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Evaluation of several tropical wheat genotypes (*Triticum aestivum* L.) on various water availability in the lowlands

Evaluation of several tropical wheat genotypes (*Triticum aestivum* L.) on various water availability in the lowlands

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Abstract. Wheat as a cereal crop has a strategic role in supporting food security and to meet human needs on food. Nutritional content of wheat is relatively higher than other cereal plants. This research aimed to study the adaptability, growth, and production of some wheat mutant lines at various water availability in the lowlands. The research was carried out in the Experimental Garden, Faculty of Agriculture, Universitas Hasanuddin from November 2017 to January 2018. Location of the trial was at an altitude of < 40 meters above sea level with an average temperature of 24 ºC in the morning and 32 ºC in the afternoon. A split plot design was employed in this study with the availability of water set as the main plot and the wheat mutant genotypes as subplots. Three levels of water availability was used, 81-100% field capacity, 61-80% field capacity, and 41-60% field capacity. The wheat mutant genotypes used consisted of 15 genotypes (13 mutants and 2 comparative varieties). The results of the research show that wheat genotypes grown in the lowland that showed better production in restricted water availability (61 - 80% of field capacity) were Nias 250 4.6.2 (0.95 g. plant^{-1}), and Nias 350 3.8. 9 (1.10 g.plant^{-1}). Whereas in the 41 - 60% of the field capacity, the Nias 250 4.6.2 and Nias 350 3.8.9 produced better yield of 0.40 g.plant^{-1}.

1. Introduction

As an introduced plant in Indonesia, wheat is a cereal plant originated from regions with warm summers and cold winters, such as in temperate, Mediterranean, subtropical, and regions with altitude of 1,000 m above sea level (asl). As the results of a long-term breeding of wheat in Indonesia, wheat can now be developed in tropical Indonesia [1]. Domestic wheat production needs to be supported by wheat variety suitable for the agro-climate in Indonesia. To reduce wheat imports, Indonesia needs to make efforts to produce domestic wheat. Therefore, it is necessary to select the genotypes of wheat produced from crossing in order to obtain wheat that is adaptive to temperature based on the altitude [2].

Wheat import policy, in short term, can be seen as a solution to meet the national demand for wheat flour, but for long-term the policy will cause state dependence on wheat exporting countries and drain the country's foreign exchange [3]. To increase the competitiveness and production of national wheat in the country as a food source and food diversification, it is necessary to develop the Indonesian wheat adaptive to highland to lower altitudes (400-600 m asl). One of the limiting factors of wheat extensification in the lowland is temperature stress [4]. The water requirement to produce wheat plants is at an optimum of 450-650 mm, depending on the efficiency and duration of plant growth [5]. The

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accuracy of the availability of water in the growth stage affects the production of wheat. Optimal results will be obtained if the plants get water in the phases of tillers formation, flowering, and grain filling. Therefore, appropriate water management technology on wheat crop requirement basis is necessary. The objectives of water management are the achievement of four main objectives, namely: high efficiency of water use and crop production, efficiency of water use costs, equitable distribution of limited available water, both in terms of time and the amount of the sustainability of water resource use systems.

2. Methodology

This research was conducted in the Experimental Farm of the Faculty of Agriculture, Universitas Hasanuddin, located in Tamalanrea District, Makassar City at an altitude of < 40 m asl with an average temperature of 24 ºC in the morning and 32 ºC in the afternoon. The research was conducted from November 2017 to January 2018. The trial was set based on a split plot design with the main plot was the availability of water (K) consisted of three levels, namely: k0 = 81-100% field capacity, k1 = 61-80% field capacity, and k2 = 41-60% field capacity. While sub plot was the wheat genotype (G) consisted of 15 genotypes (13 mutants and 2 comparative varieties), namely: g1 = Munal1.7.1, g2 = Nias 350 3.6.2, g3 = Nias250 4.2.1, g4 = Nias 350 3.1.3, g5 = Nias350 3.2.2, g6 = Nias 2504.5.2, g7 = Nias 350 3.1.4, g8 = Nias250 2.5.1, g9 = Munal200 1.7.1, g10 = Nias 250 4.6.2, g11 = Nias 350 3.8.9, g12 = Selayar 300 8.3.1, g13 = Nias 200 2.5.2, g14 = Dewata (Comparator), and g15 = Munal (Comparator). All treatments resulted in total of 45 treatment combinations and each treatment was repeated three times with three crop units resulted in 405 experimental units. The 13 mutant genotypes and 2 comparative varieties used were the collection of Indonesian Cereals Research Institute (ICERI) Maros.

