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Contribution of genotype × environment interaction on the performance of wheat breeding lines in two tropical agro ecosystems

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Abstract

Wheat production in Indonesia is directed to areas of medium elevation areas (400-800 m above sea level) with average temperature higher than the optimum temperature for wheat. The objective of this study is to obtain information of the effect of genotype × environment interaction on the performance of elite wheat breeding lines under two agro-ecosystem differing in elevation. The study was conducted at Bogor Region, West Java at 600 m above sea level and at Malino, South Sulawesi at 1600 m above sea level. The genetic materials evaluated were 25 elite lines derived from a cross of Oasis × HP1744, the two parental lines Oasis and HP1744, and four national varieties. The results showed that there is an effect of genetic × environment interaction on performance and variability of yield, protein and fat content of the elite wheat lines. A total of 18 lines showed higher potential yield at high elevation agro-ecosystem and 5 lines (O/HP-14-A19-1-8, O/HP12-A-25-3-7, O/HP-14-a10-2-10, O/HP14-A10-3-3 and O / HP-12-A-23-1-10) showed similar yield potential in high elevation and medium elevation agro ecosystem. Most lines showed elevated protein content under high temperature at medium elevation, but 2 lines showed little changes in the protein content under high temperature condition.

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Introduction

The demand for wheat in Indonesia is increasing each year due to rapid increase in wheat flour based food industries. In addition to carbohydrates, protein and fat, wheat also contain various beneficial phytochemicals namely saponins, phytosterol, aqualen, orisanol and tolotirenol that can lower cholesterols (Erwidodo *et al*, 2004). Wheat contains many proteins, but the most important is glutein. In 2016 Indonesia imported a total of 8.04 million tons of wheat (FAO, 2016). According to Sastrosoemarjo *et al.* (2004), in Indonesia wheat can only grow in high elevation areas (> 1000 m above sea level) because wheat requires growing environment with temperature of 10-25^oC and rainfall of 350mm - 1250mm per year. However, wheat production in Indonesia should be directed to lower elevation as not to compete with horticultural crops.

The constrain of wheat production at lower elevation in Indonesia is the unsuitable agro climatic condition of medium to lower elevation areas and the lack of wheat varieties adapted to high temperature and humidity of the tropics. Bogor Agricultural University has conducted wheat breeding program through hybridization of introduced lines to develop high yielding wheat lines adapted to high temperature and high humidity of the tropics since 2009 (Natawijaya, 2012).

The difference agro ecosystem between medium elevation and higher elevation areas may resulted in genetic x environment interaction which will complicate selection of high yielding and stabil wheat lines. Althahuish *et al.* (2014) reported the presence of genotype × environment interaction on the performance of introduced wheat lines in two agro ecosystem in Indonesia. In addition to yield potential, protein content of wheat and other nutritional content is also influenced by the environment (Triboї *et al*, 2003). The effect of genotype ×environment interaction on performance of wheat lines should be studied when developing wheat varieties for adaptation to tropical agro ecosystem in Indonesia (Nur *et al*, 2014). This paper reported the study on the effect of genotype × environment interaction on the performance of agronomic characters and nutritional content of elite wheat lines in medium and high elevation areas in Indonesia.

Materials and methods

Place and time of research

The study was conducted from May 2015 to February 2016 in two locations with different elevation at Cisarua, Bogor Regency, West Java at 600 m above sea level and Malino, South Sulawesi at 16d00 m above sea level. The average temperature at Cisarua, was 27.7^oC and at Malino the average temperature was 20.1^oC.

Genetic materials

The genetic materials were 25 elite wheat lines from a cross of Oasis x HP1744, the two parental lines Oasis and HP1744, and four national varieities Guri1, Guri 2, Selayar and Dewata.

Research methodology

At each location, the experiment was conducted in a Randomized Complete Block Design with three replication, in which the lines were fix factor and the locations as random factors. Each experimental unit was a 1 × 1.5 m plot. The cultivation was conducted as standard cultivation. Observations were conducted on agronomic characters of plant height, maturing date, number of seed per culm, and yield potential. The lines were harvested according to their maturing dates. Analysis of nutritional content was conducted on protein content, fat content and carbohydrate content (Danuarsa, 2006) at the Laboratory of the Department of Food Science, Bogor Agricultural University.

