.33\(^{cd}\) | 1.03 | 5.96 | 2.27\(^{cd}\) |
| G12 (S 300 2.1) | 8.45 | 14.50 | 0.73 | 4.00 | 2.29\(^{cd}\) |
| G13 (N 350 3.6.2) | 8.17 | 15.33\(^{cd}\) | 0.87 | 5.72 | 2.20\(^c\) |
| G14 (CBF6-63) | 7.78 | 14.00 | 0.67 | 4.41 | 2.07\(^c\) |
| G15 (CBF6-154) | 7.89 | 14.44 | 0.80 | 5.29 | 2.20 \(^c\) |
| G16 (CBF6-110) | 8.00 | 14.56 | 0.82 | 4.26 | 2.31\(^{cd}\) |
| G17 (CBF6-115) | 8.44 | 16.17\(^{acd}\) | 0.88 | 5.72 | 2.12\(^c\) |
| G18 (CBF6-192) | 8.94\(^c\) | 16.44\(^{acd}\) | 1.02 | 6.57\(^{ed}\) | 2.37\(^{cd}\) |
| G19 (CBF6-159) | 7.89 | 14.33 | 0.81 | 4.03 | 1.51 |
| G20 (CBF6-119) | 7.72 | 12.58 | 0.39 | 2.62 | 1.52 |
| G21 (Dewata) (a) | 9.00 | 15.11 | 0.98 | 6.67 | 2.35 |
| G22 (Selayar) (b) | 9.33 | 16.67 | 1.20 | 6.97 | 2.39 |
| G23 (Guri-3) (c) | 8.00 | 14.56 | 0.82 | 4.09 | 1.75 |
| G24 (Nias) (d) | 8.67 | 14.78 | 0.83 | 5.63 | 1.96 |

LSD\(_{0.05}\) | 0.60 | 0.37 | 0.22 | 0.37 | 0.26 |

Number followed by the same letter in column (abcd) means that it is significantly different from the control varieties of Dewata (a), Selayar (b), Guri-3 (c), and Nias (d) at the LSD\(_{0.05}\) test level.

The LSD test at 5% level in table 2 show that the N 350 wheat genotype 3.1.3 (G7) and CBF6-192 (G18) treatments had longer panicle lengths with values of 8.93 cm and 8.94 cm, respectively, and
significantly differed from the control variety of Guri-3 (c). Based on the number of spikelets, wheat genotypes S 300 7.9.1 (G4), N 350 3.1.3 (G7), CBF6-115 (G17), and CBF6 -192 (G18) have significantly more number of spikelets per plant (16.04, 16.33, 16.17, and 16.44 spikelets, respectively) compared to all control varieties except Selayar. Meanwhile, The N 350 3.1.3 (G7) also had the highest grain weight per panicle (1.07 g) and significantly different from the control varieties of Guri-3 (c) and Nias (d).

Based on the potential yield per plant, N 350 3.1.3 (G7), CBF6-192 (G18) had a significantly higher yield (6.08 g and 6.57 g, respectively) than the control varieties of Guri-3 (c), and Nias (d). Based the last character was productivity, the N 2504.6.2 (G2), S 300 7.9.1 (G4), S 300 8.3.1 (G9), N 200 2.5.2 (G11), S 300 2.1 (G12), CBF6-110 (G16) and CBF6-192 (G18) had significantly higher productivity than Guri-3 (c) and Nias (d). These genotypes showed a productivity above 2 tons per hectare of 2.27 t ha⁻¹, 2.29 t ha⁻¹, 2.35 t ha⁻¹, 2.27 t ha⁻¹, 2.29 t ha⁻¹, 2.31 t ha⁻¹, and 2.37 t ha⁻¹, respectively.

3.2 Heritability value
Table 3 showed that all observed reproductive characters in the M7 generation had high heritability with values of more than 50%. The potential yield per plant and number of spikelets are the characters with higher heritability parameter. These characters have values of more than 90%.

| No. | Character                        | h² value (%) | Category  |
|-----|----------------------------------|--------------|-----------|
| 1   | Panicle Length                   | 53.99        | High      |
| 2   | Number of Spikelets per Panicle  | 95.34        | High      |
| 3   | Seed Weight Per Panicle          | 60.83        | High      |
| 4   | The Potential Yield per Plant    | 96.77        | High      |
| 5   | Productivity                     | 68.13        | High      |

Noted: h² < 20 (low), 20 ≤ h² ≤ 50 (medium), h² > 50 (high)

4. Discussion
The research showed that some genotypes have better reproductive character value than some of the control varieties. It means that the breeding programs in these projects have run with effectiveness. The productivity characters under the lowland area also was supported by the yield component, such as panicle length, grain weight per panicle, and the potential yield per plant.

The longer panicle will have a lot of flour and wheat seeds produced so that it is closely related to the yield. This is supported by Kirby’s [7] statement that panicle length is a component of yield that has a direct relationship with the number of spikelets. The longer the panicle, the more spikelets are formed so that the potential to form a growing number of seeds [8]. The high temperature could give a negative impact on panicle length and correlated to the number of spikelets [9]. Therefore, the tolerant genotype will keep the panicle length character to increase its yield under lowland with high-temperature condition.