The level of water availability treatment was set using a weighing method based on field capacity. According to Harun [6], the calculation of water availability can be used with the following formula:

$$KLku = \frac{a-b}{b}\ x\ 100\%$$

$$KLkl = \frac{c-d}{d}\ x\ 100\%$$

$$KLkl = w\ x \frac{(100+KLkl)}{(100+KLku)}\ x\ 100\%$$

$$Vol = CTkl$$

where :

KLku: Moisture content of air-dried soil (%)
KLkl: Moisture content of soil at field capacity (%)
CTkl: Soil weight at field capacity (g)
Vol: Volume of water added so that the soil is in field capacity (ml)
a: Initial weight of air-dried soil sample (g)
b: Weight of air dried soil sample after oven (g)
c: Initial weight of soil sample at field capacity (g)
d: Weight of soil sample at field capacity after oven (g)
w: Weight of air-dried soil used (g)

The planting media was prepared by cleaning the soil from large aggregates, roots and undesirable rocks. The soil was mixed with manure and filled into polybags then weighed 3 kg before adding 1 liter of water into the polybag. Water level in the polybag was maintained on a daily basis by adding water to the pot every day. The amount of water added was adjusted to the water level treatments of K0 = 4084 g, K1 = 3867.2 g and K2 = 3650 g. The procedure was carried out a month after planting.

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Plant maintenance conducted during the growing period included fertilizing, weeding, pest and disease control. Fertilization were carried out twice at 10 days after planting (DAP) and 30 DAP, respectively. Fertilizer applied to all experimental units consisted of Urea (0.15 g/pot), SP36 (0.0795 g/pot), and NPK (0.4995 g/pot). Plant and disease control was carried out by spraying the Deltamethrin 25g / l insecticide and 70% Propineb fungicide on the infested plants. Harvest was conducted based on the level of maturity of each genotype with harvest criteria of leaf color change from green to dark yellow, panicles have ducked to the ground and seeds have hardened when pressed with finger.

3. Results

3.1. Plant height

The results of variance analysis show that there was a high significant interaction ($p \leq 0.01$) between the genotype and water availability treatment. Table 1 shows that genotype Nias 250 4.6.2 at water level of 81-100% of field capacity resulted in the highest plant height (36.40 cm) and was significantly different from the comparative varieties of Dewata and Munal. At water condition of 61 - 80% of the field capacity, best results were shown by Nias 250 4.6.2 and Nias 350 3.8.9 and were significantly different from the comparative varieties of the Dewata and Munal. At lower water availability condition, 41-60% of the field capacity (k2), most of mutant showed decline in plant height and only one mutant had significantly higher plant height compared to the comparative varieties of Dewata and Munal namely Nias 250 4.6.2.

Table l. Plant height (cm) of several wheat mutant genotypes on different water availability

Genotype	Water availability level		
	81-100% fc (k0)	61-80% fc (k1)	41-60% fc (k2)
g1 (Munal 1.7.1)	35.54^{b}	32.9^{a}	30.3_{p}
g2(Nias 350 3.6.2)	32.62	26.6_{p}	26.3_{p}
g3 (Nias 250 4.2.1)	25.31	25.0	26.5
g4 (Nias 350 3.1.3)	33.56^{b}	25.2_{p}	24.6_{p}
g5 (Nias 350 3.2.2)	25.52	23.1	20.5_{p}
g6 (Nias 250 4.5.2)	30.58	25.5_{p}	19.5_{p}
g7 (Nias 350 3.1.4)	25.94	25.5	25.0
g8 (Nias 250 2.5.1)	30.91	21.2_{p}	20.5_{p}
g9 (Munal 200 1.7.1)	27.41	28.6	25.5
g10 (Nias 250 4.6.2)	36.40^{ab}	34.5^{ab}	34.0^{ab}
g11 (Nias 350 3.8.9)	35.01^{b}	34.7^{ab}	28.1_{p}
g12 (Selayar 300 8.3.1)	23.61	21.2	19.8
g13 (Nias 200 2.5.2)	30.68	25.9_{p}	20.1_{p}
g14 (Dewata) (a)	31.77	28.1	26.4
g15 (Munal) (b)	29.07	28.8	28.1
Mean	30.3	27.1	25.0
$LSD_{0.05}$ water level =	4.18	genotype = 4.23	

The number followed by the same letter in column (a, b) means higher and significantly different from the comparative varieties of the Dewata (a) and Munal (b), and in the row (p) means lower and significantly different from k0 in the LSD test $\alpha = 0.05$. fc = field capacity.

