Assessment and selection of M3 generation of wheat mutants adaptive in lowland

Nasaruddin, M Farid, Y Musa and H Iswoyo
Department of Agronomy, Faculty of Agriculture, University of Hasanuddin, Tamalanrea Campus, Jl. Perintis Kemerdekaan KM. 10 Makassar, 90245, Indonesia.
E-mail: nnasaruddin@gmail.com

Abstract. Wheat is a sub-tropical plant which adaptability in the tropics in areas with altitudes over 1000 m above sea level (asl). Cultivation on the highlands is in competition with vegetables and fruits in terms of land use, therefore, it is essential to have wheat genotypes adaptive to the lowlands. This study aimed to test and select offspring of three adaptive mutant on lowland with high temperature ranged from 28 to 33°C. The benefit of the research is to obtain a potential strain of adaptive wheat mutants in the lowlands. The experiment was conducted at Experimental farm of Agriculture Faculty, Hasanuddin University Makassar at an altitude below 50 m from sea level. The study was conducted from March to June 2017. The experimental study applied a randomized block design with three replications. The treatments consisted of 20 mutants of wheat with 4 varieties used for comparison. They were Nias, Selayar, Dewata, and Munal. Results showed that the wheat mutant N.300 4.3.6 (1.92 t per hectare) gave highest growth and production and was significantly different from all other mutants and comparing varieties. The mutant genotypes that gave higher growth and production than all comparing varieties were N.350 3.1.4 (1.86 t per hectare), N.200 2.3.3 (1.67 t per hectare), N.250 4.2.1 (1.48 t per hectare), N.200 2.4.B.6 (1.36 t per hectare), N.250 4.5.2 (1.26 t per hectare), N.350 3.2.2 (1.26 t per hectare), and N.350 3.1.3 (1.22 t per hectare). Mutants that produce higher yields than the three comparing varieties (Dewata, Selayar and Munal) with yields > 1 t per hectare, yet lower than Nias varieties (1.15 t per hectare) are N.200 2.5.2 (1.11 t per hectare), N.250 4.6.2 (1.14 t per hectare), and N.350 3.6.2 (1.07 t per hectare. In conclusion, there are 11 potential mutant genotypes for further experiment in order to develop adaptive wheat to lowlands.

1. Introduction
Food diversity program is an alternative effort for national food self-sufficiency. Nowadays, all demands for domestic flour are fulfilled by importing wheat seeds which will then be processed into flour. Import of wheat to Indonesia in 2010 was 5.2 million ton, in 2011 was increasing to 6.3 million ton, in 2012 was 7.4 million ton, and in 2016 the import was already reaching 8.1 million ton [1]. Increase in wheat import burdened state finance and therefore require food diversification through development of wheat in Indonesia.

Various challenges in the up to downstream development of local wheat have not yet been fully managed by farmers and field officers. These challenges being: wheat is not a priority commodity, ecology of wheat growing field is the altitude of at least 800 m from sea level [2], thus in competition with highland vegetables and fruits. In the last few years, Indonesian government has set development program of wheat in the areas considered to be appropriate, such as in the highland and middle land where the temperature is relatively lower. For this purpose, various domestic wheat development
activities are carried out through the application of cultivation technology in accordance with agro-climate conditions in Indonesia [3], and seeking alternative development in lowland to middle land areas on unproductive lands. Therefore this study was conducted to obtain lowland wheat varieties from local Indonesian wheat crops that have been irradiated with gamma rays through mutation breeding and mutant heredity tests that can adapt to the lowlands. The study aimed to perform population heredity test of the Mutant three (M3), population formation for the subsequent generation up to Mutant five (M5). Also, to test the formation of family through adaptive selection of genotypes (mutants) adaptive to the lowlands high temperature with range between 28 and 33°C during dry season and high rainfall during rainy season; and tests on adaptation, stability and multiolocation.

2. Research Methodology
The research was conducted in the experimental farming of Agriculture Faculty, University of Hasanuddin, on a location of 50 m asl. The experiment was performed from March to June 2017. The experiment was designed with randomized block design consisting of 3 repetitions. Treatments were 21 different wheat mutants: g1 = Munal 1.7.1, g2 = N.350 3.6.2, g3 = N.300 3.6.1, g4 = N.250 4.2.1, g5 = N.350 3.1.3, g6 = N.350 3.2.2, g7 = N.250 4.5.2, g8 = N.350 3.1.4, g9 = Munal 200 1.7.1, g10 = N.250 4.6.2, g11 = N.350 3.8.9, g12 = S. 6.4.1, g13 = S.300 8.3.1, g14 = N.250 4.4.2, g15 = N.350 3.8.10, g16 = N.350 3.5.10, g17 = S. 8.4.2, g18 = N.200 2.4.B.6, g19 = N.200 2.5.2, g20 = N.200 2.3.3, g21 = N.300 4.3.64. Comparing varieties were g22 = Dewata, g23 = Selayar, g24 = Nias, and g25 = Munal. Experiment was conducted on 1 m x 3 m plot with 5 cm x 25 cm of plants spacing. Fertilizers applied to the plants at 10 days after planting were 150 kg per hectare of Urea, 200 kg per hectare of SP36 and 100 kg per hectare of KCl. More fertilizers were applied at 30 days after planting with 150 kg per hectare of urea. Observation variables in this research were number of productive tillers, length of panicle, number of spikelet in each panicle, number of seeds per panicle, weight of the seeds per panicle and the production per hectare. In addition, heritability value of each parameter was calculated.

