Character evaluation and selection of tropical wheat lines in the long period of the dry season and high temperature

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Abstract The problem in the development of wheat crops today is climate change that reduces wheat production in almost all regions of the world. It has an impact on rising temperatures and limited water supplies that can cause drought stress. These problems became the main issue of world wheat crop development. Therefore, the assembly of adapted varieties of wheat that adapted to climate change is crucial. This study aims to evaluate characters and select wheat lines based on the yield and yield component characters and to obtain tolerant wheat lines under those natural stress in tropical environments. The study used 56 wheat lines and 6 released varieties for controls, 3 replications with Randomized Block Design. Character evaluation shows significant differences in a large number of observational characters except for the number of seeds/spike and moisture content. Characters that can be used for selection and evaluation of promising lines are all characteristics of the yield and yield components except the Number of Seed Per spike (NSS) and Water Content (WC) characters. Promising lines were G5, G8 and G11 became potential selection lines with potential yields of 3, 3.39 and 3.03.

1. Introduction
Climate projection in the future will be extreme, caused warmer temperature and limitations of water supplies such as the El-Nino phenomenon that occurred in 2015, which is made the dry season longer and drought [1,2]. High temperature and uncertain precipitation patterns threaten world crop production by reducing crop production, especially on wheat decreased by about 5.5% [3,4]. Both of these climate factors became the main issue of the world's development wheat crop to date [5-7]. This condition will affect the direction of world wheat development and wheat assembly. Thus it is important to continue producing a tolerant line which is adaptable to climate change factors.

Optimum wheat crop produced at a temperature range of 10-20ºC. The high temperature is often encountered in the development of wheat in the tropical environment [8]. Although, it has been grown in areas with high topography, in principle, the wheat in the tropics still experienced high-temperature stress [9]. In Indonesia, the policy of wheat development directed to plant at lower elevations [10], because the competitive value of wheat is smaller than horticultural crops in the highlands, thus, the main reason why wheat assembly continues to be pursued in the lower land [8]. These conditions will increase stress on wheat crops and will affects the formation of grains, pollination process, and
shortening the filling duration of seeds, decrease the wheat weight about 504 kg.ha\(^{-1}\) every rise 1\(^{\circ}\)C [11].

A long period of dry season is identically causing drought and became the main cause of crop failure and decreased production in wheat crops within 35 years in several wheat producing countries [4]. Wheat is a cereal commodity that requires high enough irrigation at the beginning of its growth. The greatest water requirement is in the early vegetative and flowering development [12]. Drought causes a considerable loss of yield compared to other biotic and abiotic factors [13], drought in the UK causing a loss of crop yield of 1-2 t/ha [14]. Initial growth phase, flowering, and seedling formation is a critical phase; water shortage in this phase will reduce yield by up to 40% [12]. The current world challenge is to produce more food with limited water availability, and drought tolerant breeding and water use efficiency is the key [15].

Character evaluation and selection of wheat crops under two stress conditions of high temperature and drought in natural condition is essential for obtaining tolerant genotype and knowing which characters will be affected. The objectives of this study were to evaluate the character heritability and select wheat lines based on the characters of yield components and yield and to obtain tolerant wheat lines under natural environment stress in tropics.

2. Materials and Methods

The study was conducted in Malino, Gowa District at an altitude of 1,000 m asl from May to September, 2015. The study was conducted using Randomized Block Design (RAK) with 3 replications, and the plot size was 1.5 m x 5 m. Genetic material consisted of 56 lines and 6 released varieties (Guri1, Guri2, Guri4 Agritan, Guri5 Agritan, Selayar, and Dewata) was used as a control. Each genotype was planted in 6 lines along 5 m with spacing between lines 25 cm; seeds were sown in line.

The seeds were given carbaryl insecticide 85% before sowing and at planting the runway was given carbofuran 17 kg.ha\(^{-1}\). The plants were fertilized at a dose of 150 kg Urea.ha\(^{-1}\), 200 kg SP36.ha\(^{-1}\) and 100 kg KCl.ha\(^{-1}\) at the age of 10 DAP and second fertilization with Urea dose of 150 kg.ha\(^{-1}\) at age 30 DAP. Treatment of high-temperature stress and drought occurred naturally (environmental conditions). At the time of 30 days after sowing until harvesting did not occur rain (approved by climatic information from a weather station in appendix 1) and without irrigation. The average daily temperature and rainfall are recorded at the BMKG weather station in Malino.