3.2. Number of tillers

Number of tiller of the mutant varied between water availability level and genotypes. The condition of water level significantly affected the number of tillers of the mutants ($p \leq 0.01$). Table 2 shows that the Nias 250 4.6.2 and Nias 350 3.8.9 had the highest number of tillers (5.07 and 5.00 tillers, respectively)

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at the water level condition of 81-100% of field capacity (k0), and were significantly differed compared to the comparative variety of Dewata. At medium water level of 61 - 80% of field capacity (k1), genotype Nias 250 4.6.2 showed the highest number of tillers (3.83 tillers) and was significantly different from the comparative varieties of Dewata and Munal. Whereas at 41 - 60% of the field capacity (k2), Nias 350 3.8.9 had the highest number of tillers (2.83) and only differed significantly from the comparative varieties of Dewata.

Table 2. Number of Tillers of several wheat mutant genotypes on different water availability

Genotype	Water availability level		
	81-100% fc (k0)	61-80% fc (k1)	41-60% fc (k2)
g1 (Munal 1.7.1)	4.11	2.44_{p}	1.61_{p}
g2(Nias 350 3.6.2)	3.00	1.92_{p}	1.50_{p}
g3 (Nias 250 4.2.1)	2.44	1.72	1.23_{p}
g4 (Nias 350 3.1.3)	4.22	2.17_{p}	1.94_{p}
g5 (Nias 350 3.2.2)	2.33	2.00	1.22_{p}
g6 (Nias 250 4.5.2)	2.00	1.83	1.57
g7 (Nias 350 3.1.4)	1.89	1.73	1.33
g8 (Nias 250 2.5.1)	2.44	1.67	1.60_{p}
g9 (Munal 200 1.7.1)	3.33	1.83_{p}	1.32_{p}
g10 (Nias 250 4.6.2)	5.00^{a}	3.83^{ab}_{p}	2.50_{p}
g11 (Nias 350 3.8.9)	5.07^{a}	3.33p	2.83^{a}_{p}
g12 (Selayar 300 8.3.1)	1.90	2.00	1.28
g13 (Nias 200 2.5.2)	2.50	1.89	1.34_{p}
g14 (Dewata) (a)	3.67	2.67_{p}	1.97_{p}
g15 (Munal) (b)	4.50	2.68_{p}	2.56_{p}
Mean	3.16	2.23	1.73
$LSD_{0.05}$ water level =	0.80	genotype = 0.79	

The number followed by the same letter in column (a, b) means higher and significantly different from the comparative varieties of the Gods (a) and Munal (b), and in the row (p) means lower and significantly different from k0 in the LSD test α = 0.05. fc = field capacity.

Table 3. Flowering age (DAP) of several wheat mutant genotypes on different water availability

Genotype	Water availability level			Mean
	81-100% fc (k0)	61-80% fc (k1)	41-60% fc (k2)	
g1 (Munal 1.7.1)	45.34	43.22	42.20	43.59^{a}
g2(Nias 350 3.6.2)	45.34	43.53	43.48	44.12
g3 (Nias 250 4.2.1)	47.78	45.77	43.47	45.67
g4 (Nias 350 3.1.3)	45.61	44.60	43.81	44.67
g5 (Nias 350 3.2.2)	46.67	44.56	44.36	45.19
g6 (Nias 250 4.5.2)	47.28	45.06	44.19	45.51
g7 (Nias 350 3.1.4)	46.61	43.48	43.13	44.40
g8 (Nias 250 2.5.1)	45.33	44.83	42.59	44.25
g9 (Munal 200 1.7.1)	44.61	42.87	41.19	42.89^{ab}
g10 (Nias 250 4.6.2)	44.67	44.23	39.99	42.97^{ab}
g11 (Nias 350 3.8.9)	46.34	45.01	43.78	45.04
g12 (Selayar 300 8.3.1)	47.61	46.01	44.15	45.93
g13 (Nias 200 2.5.2)	45.67	42.26	41.38	43.10^{ab}
g14 (Dewata) (a)	46.34	46.01	44.37	45.57
g15 (Munal) (b)	47.33	46.67	41.04	45.01
Mean	46.23	44.64	42.92_{p}	
$LSD_{0.05}$ water level = 2.46	genotype = 1.96			

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The number followed by the same letter in column (a, b) means higher and significantly different from the comparative varieties of the Gods (a) and Munal (b), and in the row (p) means lower and significantly different from k0 in the LSD test α = 0.05. DAP = days after planting, fc = field capacity.

