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The yield and quality of black rice varieties in different altitude

E Purwanto, W Hidayati and Nandariyah
Study program of Agrotechnology, Agriculture faculty, Universitas Sebelas Maret, Surakarta, Indonesia

Email: edipur_uns@yahoo.com

Abstract. This study aims to determine the optimal environmental conditions and corresponding black rice varieties in order to produce high production and optimum quality rice. The study using nested design, first was location (2 levels: the highlands and lowland), second was varieties (3 levels: Cempo Ireng, IPB, and Gagak) the study was conducted from November 2015 until May 2016 in Karanglo and Gutanon village, Karanganyar. Anthocyanin analysis conducted in laboratory of Nutrition and Food, Faculty of Agriculture, Sebelas Maret University. Data were analyzed using analysis of variance and significant difference continued with DMRT (Duncan Multiple Range Test) level of 5%. Results showed that cultivation in highlands and use of diverse varieties showed different quantity of rice that can be seen on panicle length, and weight of grain crops. Improved quality of results showed same things, anthocyanin content and iron increased on black rice which cultivated in highlands.

1. Introduction

One of several types of rice consumed is black rice which contains anthocyanin in its pericarp [1]. This day black rice is known as a functional food and widely consumed as a staple food that is not only as a source of carbohydrates, but also source of fiber which for good health. Generally, rice was grown in lowland about 0-600 meters above sea level. The quality of ricecan be influenced by the environment for growth. The differences in elevation will lead different climate character elements such as temperature, light, and moisture. The lowlands have a relatively high temperature with high light intensity, while the highlands have a relatively low temperature with low light intensity as well. Temperature and light intensity affect the synthesis of primary metabolites and secondary metabolites in plants.

Black rice cultivation in Indonesia has not been so prevalent. Only few farmers were willing to cultivate black rice, because of the long age of cropping and use local seed production less preferred. This resulted in increased declivous productivity of rice nationally. In 1981-1990 the production of rice increased by 4.08% per year, from 1991 to 2000 years of 1.31% per year, while in 2001-2007 by 0.58%. The declivous of productivity becomes a problem to fulfill community needs for rice, so it needs a cultivation technique that can improve productivity. This research aims to study the the quantity and quality of yield of black rice from various variety grown in the highlands and lowlands to.

2. Methods

The study was conducted in November 2015 to May 2016. Research about altitude implemented at two locations with different elevation. The first location in Gutanon village, Jaten, Karanganyar with an altitude of 141 meters above the sea level in position 07^o 35 '48.8' 'South Latitude and 110^o 55' 23.0 " BT. The second location is in the village Karanglo, Tawangmangu with elevation 665.0 meters above sea level right at the position 07^o 39 '43.3' 'South Latitude and 111^o 05' 11.6 " BT. Iron content was analyzed in the Laboratory of Chemistry and Soil Fertility, Faculty of Agriculture UNS and total anthocyanin analyzed in the Laboratory of Nutrition and Food, Faculty of Agriculture, Universitas Sebelas Maret, in May 2016.

This study used a nested design with two factors. The first factor was the elevation: lowland (Gutanton village, subdistrict Jaten) and Highlands (village Karanglo, subdistrict Tawangmangu). The second factor was the varieties: Cempo Ireng, IPB, and Gagak. Variable observations include flowering time, variable quantity and quality of yield. Variables of quantity include the number of total tillers, number of productive tiller, panicle length, number of grain per panicles, grain weight per plant, crop productivity. While variables of quality include total anthocyanin content and iron content. Data were analyzed using analysis of variance (ANOVA) on 95% confidence level. If there was a significant effect on the results of the test continued using DMR (Duncan Multiple Range) on 95% confidence level.

3. Results and Discussion

Rice can grow well in the temperature range 20-35^{o}C. Based on the research that has been done, the researcher not able to show the complete data of plant samples as expected, because the Cempo Ireng varieties sample plants which were grown in lowland were lost due to technical errors. *General conditions research*

The location were in the lowland (Gutanon village, Jaten sub district) with elevation 141 meters above sea level and second location on highland (Karanglo village, Tawangmangu sub district) with elevation 665 meters above sea level.

Table 1. Elements of climate in Gutanon village, Jaten sub district and Karanglo village, Tawangmangu sub district

Elements of climate	Lowland	Highland
Elevation (mdpl)	141	665
Geographic	‘07^o 35’ 48,8’’ SL-110^o 55’ 23,0’’ EL	07^o 39’ 43,3’’ SL-111^o 05’ 11,6’’ EL
Daily temperature (^{o}C)	29 -34	26 -31
Soil temperature ^{o}C)	25- 29	24 – 27
Humidity (%)	50	65 %
Humidity around plant (%)	67	79 %
Light Intensity (lx)	832-930 x 100	1891, 2508, 2683 x 10

The differences of elevation affect micro-climatic conditions of both locations. Daily temperature in Karanglo and Gutanon village respectively between 29 °C-34 °C and 26 °C-31 °C. The temperature value is inversely to the humidity, which if the temperature high, the humidity will be low, and vice versa. Observations in humidity at high and low elevation show those such things. The humidity were 60-65 % and 55-50 % respectively. The light intensity of both is different, which is 261.5 x 103 lux for lowland and 70.82 x 103 lux on highland. The difference of light intensity in this observation is quite large about 190.68x103 lux. Elevations effect on temperature and light intensity. Temperature and light intensity will be smaller following the high point of growth [2]. Effect of elevations on plant growth tends indirectly, meaning that the difference elevation will affect the environment by temperature, humidity, oxygen in the air, and soil conditions.