Data analysis

The data were analyzed using the software SAS version 9.0 for analysis of variance for separate experiment with F test at 95% confidence level. After test for homogeneity of variance, a combine analysis of variance was done in a Randomized Complete Block Design to determine the effect of location and its interaction with genotypes (Sigh and Chaudhary 1979, Gomez and Gomez 1995). The phenotypic variance (σ^2_P), genotypic variance(σ^2_g), environmental variance (σ^2_e), and the variance of the interaction (σ^2_{GL}) were determined from the partition of the expected mean square as follows : $\sigma^2_P = \sigma^2_g + \sigma^2_{ge}/e + \sigma^2_{gm}/m + \sigma^2_e/rl$; $\sigma^2_g = (M_g - M_{gl})/rl$; $\sigma^2_{gl} = (M_{gl} - M_{ga})/r$; $\sigma^2_e = M_{ga}$ and the hertitability of the broad sense were estimated as follows $h^2_{(bs)} = (\sigma^2_G/\sigma^2)$ x 100% (Halluer and Miranda, 1995).

Results and discussion

The result of analysis showed significant effect of genotype and location on plant height (Table 3). At the same elevation, plant height varied between wheat lines. In the medium elevation Cisarua there were lines that showed a higher growth than the average of control varieties namely, O/HP-12-A25-3-7, O/HP-78-A2-5-2, O/HP-12-A25- 2-6, O/HP-82-A15-2-3 and O/HP-12-A23-1-10, whereas at high elevation in Malino only line O/HP-78 high-A2-5-2 shows the performance that exceeds the control varieties.

At high elevation with lower temperature, the wheat lines have average height of 67.40 cm, while in the medium elevation was only 51.86 cm. This is partly due to the difference in temperature at both locations. The growth of wheat lines in the medium elevation with an average temperature of 27.7 ° C experienced high temperature stress. The difference in temperature greatly affect the height of wheat plants. Wheat requires growth environment with a temperature range of 100C-250C. Higher temperature causes an increase in cellular respiration resulted in shorter plant height (Ihsan *et al.*, 2007).

Table 1. Analysis of variance and mean squared for agronomic characters of introduction wheat in each location.

Source	DF	MS	Expected MS
Repeat	r-1		
Lines	g-1	MS_1	$\sigma^2 + r\sigma^2_g$
Error	(g-1) (r-1)	MS_2	σ^2

r = repeat, g = lines amount, σ^2_g = Variance of lines, σ^2 = Error variance

Table 2. Analysis of error combination between location and random model lines.

Source	DF	MS	Expected MS
Locations (l)	l-1	M_l	$\sigma^2_l + g\,\sigma^2_{r/l} + gr\,\sigma^2_l$
Repeat/Locations	l (r-1)	$M_{u/l}$	$\sigma^2_l + g\,\sigma^2_{r/l}$
Lines (g)	(g-1)	M_g	$\sigma^2_l + r\,\sigma^2_{gl} + rl\,\sigma^2_g$
Lines × Locations	(g-1)(l-1)	M_{gl}	$\sigma^2_l + r\,\sigma^2_{gl}$
Error	l(g-1)(r-1)	M_{ga}	σ^2_l

σ^2_g = Variance of lines, σ^2_{gl} = Variance interaction, σ^2 = Error variance.

Table 3. Variance of wheat lines derivated from crossing and national varieties in two environments.

Lines	Plant Height (cm)		Maturing date (days)	
	Cisarua	Malino	Cisarua	Malino
	$\bar{X}$ ± SD	$\bar{X}$ ± SD	$\bar{X}$ ± SD	$\bar{X}$ ± SD
O/HP-12-A28-5-1	50.2 ± 1.1	68.3 ± 3.6	93.3 ± 0.5	113.0 ± 12.2
O/HP-78-A-29-3-3	53.9 ± 5.8	69.3 ± 2.3	93.0 ± 0.0	106.6 ± 8.62
O/HP-82-A-15-1-4	48.5± 7.0	68.4 ± 6.5	93.3 ± 0.5	108.3 ± 11.3
O/HP-78-A2-2-5	47.6 ± 3.8	66.9 ± 2.7	93.0 ± 0.0	114.3 ± 13.4
O/HP-12-A1-1-9	53.2 ± 5.9	67.3 ± 0.6	93.3 ± 0.5	112.6 ± 11.8
O/HP-78-A22-3-7	47.8 ± 2.4	66.4 ± 1.9	93.0 ± 0.0	118.3 ± 2.8
O/HP-78-A22-5-10	52.4 ± 6.0	66.2 ± 1.0	93.3 ± 0.5	114.0 ± 13.0
O/HP-6-A8-2-10	54.2 ± 5.7	68.3 ± 3.0	93.3 ± 0.5	112.3 ± 11.5
O/HP-22-A27-1-10	52.1 ± 2.9	66.5 ± 1.7	93.3 ± 0.5	118.6 ± 2.0
O/HP-93-A1-1-3	53.4 ± 5.8	69.4 ± 2.2	93.0 ± 0.0	115.0 ± 8.7
O/HP-14-A19-1-8	54.7 ± 3.3	63.2 ± 2.3	93.3 ± 0.5	119.6 ± 2.0
O/HP-12-A5-4-5	50.0 ± 6.4	70.9 ± 0.2	93.3 ± 0.5	112.6 ± 12.1
O/HP-12-A25-3-7	55.3 ± 6.4	68.1 ± 0.7	93.3 ± 0.5	111.6 ± 11.1
O/HP-82-A7-2-6	52.4 ± 5.4	65.1 ± 0.8	93.0 ± 0.0	117.6 ± 2.8
O/HP-49-A1-1-4	49.5 ± 3.9	68.5 ± 1.7	93.0 ± 0.0	111.0 ± 10.4
O/HP-78-A2-1-9	48.0 ± 0.8	68.1 ± 3.4	93.3 ± 0.5	110.6 ± 11.0
O/HP-14-A21-5-7	50.8 ± 3.2	65.7 ± 3.7	93.0 ± 0.0	113.0 ± 12.1
O/HP-14-A10-2-10	50.6 ± 5.7	64.4 ± 1.0	93.3 ± 0.5	118.3 ± 5.5
O/HP-78-A2-5-2	55.1 ± 6.8	72.3 ± 2.0	93.0 ± 0.0	119.3 ± 1.1
O/HP-12-A25-2-6	55.7 ± 7.1	67.5 ± 1.4	93.3 ± 0.5	113.0 ± 7.5
O/HP-14-A10-3-3	50.4 ± 6.1	65.6 ± 0.7	93.3 ± 0.5	118.6 ± 2.0
O/HP-82-A15-2-3	54.8 ± 4.1	67.9 ± 1.7	93.0 ± 0.0	118.6 ± 3.0
O/HP-93-A3-1-9	46.2 ± 0.7	65.9 ± 4.6	93.0 ± 0.0	111.0 ± 10.4