The grain weight per panicle was also closely related to productivity. The higher value of this character could induce high productivity. One of the factors determined the grain weight per panicle of wheat in the lowlands is the high temperature. This condition could disrupt the supply of assimilates in forming an obstructed sink and low pollen viability [10]. It was supported by the study of Natawijaya [11] who found that four lines and two varieties tested at Tajur-Bogor (< 400 m asl) experienced a decrease in pollen viability and the most sensitive Dewata variety. It was indicated that the low wheat yields in the < 400m asl were the negative effect of high temperature in decreasing of pollen viability. Study pollen viability and dispersal is need for maintenance genetic of plant [12,13].
The last character related to the productivity per hectare was the potential yield per plant. This character also related to productive tillers. The more tillers were formed, the yield per plant would also be higher [10]. However, the tiller character also was influenced by high temperatures. The higher of the temperature could press the wheat in developing its tiller [9]. Therefore, the tolerant plant will keep the tiller development through the thermostability of cell membranes. It could support some changes in physiological processes intolerant genotypes under lowland [14].

Heritability is one of the important parameter to support breeding selection [4]. Based on this research, all characters have a high heritability value so that all characters, especially productivity, could be good selection characters [15]. The high heritability also suggested that the environmental effect is in the low level and the selection process could be effective to continue in the next step [16]. Based on the productivity phenotype and its heritability, seven lines were considered could be select as the good advance genotypes. Based on the previous study, the selected lines were considered to have better productivity than the lines of Zubaidi et al. [10] who planted wheat at Lombok Island with altitude as 200 m asl. Therefore, seven selected wheat lines were recommended to the next steps in variety release proposal.

5. Conclusion

Based on research that has been carried out, Adaptive wheat genotypes in the lowlands with high productivity were shown by N 250 4.6.2 (G2), S 300 7.9.1 (G4), S 300 8.3.1 (G9), N 200 2.5.2 (G11), S 300 2.1 (G12), CBF6-110 (G16) and CBF6-192 (G18). All characters have high heritability values and could be as a good selection characters.

Reference

[1] Global Agricultural Information Network 2019 Indonesia Grand and Feed Annual Report. (Jakarta: USDA Foreign Agricultural Service).
[2] Hamdani M, Sriwidodo, Ismail and Dahlan M M 2002 Evaluation of the introductory line and CIMMYT Proceedings of the IV Congress and the National Symposium of the Indonesian Breeding Sciences Association. (Yogyakarta: Gadjah Mada University).
[3] Guendouz A, Guessoum S, Maamri K, Benidir M and Hafsi M 2012 J Agric Sustain 1 23-38.
[4] Syukur M, Sujiprihati S, Yunianti R 2015 Teknik Pemuliaan Tanaman: Edisi Revisi. (Depok: Penebar Swadaya).
[5] Nur A 2013 Adaptation of High-Temperature Tolerant Wheat (Triticum aestivum L.) Plants and Increased Genetic Diversity through Mutation Induction Using Gamma-Ray Irradiation. (Bogor: Postgraduate School, Bogor Agricultural University).
[6] Nur A 2015 J. Agric. Res. and Dev. 34 19-30.
[7] Kirby E J M 2002 Botany of the wheat plant Bread Wheat: Improvement and Production, ed B C Curtis S Rajaram, G H MacPherson (Rome: FAO).
[8] Anshori M F, Purwoko B S, Dewi I S, Ardie S W and Suwarno W B 2018 J. Agron. Indonesia 46 119-25
[9] Modarresi M, Mohammadi V, Zali A and Mardi M 2010 Cereal Res. Commun. 38 23–31
[10] Zubaidi A, Budianto V F A, Wiressesmi A and Abdurrahman H. 2014 J. Degrade. Min. Land Manage. 2 243-50
[11] Natawijaya A 2012 Genetic Analysis and Selection of Early Generations of High Yielding Wheat (Triticum aestivum L.) Segments. (Bogor: Postgraduate School of Bogor Agricultural Institute).
[12] Larekeng S H, Gusmiaty, Cahyaningsih Y F, Arsyad M A, Sari W M, Restu M and Arif A 2020 Estimation of Pollination in Mahogany Revealed by Microsatellite Markers : Case in South Sulawesi , Indonesia Syst. Rev. Pharm. 11 660–73
[13] Larekeng S H, Purwoto A, Mattjik N A and Sudarsono S 2018 Microsatellite and SNAP markers used for evaluating pollen dispersal on Pati tall coconuts and Xenia effect on the production of “Kopyor” fruits IOP Conf. Ser. Earth Environ. Sci. 157
[14] Haque M Z, Hasan M M and Rajib M M R 2009 *J. Bangladesh. Agril. Univ.* 7 241-6.
[15] Anshori M F, Purwoko B S, Dewi I S, Ardie S W and Suwarno W B 2019 *SABRAO J. Breed. Genet.* 51 161-174.
[16] Rachmadi M 2000 *Introduction to Vegetative Breeding*. (Bandung: Padjadjaran University).