Observation variables include days to flowering, days of harvesting, plant height (cm), number of spike/meters (NSM), spike length (SL) (cm), number of seeds/spike (NSS), number of floret (NF), water content (WC), weight of seed per spike (WSS), weight of 1000 seeds (W1000) (g), and yield (Y) (t/ha).

The data were analyzed variance using F-test (Tabel 1). Heritability value and genetic diversity analysis were performed following the methods proposed by Singh and Chaudhary (1985) and Falconer (1989). The selection was done on the character of yield by selecting genotype which weighted 1.54 ton/ha, the genotype that did not meet the criteria was discarded. The average results were further analyzed using the least significant difference (LSD) at the 5% level and compared to released varieties as a control. All data were analyzed using the STAR program version 2.0.1.

| Source of variance | Df | MS   | Expected MS |
|--------------------|----|------|-------------|
| Replication lines  | r-1| KT\(_1\) | \(\sigma^2 + r\sigma_g^2\) |
| Error              | (g-1)(r-1) | KT\(_2\) | \(\sigma^2\) |

Annotations: \(r = \) replication number, \(g = \) lines number, \(\sigma_g^2 = \) variance of lines, \(\sigma^2 = \) variance of error

Estimation of variance components comprise of genotype and phenotype variation as well as heritability is estimated using equations:
Estimation variance component (Table 1):

\[
\sigma_G^2 = \frac{(M_1 - M_2)}{f} \quad \text{..................................................} \quad (1)
\]
\[
\sigma_B^2 = M_2 \quad \text{..................................................} \quad (2)
\]
\[
\sigma_F^2 = \text{equations } 1 + (\text{equation } 2/f) = \frac{(M_1 - M_2)/f = (M_2/f)}{f} \quad \text{..................................................} \quad (3)
\]
\[
h_{2s}^2 = \frac{(M_1 - M_2)/f}{((M_1 - M_2)/f - (M_2/f))} = \frac{\sigma^2_G}{\sigma^2_F} = 1 - M_2/M_1
\]

3. Result and Discussions

The observed temperature and rainfall in Gowa district were provided by Maros weather station. Both climate data were important in determining the success of wheat cultivation in the tropical region. The average air temperature was about 20.7-22°C. It showed the average daily air temperature for 24 hours. Rainfall occurs only in the first 2 months of May and June with an average of rainfall 12.1 and 12.8, respectively and counted to low monthly intensity rainfall criteria.

Temperature is an important factor in determining the suitability of land for wheat crops. In the tropics, the production of the wheat crop is strongly influenced by the topography of the region. The simulation model in predicting wheat productivity in the temperature range 17.5-22.5°C will yield about 4.5-6.9 t/ha, but due to the drying factor in the seedling and flowering phase (30-50 DAP) the potential loss of yield will increase until 74% [16]. In this study the plant began to experience drought stress at 30 days after sowing as well as during the formation of tiller in late June and July where the average rainfall was only about 12.8 mm, while the water requirement of wheat crops in this stage is around 400-450 mm. Therefore the predicted yield for each genotype will be lower than the yield range of 2.7-4.1 t/ha. Drought impedes wheat performance at all growth stages; it is more critical during the flowering and grain-filling phases (terminal drought) at 50-60 DAP and results in substantial yield losses [15].