Lines	Plant Height (cm)		Maturing date (days)	
	Cisarua	Malino	Cisarua	Malino
	$\bar{X}$ ± SD	$\bar{X}$ ± SD	$\bar{X}$ ± SD	$\bar{X}$ ± SD
O/HP-12-A23-1-10	60.3 ± 6.4	65.1 ± 2.4	93.0 ± 0.0	119.3 ± 2.3
O/HP-12-A1-2-2	48.7 ± 1.7	68.4 ± 1.6	93.3 ± 0.5	106.0 ± 7.5
Guri 1	55.0 ± 5.8	70.5 ± 4.7	93.3 ± 0.5	119.3 ± 3.0
Guri 2	52.2 ± 8.7	66.5 ± 0.8	93.0 ± 0.0	122.6 ± 2.5
Selayar	56.9 ± 1.8	71.0 ± 2.7	93.3 ± 0.5	108.0 ± 10.8
Dewata	57.4 ± 7.4	78.0 ± 2.9	93.3 ± 0.5	123.0 ± 0.0
Oasis	53.8 ± 9.6	73.7 ± 3.2	93.3 ± 0.5	114.3 ± 8.0
HP1744	53.2 ± 4.5	70.2 ± 0.5	93.3 ± 0.5	108.6 ± 11.9
$\bar{X}$ Comparison	54.7 ± 2.0	71.6 ± 3.8	93.2 ± 0.1	116.0 ± 6.7

The genotypes does not affect the maturing dates of wheat lines but the different elevation significantly affected the maturing date wheat lines. The maturing date wheat lines in the high elevation of Malino was longer than harvesting in the medium elevation of Cisarua. Higher temperatures in the tropical lowlands leading caused earlier maturing dates introduced wheat lines (Altahuish *et al.* 2014). The different elevation also significantly influenced the character of the number of grains per panicle. In the higher elevation of Malino, the number of grains per panicle was higher than in the medium elevation of Cisarua. Altahuish *et al.* (2014) reported that the number of grains per panicle of introduced wheat lines grown in lowland Indonesia only half of those grown in the higher elevation.

Genotype × environment interaction effects the performance wheat elite lines tested. There are differences in the performance of a line at the two agro-ecosystem. There are 18 strains of with potential yields medium elevation of Cisarua with higher temperature compared with the highlands and only two line that have potential yield not different in both altitudes. Subagyo (2001) reported that in the tropics, production of wheat in the highlands are better than the medium or low elevation. In this study there were five strains that showed good adaptation in the medium elevation with a higher yield than in the highlands, namely O/HP-14-A19-1-8, O/HP12-A-25-3-7, O/HP-14-a10-2-10, O/HP14-A10-3-3 and O/HP-12-A-23-1-10 (Table 4).

Table 4. Variance of wheat lines derivated from crossing and national varieties in two environments.