3. Results and Discussion
3.1. Results
Parameters values of each genotype observed in the experiment including number of productive tillers, panicle length, number of spikelet in each panicle, number of seeds per panicle, weight of 100 Seeds and yields per hectare are shown in table 1. Statistical analysis showed that genetic material had a very significant effect on the number of productive tillers, the length of panicle, the number of spikelet per panicle, the number seeds per panicle, the weight of the seeds per panicle and the production per hectare. The Least Significant Difference test of 0.05 in table 1 shows that the genetic material N.300 4.3.6 (g21) has an average number of productive tillers, panicle length, number of spikelet probes, number of seeds per panicle, the seeds weight per panicle and the highest yield per hectare when compared to other genetic materials.

Table 2 shows that all observed characters, whether vegetative, generative to production, have moderate to high heritability values based on the index values of each character. Heritability analysis in table 2 shows that there are six parameters having high heritability value and one having medium heritability value. The highest heritability value is shown in production parameters i.e. 93.48%.

3.2. Discussion
Treatment N.300 4.3.6 (g21) shows a good potential for development in high temperature regions. This is because the given irradiation dose is not too high. Excessively high doses of irradiation can cause the plant to become abnormal and damage the genetic makeup of plants. This is in accordance with [4] which states that the higher the dose, the more mutations occur and the more damage may occur.
**Table 1.** Number of productive tillers, panicle length, number of spikelet in each panicle, number of seeds per panicle, weight of 100 Seeds and yields per hectare.