| Characters                  | Range          | Mean Square          | Lines | Error | CV   | LSD  |
|-----------------------------|----------------|----------------------|-------|-------|------|------|
| Days to flowering           | 49.33-75.00    | 63.452**             | 7.7002| 4.3   | 4.64 |
| Days to harvesting          | 103.00-132.00  | 167.528**            | 3.5861| 5.95  | 11.05|
| Plant height                | 60.81 - 84.91  | 88.329**             | 4.9049| 5.94  | 6.87 |
| Spike number/meter          | 91.00 - 313.30 | 5123.904**           | 2.5076| 22.61 | 73.06|
| Spike length                | 5.83 - 12.78   | 2.745**              | 3.6595| 9.74  | 1.4  |
| Seed number/Malai           | 32.53 - 53.90  | 50.565*              | 1.8154| 11.84 | 8.53 |
| Seed weight/Malai           | 1.01 - 2.18    | 0.149**              | 1.6518| 16.67 | 0.49 |
| Spikelet number             | 14.50 - 20.47  | 4.681*               | 1.8913| 9.09  | 2.54 |
| Floret number               | 43.50 - 61.40  | 41.51*               | 1.7954| 9.24  | 7.77 |
| Hollow floret number        | 0.00 - 15.55   | 0.726**              | 0     | 60.59 | 7.28 |
| Water content               | 9.83 - 13.55   | 1.327*               | 1.0053| 10.32 | 1.86 |
| Weight of 1000 seeds        | 28.33 - 49.67  | 42.633*              | 1.9239| 11.64 | 7.61 |
| Yield                       | 1.06 - 3.90    | 1.091**              | 5.8745| 17.64 | 0.697|

Analysis of variance of tropical wheat line characters showed that there were significant and very significant differences between the genotypes. Selection is performed on the character of the yield by removing the wheat genotype which has yield below 1.54 ton/ha, where the character of this yield was heavily influenced by climatic factors in the tropics, especially temperature stress [10, 20] and drought [17]. The selection acquired 25 wheat lines, with yields potential ranging from 1.54-3.90 ton/ha and had an average yield about 2.45 t/ha. The lines with an average yield below 1.54 ton/ha were then eliminated. The selection lines then analyzed by F-tested for the second time to see the variance of selected lines (Table 1) and further analyzed for the mean value of yield component (Table 2) and yield characters (Table 3) which is compared to controls.
Based on the value of heritability showed all characters had various heritability values that spread from narrow to broad. Seed water content character had narrow heritability value, caused by a long period of the dry season; therefore the seed water content of all wheat genotype will decline. Thus the character is not suitable to be used for selection in drought condition. In characters with wide heritability values indicate the various responses of plants to both environmental stresses. Flowering characters and results are the characters that show the greatest environmental response which means both these characters are very well used to select the wheat genotype in two environmental stresses (search for literature).

Variance analysis of selected wheat lines character showed very significant differences in days to flowering, days to harvesting, plant height, number of spike/meter, spike length, hollow floret, and yield. Characters of seed weight/spike and weight of 1000 seeds showed significant differences, while the number of seeds/spike, number of spikelets, the number of florets and water content was not significantly different. This suggests that temperature and drought stresses affect most of the growth components, yield components and yield. High temperature can have a rapid impact on yield reduction and yield components even in a short time [18].

### Table 3. Genotypic and phenotypic variance, broad heritability values and criteria of wheat line characters

| Characters                  | $\sigma^2_G$ | $\sigma^2_P$ | $h^2_B$ (%) | Criteria |
|-----------------------------|--------------|--------------|-------------|----------|
| Days to flowering           | 18.40        | 21.15        | 0.87        | high     |
| Days to harvesting          | 40.27        | 55.84        | 0.72        | high     |
| Plant height                | 23.44        | 29.44        | 0.80        | high     |
| Spike number/meter          | 1.027        | 1.708        | 0.60        | high     |
| Spike length                | 0.67         | 0.92         | 0.73        | high     |
| Seed number/Malai           | 7.57         | 16.86        | 0.45        | medium   |
| Seed weight/Malai           | 0.02         | 0.05         | 0.40        | medium   |
| Spikelet number             | 0.74         | 1.56         | 0.47        | medium   |
| Floret number               | 6.13         | 13.84        | 0.44        | medium   |
| Hollow floret number        | 6.78         | 13.54        | 0.55        | high     |
| Water content               | 0.00         | 0.44         | 0.01        | low      |
| Weight of 1000 seeds        | 6.83         | 14.21        | 0.48        | medium   |
| Yield                       | 0.30         | 0.36         | 0.82        | high     |