Lines	Number of seed per culm		Yield potential (ton ha^{-1})	
	Cisarua	Malino	Cisarua	Malino
	$\bar{X}$ ± SD	$\bar{X}$ ± SD	$\bar{X}$ ± SD	$\bar{X}$ ± SD
O/HP-12-A28-5-1	29.9 ± 2.6	41.1 ± 7.6	2.0 ± 0.04	2.6 ± 0.5
O/HP-78-A-29-3-3	33.4 ± 3.6	45.3 ± 0.6	2.1 ± 0.33	2.4 ± 0.0
O/HP-82-A-15-1-4	31.1 ± 3.2	41.0 ± 2.5	2.3 ± 0.40	2.6 ± 0.6
O/HP-78-A2-2-5	28.3 ± 3.1	33.8 ± 0.9	1.9 ± 0.19	3.1 ± 0.8
O/HP-12-A1-1-9	30.6 ± 5.0	43.1 ± 6.8	2.3 ± 0.39	2.9 ± 0.7
O/HP-78-A22-3-7	28.0 ± 3.4	46.3 ± 1.7	1.9 ± 0.13	3.3 ± 0.2
O/HP-78-A22-5-10	28.8 ± 1.3	45.8 ± 1.9	2.1 ± 0.40	2.8 ± 0.1
O/HP-6-A8-2-10	32.4 ± 2.2	45.9 ± 3.0	2.5 ± 0.51	2.7 ± 0.4
O/HP-22-A27-1-10	32.2 ± 3.0	49.3 ± 2.6	2.2 ± 0.12	3.9 ± 0.3
O/HP-93-A1-1-3	31.8 ± 5.0	43.2 ± 4.5	2.3 ± 0.19	2.9 ± 0.7
O/HP-14-A19-1-8	28.3 ± 6.0	40.0 ± 5.9	2.2 ± 0.19	1.6 ± 0.1
O/HP-12-A5-4-5	29.6 ± 4.9	46.3 ± 7.4	2.2 ± 0.41	3.2 ± 0.1
O/HP-12-A25-3-7	31.4 ± 2.9	43.0 ± 3.6	2.0 ± 0.2	1.8 ± 0.0
O/HP-82-A7-2-6	30.1 ± 4.5	41.4 ± 4.8	2.0 ± 0.2	2.2 ± 0.2
O/HP-49-A1-1-4	29.3 ± 5.5	40.1 ± 5.7	1.9 ± 0.0	2.8 ± 0.3
O/HP-78-A2-1-9	31.3 ± 1.2	44.6 ± 0.7	2.1 ± 0.1	2.6 ± 0.3
O/HP-14-A21-5-7	29.3 ± 2.9	41.7 ± 1.0	2.2 ± 0.2	2.6 ± 0.2
O/HP-14-A10-2-10	27.6 ± 5.1	45.9 ± 2.8	2.4 ± 0.4	1.9 ± 0.0
O/HP-78-A2-5-2	32.2 ± 1.9	36.8 ± 1.7	2.4 ± 0.6	2.6 ± 0.4
O/HP-12-A25-2-6	32.6 ± 2.8	45.3 ± 5.4	2.2 ± 0.2	2.5 ± 0.3
O/HP-14-A10-3-3	29.8 ± 4.6	42.4 ± 0.4	2.1 ± 0.1	1.9 ± 0.2
O/HP-82-A15-2-3	32.2 ± 0.5	47.2 ± 6.4	2.2 ± 0.7	3.2 ± 0.6
O/HP-93-A3-1-9	27.8 ± 2.5	43.7 ± 6.0	2.1 ± 0.2	2.9 ± 0.2

O/HP-12-A23-1-10	32.3 ± 1.8	48.9 ± 4.5	2.3 ± 0.6	1.7 ± 0.4
O/HP-12-A1-2-2	30.2 ± 2.4	43.7 ± 2.7	2.3 ± 0.4	2.7 ± 0.4
Guri 1	32.0 ± 4.0	47.2 ± 5.5	2.0 ± 0.2	2.7 ± 0.4
Guri 2	31.9 ± 1.2	48.7 ± 4.3	2.3 ± 0.3	2.2 ± 0.1
Selayar	33.2 ± 2.1	46.3 ± 2.6	2.2 ± 0.3	3.3 ± 0.0
Dewata	35.9 ± 8.1	48.4 ± 6.6	1.9 ± 0.2	2.3 ± 0.2
Oasis	31.7 ± 4.0	49.4 ± 4.6	2.2 ± 0.0	3.9 ± 0.1
HP1744	32.2 ± 3.5	47.5 ± 2.8	2.0 ± 0.3	2.8 ± 0.0
$\overline{X}$ Comparison	32.8 ± 1.5	47.9 ± 1.1	2.1 ± 0.1	2.9 ± 0.6