| Treatment (Genotype materials) | Number of productive tillers | Panicle length (cm) | Number of Spikelet in each panicle | Number of seeds per panicle | Weight of seed per panicle (g) | Weight of 100 Seeds (g) | Yield productivity (kg) |
|-------------------------------|-------------------------------|---------------------|-----------------------------------|----------------------------|-------------------------------|------------------------|------------------------|
| g1 (M 1.7.1)                 | 4.77<sup>bc</sup>           | 6.63<sup>de</sup>  | 11.93<sup>c</sup>                | 20.07<sup>e</sup>          | 1.94<sup>d</sup>              | 3.13<sup>d</sup>           | 0.53<sup>g</sup>       |
| g2 (N.350 3.6.2)             | 4.47<sup>bc</sup>           | 7.74<sup>c</sup>   | 12.03<sup>c</sup>                | 27.07<sup>cd</sup>         | 2.30<sup>e</sup>              | 4.54<sup>bc</sup>         | 1.07<sup>e</sup>       |
| g3 (N.300 3.6.1)             | 4.67<sup>bc</sup>           | 7.13<sup>de</sup>  | 12.03<sup>c</sup>                | 20.27<sup>e</sup>          | 1.75<sup>cd</sup>             | 4.34<sup>bc</sup>         | 0.53<sup>g</sup>       |
| g4 (N.250 4.2.1)             | 5.47<sup>a</sup>            | 8.47<sup>ab</sup>  | 14.23<sup>ab</sup>               | 30.67<sup>bc</sup>         | 2.45<sup>dh</sup>             | 5.59<sup>a</sup>          | 1.48<sup>c</sup>       |
| g5 (N.350 3.1.3)             | 5.27<sup>ab</sup>           | 8.36<sup>de</sup>  | 13.83<sup>ab</sup>               | 37.27<sup>ab</sup>         | 2.46<sup>dh</sup>             | 4.45<sup>bc</sup>         | 1.22<sup>de</sup>      |
| g6 (N.350 3.2.2)             | 5.27<sup>ab</sup>           | 8.18<sup>ab</sup>  | 13.53<sup>b</sup>                | 29.37<sup>c</sup>          | 2.40<sup>h</sup>              | 5.48<sup>ab</sup>         | 1.26<sup>d</sup>       |
| g7 (N.250 4.5.2)             | 5.17<sup>ab</sup>           | 8.11<sup>bc</sup>  | 13.13<sup>b</sup>                | 37.27<sup>ab</sup>         | 2.51<sup>ab</sup>             | 5.31<sup>ab</sup>         | 1.26<sup>d</sup>       |
| g8 (N.350 3.1.4)             | 5.17<sup>ab</sup>           | 8.20<sup>ab</sup>  | 13.23<sup>b</sup>                | 34.27<sup>b</sup>          | 2.51<sup>ab</sup>             | 5.59<sup>a</sup>          | 1.86<sup>a</sup>       |
| g9 (M. 200 1.7.1)            | 3.57<sup>d</sup>            | 6.24<sup>f</sup>   | 8.83<sup>d</sup>                 | 18.77<sup>c</sup>          | 2.00<sup>d</sup>              | 3.13<sup>d</sup>          | 0.51<sup>g</sup>       |
| g10 (N.250 4.6.2)            | 5.27<sup>ab</sup>           | 8.47<sup>ab</sup>  | 13.43<sup>b</sup>                | 31.47<sup>bc</sup>         | 2.41<sup>b</sup>              | 5.39<sup>ab</sup>         | 1.14<sup>de</sup>      |
| g11 (N.350 3.8.9)            | 4.57<sup>bc</sup>           | 7.83<sup>bc</sup>  | 12.53<sup>b</sup>                | 27.47<sup>cd</sup>         | 2.38<sup>b</sup>              | 4.94<sup>b</sup>          | 0.87<sup>g</sup>       |
| g12 (S. 6.4.1)               | 4.47<sup>bc</sup>           | 6.79<sup>g</sup>   | 13.13<sup>b</sup>                | 23.77<sup>de</sup>         | 2.08<sup>d</sup>              | 3.13<sup>d</sup>          | 0.51<sup>g</sup>       |
| g13 (S.300 8.3.1)            | 4.87<sup>b</sup>            | 7.28<sup>d</sup>   | 12.83<sup>b</sup>                | 20.27<sup>e</sup>          | 1.66<sup>c</sup>              | 3.13<sup>d</sup>          | 0.51<sup>g</sup>       |
| g14 (N.250 4.4.2)            | 4.27<sup>c</sup>            | 7.84<sup>bc</sup>  | 13.03<sup>b</sup>                | 28.87<sup>cd</sup>         | 2.35<sup>b</sup>              | 4.73<sup>bc</sup>         | 0.77<sup>gf</sup>      |
| g15 (N.350 3.8.10)           | 3.77<sup>d</sup>            | 7.57<sup>cd</sup>  | 11.63<sup>c</sup>                | 19.57<sup>e</sup>          | 1.53<sup>e</sup>              | 3.13<sup>d</sup>          | 0.51<sup>g</sup>       |
| g16 (N.350 3.5.10)           | 3.77<sup>d</sup>            | 7.45<sup>cd</sup>  | 11.73<sup>c</sup>                | 23.17<sup>de</sup>         | 2.07<sup>d</sup>              | 3.13<sup>d</sup>          | 0.51<sup>g</sup>       |
| g17 (S. 8.4.2)               | 4.97<sup>ab</sup>           | 7.43<sup>cd</sup>  | 12.93<sup>bc</sup>               | 19.87<sup>e</sup>          | 2.06<sup>d</sup>              | 4.25<sup>c</sup>          | 0.51<sup>g</sup>       |
| g18 (N.200 2.4.B.6)          | 5.27<sup>ab</sup>           | 8.25<sup>ab</sup>  | 13.73<sup>ab</sup>               | 37.67<sup>ab</sup>         | 2.53<sup>ab</sup>             | 5.54<sup>ab</sup>         | 1.36<sup>cd</sup>      |
| g19 (N.200 2.5.2)            | 5.07<sup>ab</sup>           | 8.14<sup>b</sup>   | 13.33<sup>b</sup>                | 32.47<sup>bc</sup>         | 2.47<sup>ab</sup>             | 5.45<sup>b</sup>          | 1.11<sup>e</sup>       |
| g20 (N.200 2.3.3)            | 5.37<sup>ab</sup>           | 8.38<sup>ab</sup>  | 14.63<sup>ab</sup>               | 38.17<sup>ab</sup>         | 2.61<sup>ab</sup>             | 5.62<sup>a</sup>          | 1.67<sup>fa</sup>      |
| g21 (N.300 4.3.6)            | 5.47<sup>ab</sup>           | 8.55<sup>a</sup>   | 14.83<sup>a</sup>                | 40.47<sup>a</sup>          | 2.64<sup>a</sup>              | 5.70<sup>a</sup>          | 1.92<sup>g</sup>       |

Average: 4.80, 7.76, 12.89, 28.49, 2.24, 4.56, 1.00

**Genotype***

| CoV (%) | LSD | Remarks |
|---------|-----|---------|
| 9.61    | 0.54| High    |