### Table 4. Variance analysis of selected wheat line characters on high temperature and drought stresses.

| Characters                  | Range       | Lines     | Error | CV (%) | LSD   |
|-----------------------------|-------------|-----------|-------|--------|-------|
| Days to flowering           | 54.33 - 70.00 | 39.35**   | 9.14  | 5.00   | 4.64  |
| Days to harvesting          | 104.00 - 132.33 | 142.16** | 49.60 | 6.07   | 11.05 |
| Plant height                | 60.80 - 84.91 | 100.26**  | 15.38 | 5.52   | 6.87  |
| Spike number/meter          | 91.00 - 313.33 | 6.396**   | 1.619 | 19.81  | 73.06 |
| Spike length                | 7.95 - 12.78  | 2.55**    | 1.01  | 11.12  | 1.4   |
| Seed number/Malai           | 36.80 - 53.90 | 41.12 in  | 27.77 | 11.61  | 8.53  |
| Seed weight/Malai           | 1.01 - 2.18   | 0.17*     | 0.10  | 17.45  | 0.49  |
| Spikelet number             | 15.00 - 20.10 | 3.76 in   | 2.88  | 9.70   | 2.54  |
| Floret number               | 45.20 - 60.30 | 34.40 in  | 27.98 | 10.06  | 7.77  |
| Hollow floret number        | 0.00 - 14.50  | 39.82**   | 17.20 | 57.63  | 7.28  |
| Water content               | 9.93 - 12.20  | 0.79 in   | 1.33  | 10.38  | 1.86  |
| Weight of 1000 seeds        | 28.33 - 49.67 | 52.75*    | 30.71 | 13.66  | 7.61  |
| Yield                       | 1.54 - 3.90   | 1.07**    | 0.23  | 19.37  | 0.697 |

* = significant on P < 0.05; ** = significant on P < 0.01; in = no significant

High temperature and drought stress often decrease stem growth and plant height. When plants experience drought stress, the diameter of stem reduced response to changes in internal water status.
Evaluation of yield component character to promising wheat lines showed that character of days to flowering (DF), days to harvesting (DH), plant height (PH), number of spike per meter (NSM) and length of spike (LS) showing significant difference to controls (Table 2), while the number of seed/spike (NSS) showed no significant differences to controls. Character evaluation takes precedence over the character of the results component, as it is the character most affected by stress and drought stress. High temperature and drought stresses will affect vegetative growth, flowering and tillering. DF and DH are important characters in the development of tropical wheat; these two characters will affect the filling period of the seeds. The time interval of DF to DH is the period of filling seeds and usually until the ripening phase. DF phase that is most sensitive to drought stress is 7 days before and when anthesis occurs and it will decrease the yield of seed/spike. The developmental stage that is most sensitive to drought stress generally occurs at the time of development of spike and when flowering on cereal plants and the period before and at a flowering time on the plant nuts. However, much of the research is still limited to basic understanding, the stress tolerance and its application is focused on the developmental stage until the flowering stage, and is still very limited in the flowering and filling/seed stages. PH, NSM and LS characters show that G1, G3, G7, G9 lines show significant differences to all controls. In character of LS, only G7 and G9 show a significant difference to control. The LS is highly correlated to yield production, although, the LS was not correlated to the number of seeds per spike. It can be seen that the number of seeds per spike (NSS) is not significantly different from the control.

**Table 5.** Genotypic and phenotypic variance, heritability value and criteria character after selection

| Characters                  | $\sigma^2_g$ | $\sigma^2_r$ | $h^2_{ph}$ (%) | Criteria |
|-----------------------------|--------------|--------------|----------------|----------|
| Days to flowering           | 10.07        | 13.12        | 0.76           | high     |
| Days to harvesting          | 30.86        | 47.39        | 0.65           | high     |
| Plant height                | 28.29        | 33.42        | 0.84           | high     |
| Spike number/meter          | 1.591        | 2.132        | 0.74           | high     |
| Spike length                | 0.51         | 0.85         | 0.60           | high     |
| Seed number/Malai           | 4.45         | 13.71        | 0.32           | low      |
| Seed weight/Malai           | 0.02         | 0.057        | 0.40           | medium   |
| Spikelet number             | 0.29         | 1.26         | 0.23           | low      |
| Floret number               | 2.14         | 11.47        | 0.18           | low      |
| Hollow floret number        | 7.54         | 13.27        | 0.56           | high     |
| Water content               | 0            | 0.44         | 0              | low      |
| Weight of 1000 seeds        | 7.35         | 17.58        | 0.41           | medium   |
| Yield                       | 0.28         | 0.36         | 0.78           | high     |