There are changes in the ranks of lines at medium elevation compared to higher elevation. At medium elevation the line O/HP-12-A23-1-10 showed the highest yield potential of 2.37 ton ha-1, but at higher elevation of Malino, line O/HP-78-A2-2-5 has the highest yield potential of 3.14 ton ha-1. The change in rank of lines in the two environment indicated that the forms of interaction that occurs is a qualitative interaction where growing environment greatly affects the yield potential, and selection should be made for specific location. Genotype × environment interaction effects was also observed on the evaluation of introduced wheat lines in Indonesia by Nur *et al.* (2012) and Altahuish *et al.* (2014). Handoko *et al.* (2008) states that the plants are sensitive to temperature changes, such as wheat, very sharp decline in the harvest if the crop is planted at lower altitudes with higher temperatures.

The effect of genotype ×environment interaction was significant on fat and protein content, but not on the carbohydrates. For 13 lines the fat content was higher when grown at higher elevation, but 6 lines showed hunger fat content at medium elevation. There are 5 lines that showed similar fat content in the two elevations. There is a change in the ranking of content level in Cisarua and Malino, which shows the genotype x environment interaction qualitatively. The fat content of line O/HP-12-A1-1-9 in Cisarua was 2:17% but in Malino was only 1:40%. In Malino, the line O/HP-78-A22-5-10 has a fat content of 2:03% but in Cisarua only 1:55%. The carbohydrate content of wheat lines were affected by locations. The carbohydrate content was higher when the lines were grown in high elevation in Malino compared to when grown in medium elevation. The protein content is also affected by genotype × environment. The highest increase in protein content was observed in line O/HP-12-A28-5-1 at 47.28%.

Two lines showed the lowest increase in protein content, namely O/HP-12-A5-4-5 with a value of 7:26% and O/HP-93-A3-1-9 amounted to 9.94%. Douglas *et al.* (2001) suggest that the protein was significantly correlated to environmental factors, as well as carbohydrate content. High temperature after flowering reduce the levels of starch and have a significant effect on the size distribution of starch granules in wheat kernels (Panozzo and Eagles 1998; Viswanath and Khanna-chopra 2001; Chinnusamy and Khanna-Chopra 2003; Hurkman *et al.*, 2003; Zhao *et al.* 2008). The grain of wheat that have a high protein content has a size smaller than a grain of wheat that contain lower protein levels, not just the size of the starch granules, but also the protein component is very sensitive to extreme weather conditions (Zhao *et al.*, 2009). Differences in the content of proteins thought to be caused by changes in temperature ahead of the grain to be old, that disturbed seed formation. Thus, the portion of the protein that has been formed since the beginning of the development of the seed becomes larger than a grain of wheat if fully developed. It is based on the fact that the seed samples containing high protein wheat is small and somewhat shriveled. It was shown by Zhao *et al.* (2009) that the protein component is very sensitive to drought during the grain filling. High temperature stress has a greater influence on starch accumulation in the middle phase than in the initial phase in the grain filling (Yan *et al.*, 2008).

Heritability values are classified into three criteria: low heritability (h2 <0.2), moderate heritability (0.2 <h2 <0.5), and high heritability (0.5 <h2≤1.0). Genetic parameters of agronomic and nutritional content of wheat lines (Table 8) shows the heritability of agronomic characters in the high elevation of Malino there are two characters that have a high heritability values, ie the number of grains per panicle (51.39) and crops (86.64).

According to Lopez *et al.* (2012), plant height and yield had high heritability values on testing some moderate temperature environments. The heritability estimates at medium elevation in Cisarua are low,, only plant height (62.26) which has a high heritability values.

Characters with low heritability values-was thought to occur because of high stress environment for the growth of plants so that strains unable to reproduce the optimum genetic potential (Nur *et al.* 2014).

Table 5. Variance of wheat lines derivated from crossing and national varieties in two environments.