**Tabel 2.** Heritability value of wheat M3 mutant strains

| No | Observation variables | h2 value (%) | Remarks |
|----|-----------------------|--------------|---------|
| 1  | Productive yields     | 50.33        | High    |
| 2  | Length of panicle     | 74.87        | High    |
| 3  | Number of Spikelet in each panicle | 48.71 | Medium |
| 4  | Number of seeds per panicle | 79.00 | High |
| 5  | Weight of seed per panicle | 74.33 | High |
| 6  | Weight of 100 Seeds   | 77.04        | High    |
| 7  | Yield production      | 93.48        | High    |

*Numbers followed by same letter in the same column (a, b, c, d, e, f, g) denote the insignificant difference at test level of BNT=0.05

** CoV = Coefficient of Variance

0 < h2 ≤ 20 (low); 21 < h2 ≤ 50 (medium); 50 < h2 ≤ 100 (high)
The number of productive tillers that formed during the vegetative period generally decreased due to the stresses of the growing environment due to the decrease of elevation from high to lowlands. According to Nur et al. [5] the growing environment of wheat flour from highland to lowland in wet tropical environments leads to a decrease in seed germination and a decrease in the number of productive tillers of each genotype of wheat. The results showed that genetic material N.300 4.3.6 (g21) had the most productive tillers.

The results of the variance indicated that for panicle length parameter, the mutant genotypes N.300 4.3.6 (g21) had the average best panicle length (8.55 cm) and were significantly different from all genotypes except g4, g5, g6, g8, g10, g18, g20 and g24. For the parameter of spikelet number per panicle, N.300 4.3.6 (g21) has average spikelet number more than any other genotypes (14.83) and significantly different from all genotypes except g4, g5, g18, g20 and g24. The formation of panicle, panicle length and the amount of spikelet in wheat is affected by the assimilates content when the wheat is in its vegetative phase. It is in line with Nur [6] that the panicle length character and the number of spikelet is determined by the supply of assimilates in the vegetative phase as the source to form the panicles in the generative phase. If the source is insufficient in the formation of a sink (generative phase), then the spikelet formation becomes low.

For the parameter of seeds number per panicle, the weight of 100 seeds, seeds production per hectare shows that N.300 4.3.6 (g21), has a higher mean compared to other genetic materials. This is due to the high temperature stress causing the seeds to fail to form which will affect the number of seeds produced in panicles and also affect the weight of the seeds of the barn. This is in accordance with [7] which states that wheat productivity has a close relation with air temperature[8]. At the Celsius scale a degree increase in average air temperature, the yield of wheat will drop 504 kg per hectare.

Heritability analysis is a quantitative benchmark to determine the phenotype difference of a character caused by genetic or environmental factors, therefore, it can give an idea whether the observed character is more influenced by genetic or environmental factors. Table 2 shows that almost all morphological characters have high heritability values. In the parameters of the number of productive tillers (50.33%), the length of panicle (74.87%), the number of the seeds per panicle (79.00%) seeds weight per panicle (74.33%), weight of 100 seeds (77.04%) and yield production (93.48%) belongs to high heritability. While the number of spikelet per panicle (48.71%) is classified as moderate heritability. This is stated in Basir [9] and Ferris et al. [10] that characters with high heritability will increase the effectiveness of selection in endurance testing because the observed character is a reflection of the influence of genetic factors rather than environmental influences.

4. Conclusions
Based on the results obtained, this result drew the following conclusions:

- Wheat mutant genotype N.300 4.3.6 gave best growth and highest yield (1.92 tons per hectare) and is significantly different from all other mutants and comparing varieties. The mutant genotypes that gave higher growth and production compared to all comparing varieties were N.350 3.1.4 (1.86 tons per hectare), N.200 2.3.3 (1.67 tons per hectare), N. 250 4.2.1 (1.48 tons per hectare), N.200 2.4.B.6 (1.36 tons per hectare), N.250 4.5.2 (1.26 tons per hectare), N.350 3.2.2 (1.26 tons per hectare), and N.350 3.1.3 (1.22 tons per hectare). Mutants that produce higher yields than three of comparing varieties (Dewata, Selayar and Munai) with yields > 1 tons per hectare, but lower than Nias varieties (1.15 tons per hectare) are N.200 2.5.2 (1.11 tons per hectare), N.250 4.6.2 (1.14 tons per hectare), and N.350 3.6.2 (1.07 tons per hectare). Thus, there are 11 potential mutant genotypes to be selected further in an effort for adaptive wheat development in the lowlands.

- High heritability prediction value, followed by heritability more than 50% possessed by the characters in: productive tiller, long panicle, number of seeds of per panicle, seeds weight per panicle, weight of 1000 seeds and production.
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