3.3. Flowering age

The results of variance analysis shows that genotype and water availability treatments had significant effect on flowering age parameter ($p \leq 0.05$) but no significant effect on the interaction between the two treatments. Table 3 shows limited water condition (40-60% of field capacity) resulted in earlier flowering. Munal 200 1.7.1, Nias 250 4.6.2, and Nias 200 2.5.2 mutants resulted in the faster flowering age (42.89, 42.97, and 43.10 DAP, respectively) and differed significantly from the comparative varieties of the Dewata and Munal, whereas the Munal 1.7.1 genotype was only significantly different from the comparative varieties of the Dewata.

3.4. Length of panicle

Length of panicle of the mutant genotypes on different water availability levels is shown in table 4. The results of variance shows that length of panicle parameter of the wheat mutant genotypes was highly affected significantly ($p \leq 0.01$) either by genotype or water availability treatments, but no significant effect of the interaction between the two treatments on the respective parameter. Table 4 shows that the Nias 250 4.6.2 genotype had the longest panicle (6.39 cm) compared to other genotypes and was significantly different from the comparative varieties of Dewata (a) and Munal (b). The shortest panicle was found at water level condition of 41-60% of field capacity (k2).

Table 4. Panicle length (cm) of several wheat mutant genotypes on different water availability

Genotype	Water availability level			Mean
	81-100% fc (k0)	61-80% fc (k1)	41-60% fc (k2)	
g1 (Munal 1.7.1)	6.13	5.14	4.23	5.17
g2(Nias 350 3.6.2)	6.43	5.09	5.07	5.53^{b}
g3 (Nias 250 4.2.1)	5.64	5.05	3.65	4.78
g4 (Nias 350 3.1.3)	5.67	5.62	4.30	5.19
g5 (Nias350 3.2.2)	6.00	5.57	4.93	5.50^{b}
g6 (Nias 2504.5.2)	6.04	6.41	5.10	5.85^{b}
g7 (Nias 350 3.1.4)	5.22	4.37	4.17	4.59
g8 (Nias 250 2.5.1)	5.67	5.24	4.70	5.20
g9 (Munal200 1.7.1)	6.17	4.90	4.33	5.13
g10 (Nias 250 4.6.2)	6.30	6.22	6.67	6.39^{ab}
g11 (Nias 350 3.8.9)	6.00	5.60	5.33	5.64^{b}
g12 (Selayar 300 8.3.1)	5.21	5.07	4.13	4.80
g13 (Nias 200 2.5.2)	5.40	5.00	4.47	4.96
g14 (Dewata) (a)	6.15	5.93	5.10	5.73
g15 (Munal) (b)	5.10	4.97	4.53	4.87
Mean	5.81	5.35$_{p}$	4.71$_{p}$	
$LSD_{0.05}$ water level = 0.41 genotype = 0.49				

The number followed by the same letter in column (a, b) means higher and significantly different from the comparative varieties of the Gods (a) and Munal (b), and in the row (p) means lower and significantly different from k0 in the LSD test α = 0.05. fc = field capacity.

3.5. Production per plant

The results of variance analysis show that genotype and water availability treatments interacted significantly ($p \leq 0.01$) in affecting the production per plant of the wheat mutant genotypes. Table 5 shows that genotypes showed higher production per plant at normal water condition are Munal 1.7.1,

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Nias 250 4.6.2, and Nias 350 3.8.9 (1.01, 1.62, and 1.58 g, respectively) and significantly different from the comparative varieties of Dewata and Munal. At the lower water level of 61 - 80% of field capacity, the Nias 250 4.6.2, and Nias 350 3.8.9 genotypes had higher production (0.95 and 1.10 g, respectively) compared to other genotypes and differed significantly from comparative varieties of Dewata and Munal. In water limited condition of 41 - 60% of field capacity (k2), the genotypes of Nias 250 4.6.2, and Nias 350 3.8.9 had higher production and were significantly different from the comparative varieties of Dewata and Munal.