Lines	Content analysis			
	Fat content (%)		Carbohydrate content (%)	
	Cisarua	Malino	Cisarua	Malino
	$\bar{X}$ ± SD	$\bar{X}$ ± SD	$\bar{X}$ ± SD	$\bar{X}$ ± SD
O/HP-12-A28-5-1	1.7 ± 0.2	1.6 ± 0.0	68.3 ± 0.5	77.1 ± 0.4
O/HP-78-A-29-3-3	1.6 ± 0.0	1.9 ± 0.2	68.0 ± 0.6	76.9 ± 0.1
O/HP-82-A-15-1-4	1.8 ± 0.0	1.6 ± 0.0	70.2 ± 0.3	76.4 ± 0.4
O/HP-78-A2-2-5	1.8 ± 0.0	1.5 ± 0.0	68.6 ± 0.2	76.4 ± 0.6
O/HP-12-A1-1-9	2.1 ± 0.0	1.4 ± 0.8	69.0 ± 0.5	76.6 ± 0.0
O/HP-78-A22-3-7	1.7 ± 0.0	1.4 ± 0.1	70.4 ± 0.4	76.4 ± 0.1
O/HP-78-A22-5-10	1.5 ± 0.0	2.0 ± 0.1	71.6 ± 0.2	74.2 ± 0.5
O/HP-6-A8-2-10	1.6 ± 0.1	1.8 ± 0.0	68.5 ± 0.4	74.4 ± 0.7
O/HP-22-A27-1-10	1.5 ± 0.1	1.7 ± 0.0	69.8 ± 0.6	75.9 ± 1.9
O/HP-93-A1-1-3	1.1 ± 0.0	1.5 ± 0.0	69.8 ± 0.2	77.1 ± 0.4
O/HP-14-A19-1-8	1.1 ± 0.0	1.2 ± 0.0	68.9 ± 0.2	75.6 ± 0.3
O/HP-12-A5-4-5	1.5 ± 0.0	1.4 ± 0.1	68.2 ± 4.5	72.3 ± 5.7
O/HP-12-A25-3-7	1.5 ± 0.0	2.1 ± 0.1	68.1 ± 0.2	74.9 ± 0.3
O/HP-82-A7-2-6	1.0 ± 0.0	1.8 ± 0.0	70.5 ± 0.0	75.4 ± 0.0
O/HP-49-A1-1-4	0.9 ± 0.0	1.9 ± 0.0	71.9 ± 0.3	75.9 ± 0.3
O/HP-78-A2-1-9	1.4 ± 0.0	1.6 ± 0.0	70.3 ± 0.1	75.7 ± 0.0
O/HP-14-A21-5-7	1.5 ± 0.0	1.6 ± 0.0	70.3 ± 0.6	75.4 ± 0.6
O/HP-14-A10-2-10	1.3 ± 0.0	1.5 ± 0.0	69.4 ± 0.6	75.4 ± 0.1
O/HP-78-A2-5-2	1.0 ± 0.0	1.7 ± 0.0	70.9 ± 0.3	75.0 ± 0.0
O/HP-12-A25-2-6	1.1 ± 0.1	1.8 ± 0.0	69.8 ± 0.2	74.8 ± 0.1
O/HP-14-A10-3-3	1.7 ± 0.1	1.3 ± 0.0	69.6 ± 0.1	75.0 ± 0.0
O/HP-82-A15-2-3	1.4 ± 0.1	1.5 ± 0.0	70.3 ± 0.3	74.6 ± 0.2
O/HP-93-A3-1-9	1.4 ± 0.0	1.4 ± 0.1	73.0 ± 0.9	74.9 ± 0.2
O/HP-12-A23-1-10	1.3 ± 0.0	1.3 ± 0.0	71.4 ± 0.0	74.9 ± 0.4
O/HP-12-A1-2-2	1.6 ± 0.0	1.3 ± 0.0	70.0 ± 0.2	74.2 ± 0.1
Guri 1	1.3 ± 0.0	1.7 ± 0.0	69.9 ± 0.4	73.3 ± 0.1
Guri 2	1.4 ± 0.0	1.6 ± 0.0	68.8 ± 0.3	73.0 ± 0.1
Selayar	1.8 ± 0.0	1.5 ± 0.1	71.3 ± 0.4	74.0 ± 0.0
Dewata	1.7 ± 0.1	1.7 ± 0.0	70.1 ± 0.5	73.5 ± 0.1
Oasis	1.3 ± 0.1	1.6 ± 0.0	71.7 ± 0.5	74.0 ± 0.1
HP1744	1.5 ± 0.2	1.5 ± 0.0	69.2 ± 0.4	73.6 ± 0.0
$\bar{X}$ Comparison	1.5 ± 0.1	1.6 ± 0.0	70.2 ± 1.1	73.6 ± 0.4

Table 6. Variance of wheat lines derivated from crossing and national varieties in two environments.