Selection on yield characters by removing genotypes that have yield potential below 1.54 ton/ha. The character that remains has broad criteria of heritability indicate to highly responded characters in environments. This research will support breeding programs in the process of climate change adaptation. This research will be comprehensive if it is continued by identifying the use of molecular markers that are very adaptive for the identification of related genes.

**Table 6.** Average value of yield and yield component characters of selected wheat lines on high temperature and drought stresses.

| Lines | DF     | DH      | PH     | NSM    | LS     | NSS    |
|-------|--------|---------|--------|--------|--------|--------|
| G1    | 60.33  | 124.67  | 70.89  | 300.50 | 8.27   | 46.60  |
| G2    | 60.67  | 118.67  | 76.36  | 191.33 | 8.35   | 44.40  |
| G3    | 61.00  | 111.00  | 73.89  | 313.33 | 8.97   | 43.13  |
| G4    | 60.00  | 112.00  | 78.87  | 221.67 | 8.31   | 49.30  |
| G5    | 63.67bc| 123.33bc| 74.02  | 209.00 | 9.14   | 53.90  |
| G6    | 69.33abc| 129.33abc| 62.98  | 146.67 | 9.40   | 43.77  |
| G7    | 70.00abc| 113.67  | 84.91def| 212.50 | 10.63c | 43.95  |
| G8    | 62.33abc| 129.00abc| 79.41  | 223.33 | 10.26  | 44.73  |
Evaluation on yield character of wheat lines indicated that only on water content (WC) character had no significant difference to the controls (Table 4). The WSS, NS, NF, and NHF characters are the most important characters in the formation of wheat kernels and affect the yield. In the NHF character, the G5 line has a zero hollow floret number this indicated that almost all of the spikes are formed seeds. The G5 line can be tested with further assessment regarding the physiological character of floret formation and seeds. In character W1000S only G7 line showed a significant difference to all control, while the G8, G15, G16, G17, and G21 lines only showed significant differences to the control Guri5 Agritan.

The yield average of genotypes was 2.45 t/ha, with a yield range of 1.54-3.9 t/ha. G5, G8 and G11 lines showed an average yield of 3 t/ha. G8 and G11 showed significant differences to Selayar control which is high-temperature resistant variety, shorter days to harvesting and high yielding. Some research results indicate that seed size is generally more conservative than the number of seeds that experience high-temperature stress [25]. Seed size influences the yield weight and has a positive correlation to yield.

Table 7. Average value of yield characters on high temperature and drought stresses of selected tropical wheat lines.

| Lines | WSS | NSPKL | NFLRT | NHFLRT | WC | W1000S | Y |
|-------|-----|-------|-------|--------|----|--------|---|
| G1    | 1.66| 17.1  | 51.3  | 4.7    | 11.6| 35.67  | 2.14 |
| G2    | 1.98| 17.93 | 53.8  | 9.4    | 11.2| 44.67  | 2.05 |
### 4. Conclusion

Selection and evaluation characters of promising wheat lines on high temperature and drought stress conditions are very important in order to continue to produce tolerant wheat adaptive to climate change and answer the challenge of global warming. Character evaluation shows significant differences in most of the yield and yield component. Based on the heritability value, the characters that can be used for evaluation and selection on both stresses were all character of the yield and yield components except the Number of seed per spike (NSS) and Water Content (WC) characters. Expected lines, G5, G8 and G11 became promising wheat lines for high temperature and drought stresses with potential yields 3, 3.39 and 3.03 t/ha, respectively.
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