Table 5. Production (g.plant^{-1}) of several wheat mutant genotypes on different water availability

Genotype	Water availability level		
	81-100% fc (k0)	61-80% fc (k1)	41-60% fc (k2)
g1 (Munal 1.7.1)	1.01^{ab}	0.51_p	0.12_p
g2(Nias 350 3.6.2)	0.76	0.38_p	0.10_p
g3 (Nias 250 4.2.1)	0.56	0.36	0.09_p
g4 (Nias 350 3.1.3)	0.95	0.37_p	0.09_p
g5 (Nias350 3.2.2)	0.40	0.30	0.09_p
g6 (Nias 2504.5.2)	0.85	0.59_p	0.21_p
g7 (Nias 350 3.1.4)	0.78	0.46_p	0.12_p
g8 (Nias 250 2.5.1)	0.54	0.33	0.15_p
g9 (Munal200 1.7.1)	0.59	0.47	0.11_p
g10 (Nias 250 4.6.2)	1.62^{ab}	0.95_p^{ab}	0.40_p^{ab}
g11 (Nias 350 3.8.9)	1.58^{ab}	1.10_p^{ab}	0.40_p^{ab}
g12 (Selayar 300 8.3.1)	0.39	0.30	0.05_p
g13 (Nias 200 2.5.2)	0.96	0.60_p	0.13_p
g14 (Dewata) (a)	0.74	0.49_p	0.14_p
g15 (Munal) (b)	0.75	0.47_p	0.14_p
Mean	0.83	0.51	0.16
$LSD_{0.05}$	water level = 0.23	genotype = 0.23	

The number followed by the same letter in column (a, b) means higher and significantly different from the comparative varieties of the Gods (a) and Munal (b), and in the row (p) means lower and significantly different from k0 in the LSD test α = 0.05. fc = field capacity.

4. Discussion

Growth and production of several mutant genotypes tested in this recent study are shown to be affected by the water level condition during plant growth. Although growth and production of the mutant generally declined with the water availability level, few mutant showed higher growth and production in the limited water level compared to the other mutant even to the comparative varieties. Mutant genotypes Nias 250 4.6.2 and Nias 350 3.8.9 showed relatively better growth and production even under unfavourable water condition.

Nias 250 4.6.2 had higher plant height, more tiller, earlier flowering, longer panicle and higher yield compared to other genotypes at 40-60% of field capacity. Plant height is a character closely related to the absorption of light, therefore, taller wheat plants potentially obtained more light hence physiological and biochemical processes can take place more optimal compared to shorter plants. This is in accordance to the opinion of Anderson [7] [8] which stated that the higher the plant, the more light can be absorbed, so photosynthesis is better. The number of tillers formed is strongly influenced by genetic factors of each wheat genotype. In addition to affecting the formation of tillers, environmental factors such as light intensity and high temperature can also affect plant growth and development. Therefore, the development of the number of tillers, and the number of productive tillers are determined by environmental factors, especially air temperature, the higher the air temperature tends to slow the development of the amount productive tillers [9].

Munal 2001.7.1 showed earliest flowering age and was significantly different from comparative varieties (Dewata and Munal). Each wheat genotype had a different flowering age. Almost all genotypes planted on each test did not flower simultaneously. However, 50% of all wheat genotypes showed flower in the 6th week and so on. The difference in flowering age is due to the adjustment of the flowering time of the wheat crop and also the physiological conditions of each plant as responses to the environment. This is consistent with the opinion of Glover [10], which stated that the flowering behaviour and flowering of plants are closely related to the physiological conditions of plants and the influence of environmental factors which specifically include the influence of the intensity and duration of irradiation, the effect of temperature, and water availability on the plant growth environment. Leaf possessing high chlorophyll content is expected to be more efficient in absorbing energy from sunlight for photosynthesis process [11].

The higher panicle length was found in Nias 250 4.6.2 genotype, when water level declined to 41 - 60% (k2). The longer panicle, the more wheat seeds produced therefore the parameter is a parameter that supports high and low productivity [12]. This was indicated by the production parameter with genotype Nias 250 4.6.2 that also showed higher production and was significantly different from the comparative varieties (Dewata and Munal).

5. Conclusions

a) Wheat genotypes planted in lowland with limited water availability that provide better production are Nias 250 4.6.2 (1.95 $g.plant^{-1}$) and Nias 350 3.8.9 (1.10 $g.plant^{-1}$) at the water availability level of 61 - 80% field capacity. Whereas at water availability level of 41 - 60% field capacity, better production is shown by Nias 250 4.6.2 and Nias 350 3.8.9 (0.40 $g.plant^{-1}$).

b) At water availability level of 61 - 80% of field capacity, two tolerant genotypes are Nias 250 2.4.6 and Nias 350 3.8.9, while at water availability of 41 - 60% field capacity, one tolerant genotype found is Nias 250 4.6.2.

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