Lines	Protein content (%)		% Changes
	Cisarua	Malino	
	$\bar{X}$ ± SD	$\bar{X}$ ± SD	
O/HP-12-A28-5-1	16.7 ± 0.1	8.5 ± 0.0	47.2
O/HP-78-A-29-3-3	16.3 ± 0.0	8.3 ± 0.2	47.2
O/HP-82-A-15-1-4	14.9 ± 0.5	9.2 ± 0.3	38.0
O/HP-78-A2-2-5	16.1± 0.1	9.4 ± 0.2	41.5
O/HP-12-A1-1-9	15.4 ± 0.2	9.6 ± 0.0	37.1
O/HP-78-A22-3-7	14.6 ± 0.2	9.4 ± 0.2	35.9
O/HP-78-A22-5-10	14.2 ± 0.3	11.2 ± 0.1	21.1
O/HP-6-A8-2-10	16.3 ± 0.2	11.2 ± 0.1	31.5
O/HP-22-A27-1-10	16.0 ± 0.0	9.9 ± 1.6	38.1
O/HP-93-A1-1-3	15.6 ± 0.1	9.1 ± 0.1	41.8
O/HP-14-A19-1-8	14.5 ± 0.1	10.9 ± 0.3	26.2
O/HP-12-A5-4-5	14.6 ± 0.1	13.5 ± 5.6	7.2
O/HP-12-A25-3-7	15.4 ± 0.2	10.3 ± 0.3	32.9

Lines	Protein content (%)		% Changes
	Cisarua	Malino	
	$\overline{X}$ ± SD	$\overline{X}$ ± SD	
O/HP-82-A7-2-6	14.8 ± 0.0	9.7 ± 0.1	34.6
O/HP-49-A1-1-4	13.3 ± 0.1	9.2 ± 0.2	30.6
O/HP-78-A2-1-9	14.4 ± 0.1	10.2 ± 0.0	29.2
O/HP-14-A21-5-7	14.0 ± 0.4	11.2 ± 0.0	20.1
O/HP-14-A10-2-10	14.7 ± 0.1	10.3 ± 0.0	29.6
O/HP-78-A2-5-2	14.6 ± 0.0	10.3± 0.0	29.4
O/HP-12-A25-2-6	14.8 ± 0.0	11.8 ± 0.1	19.7
O/HP-14-A10-3-3	13.4 ± 0.0	11.2 ± 0.0	16.0
O/HP-82-A15-2-3	13.7 ± 0.0	11.9 ± 0.0	13.2
O/HP-93-A3-1-9	13.2 ± 0.3	11.9 ± 0.0	9.94
O/HP-12-A23-1-10	14.4 ± 0.0	11.5 ± 0.0	19.5
O/HP-12-A1-2-2	15.0 ± 0.1	11.8 ± 0.0	21.6
Guri 1	15.3 ± 0.5	11.6 ± 0.0	23.9
Guri 2	16.5 ± 0.2	11.9 ± 0.0	28.0
Selayar	13.5 ± 0.2	11.2 ± 0.0	17.0
Dewata	14.7 ± 0.1	11.3 ± 0.1	22.9
Oasis	13.5 ± 0.4	11.2 ± 0.0	16.7
HP1744	16.1 ± 0.1	11.2 ± 0.0	30.0
$\overline{X}$ Comparison	14.9 ± 1.2	11.4 ± 0.2	23.1

Table 7. Analysis of combine variation of lines (G), locations (L) and interaction effect G × E from crossing introduction wheat lines and national varieties in two environments.

Parameters	MS Lines (G)	MS Locations (L)	MS Interactions (GxE)
Agronomical characters			
Plant height	50.5**	11602.4**	15.7
Maturing date	32.0	21098.7**	31.9
Number of seed per culm	34.7	8366.9**	16.3
Yield potential	0.4**	12.4**	0.5**
Nutrition Content			
Carbohydrate content	4.1	1239.9**	5.2
Protein content	2.3	829.1**	4.9**
Fat Content	0.1	0.8	0.2**

Noted : *,** = significant different in 5%.

Table 8. Genetic parameters of wheat lines derivated from crossing and national varieties in two environments.

Parameters	Malino		Cisarua	
	σ^2_g	h^2(bs)	σ^2_g	h^2(bs)
Agronomical characters				
Plant height	-3.1	-36.3	8.3	62.2
Maturing date	3.4	16.1	0.0	-23.6
Number of seed per culm	6.9	51.3	-1.3	-38.2
Yield potential	0.2	86.6	0.0	3.0
Nutrition content				
Carbohydrate content	1.1	0.7	1.3	0.8
Protein content	1.0	0.7	0.9	0.9
Fat Content	0.0	0.9	0.0	0.9

Noted: σ^2g= Genetic variance, where values (-) was assumed as zero in heritability calculation, h^2(bs) = heritability.

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References

Altuhaish AAK, Miftahudin, Trikoesoemaningtyas, Yahya S. 2014. Field Adaptation of Some Introduced Wheat (*Triticum aestivum* L.) *Genotypes in Two Altitudes of Tropical Agro-Ecosystem Environment of Indonesia*. HAYATI Journal of Biosciences March 2014 Vol. 21 **No. 1,** p 31-38. DOI: 10.4308/hjb.21.1.31.

Chinnusamy V, Khanna - Chopra R. 2003. Effect of heat stress on grain starch content in diploid, tetraploid and hexaploid wheat species. Journal of Agronomy and Crop Science **189,** 242–249.

Danuarsa. 2006. Proximate analysis and fat acids in some nuts commodities. Agriculture Technique Bulletin. Vol. 11 **No. 1.**

Douglas C. Doehlert,* Michael S. McMullen, and James Hammond J. 2001. Genotypic and Environmental Effects on Grain Yield and Quality of Oat Grown in North Dakota. Crop Science **41,** 1072–1079.

Erwidodo HP, Saliem Arianidan M, Ariningsih E. 2004. Food Consumption Assessment in Indonesia. Research Report. Research Center of Agriculture Socio-Economic. Agricultural of Indonesia Bogor.

Food Agricultural Organization. 2016. Dataset: FAO Agricultural Outlook [Internet]. [diunduhpada 27 Oktober 2016]. Tersediapada http://www.fao.org.

Gomez KA, Gomez AA. 1995. Statistical Procedures for Agricultural Research. Edisi ke-2. Sjamsudin E, Baharsjah JS, Translated. Jakarta (ID).

Hallauer AR, dan Miranda JB. 1995. Quantitative Genetics in Maize Breeding. Ames; lowa State University Press.

Handoko I, Sugiarto Y, Syaukat Y. 2008. Linkage of Seasonal Changes and Strategic Food Production: Study of Independent Policy in Trading and Development sector. Bogor: SEAMEO Biotrop.

Hurkman WJ, McCue KF, Altenbach SB, Korn A, Tanaka CK, Kothari KM, Johnson EL, Bechtel DB, Wilson JD, Anderson OD, Dupont FM. 2003. Effect of temperature on expression of genes encoding enzymes for starch biosynthesis in developing wheat endosperm. Plant Science **164,** 873-881.

Ihsan M, Mahmood A, Mian MA, Cheema NM. 2007. Effect of different methods of fertilizer application to wheat after germination under rain fed conditions. Journal Agriculture **45,** 97-109.

Lopes MS, MP, Reynolds MR, Jalal-Kamali M, Moussa Y, Feltaous IS, Tahir A, Barma N, Vargas M, Mannes Y, Baum M. 2012. The yield correlations of selectable physiological traits in aopulation of advanced spring wheat lines grown in warm and drought environments. Field Crops Research **128,** 29-136.

Natawijaya A. 2012. Genetic Analysis and Early Generation Selection to Identify High Yielding Segregants in Wheat (*Triticum aestivum* L.). [Thesis]. Bogor: Sekolah Pascasarjana, Institut Pertanian Bogor.

Nur A, Azrai Trikoesoemaningtyas M. 2014. Genotype x Environment Interaction and Genetic Variability of Introduction Wheat Lines in Tropical Agro-ecosystem. Journal of Agri Biogen **10(3),** 93-100.

Panozzo JF, Eagles HA. 1998. Cultivar and environmental effects on quality characters in wheat. I. Starch. Australian Journal of Agricultural Research **49,** 757-766.

Sastrosoemarjo, Bahmany S, Trikoesoemaningtyas N. 2004. Evaluation of Adaptation Ability Introduction Wheat genotype Lines in Lowlands. Proceeding of symposium PERIPI, Bogor 5-7 Agustus 2004.

Singh RK, Chaudhary BD. 1979. Biometrical Methods in Quantitative Genetics Analysis. New Delhi: Kaylani Publisher.

Subagyo. 2001. Adaptation or Wheat Variety Releasing Assessment in Middle Java. National Seminar. Center of Security and Seed Certification. Semarang: Crop and Horticulture II.

Syukur M, Sujiprihati S, Yunianti R. 2012. Plant Breeding Technique. Jakarta (ID): Penebar Swadaya.

Viswanathan C, Khanna - Chopra R. (2001): Effect of heat stress on grain growth, starch synthesis and protein synthesis in grains of wheat (*Triticum aestivum* L.) varieties differing in grain weight stability. Journal of Agronomy and Crop Science **186,** 1-7.

Yan SH, Yin YP, Li WY, Li Y, Liang TB, Wu YH, Geng QH, Wang ZL. 2008. Effect of high temperature after an thesis on starch formation of two wheat cultivars differing in heat tolerance. Acta Ecologica Sinica **28,** 6138-6147.

Zhao CX, He MR, Wang ZL, Wang YF, Lin Q. 2009. Effects of different water availability at pos-tanthesis stage on grain nutrition and quality in strong-gluten winter wheat. Comptes Rendus Biologies **332,** 759-764.

Zhao H, Dai T, Jiang D, Cao W. 2008. Effects of high temperature on key enzymes involved in starch and protein formation in grains of two wheat cultivars. Journal of Agronomy and Crop Science **194,** 47-54.