3.1. Observation of flowering time

The transition from the vegetative phase to the generative phase is shown by the flowering time of plant. The development of the plant at this stage begins with the initiation of flower. Flowering (anthesis) on rice begins when the tip of stamens on the panicle has looked out of the grains and fertilization process begin [3].

Table 2. Differences of flowering time in black rice

Location	Flowering time (Days after planting)		
	Cempo Ireng	IPB	Gagak
Highland	116	83	85
Lowland	110	80	83

Flowering in Cempo Ireng variety was 5 days faster than those in the highlands, 3 days on IPB variety, and 2 days on Gagak variety (Table 2). This shows that Cempo Ireng variety has vegetative and flowering time period longer than IPB and Gagak. [4] states that flower initiation depends on genotype interaction and specific environmental conditions such as low temperature period, the length of the day or photoperiodism. Rice plants flowering time affected by environmental conditions during pollination and flowering. High temperatures can accelerate the rate of initiation time devoted with the cultivation of lowland showing flowering time faster than the highland.

3.2. Effect of treatment to quantities of product

3.2.1. The number of total tillers Based on the observations, the tillers at three different varieties used have different number of the average. Number of tillers in highland locations tend to be lower than the lowlands.

Table 3. Average of Total Tillers in Paddy at Different Altitude

Location	Total Tillers (Days after planting)		
	Cempo Ireng	IPB	Gagak
Highland	14.95±3.27a	16.65±1.81c	17.1±2.81b
Lowland		19.7±3.66 c	15.95±3.30 b
Mean	14.95 a	18.17 c	16.53 b

Addition: The figure is followed by different letters on the same line, significantly different (P < 0.05).

Results of analysis of variance showed that the location does not affect the number of tillers, while varieties those are nested within location show significant difference in the number of tillers. Cempo Ireng have the lowest Number of tillers, followed by IPB and Gagak (Figure 1). The highest number of tillers obtained Gagak varieties which cultivated in the highlands with a mean of 19.7 and the lowest number of tillers obtained Cempo Ireng by the number of tillers 14.95. The number of tillers are influenced by genotype factors in plant and also can be influenced by cultivation technique factors such as the wide spacing can increase the production of rice tillers because it can minimize the occurrence of light and nutrient competition. [5] explains that the ability of the rice plant to produce tillers are genetically different. However, the number of tillers can be increased because it depends on environmental factors and cultivation technique.

3.2.2. Length of Panicle Overall, rice flower called panicles. Panicles consists of 8-10 nodes that produce primary branches then produces a secondary branch. From the panicle nodes generally it will appear only one primary branch, but in certain condition the nodes can produce 2-3 primary branches [6].

Table 4. Average of length of panicle at different elevation

Location	Length of Panicle		
	Cempo Ireng	IPB	Gagak
Highland	22.55 a±2.09	24.40 b±1.30	23.67b±1.76
Lowland		22.68 b±1.05	22.93b±1.00
Mean	22.55 a	23.54 b	23.30 b

Addition: The figure is followed by different letters on the same line, significantly different (P < 0.05).

Results of analysis of variance showed no significant difference occurred in the treatment location, but there was a significant difference in varieties that are nested within the location. Figure 2 shows that the highest panicle length obtained IPB varieties (highlands) with an average 24.4 cm, the lowest one was Cempo Ireng (lowland) with panicle length 22.55 cm. As explained by [7] panicle length character controlled by a genetic trait, so the difference in the character of each variety is a genetic trait. Panicle length is one indicator of the high productivity of rice. The longer panicles, the more number of grain that increases the weight of grain per crops and can increase productivity of rice.

3.2.3. Grain weight per crop Crop production in addition influenced by genetic factors may also be influenced by environmental factors and cultivation. Environmental factors such as temperature, humidity, light intensity and others will strongly support the plants for optimal production. Crop production can also be improved by enhancing cultivation technique such as spacing, selection of appropriate seedlings, irrigation scheduled and others.

Table 5. Average weight of Paddy crop in Different Elevation

Location	Grain weight per crop		
	Cempo Ireng	IPB	Gagak
Highland	16.81±8.93 a	23.94±5.50 b	23.08±7.75 ab
Lowland		17.07±5.58 b	17.19±4.80 ab
Mean	16.81 a	20.50 b	20.14 ab

Addition: The figure is followed by different letters on the same line, significantly different (P < 0.05).

Results of analysis of variance showed significant difference in location and varieties those are nested within the location treatment. Grain weight per plant (highland) derived IPB varieties with highest average about 23.94 g, 23.07 g Gagak, and the lowest one Cempo Ireng 16.81 g. Grain weight per plant affected by the amount of grain per panicle and panicle length. It is influenced by products of photosynthesis which produced during the ripening grain period [8]. Environmental factors one of them is temperature effect on the formation of grain, which at the optimal temperature (± 30 °C) flowering and fruiting can occur well. If the temperature is high, then the stigma that there is liquid sugar for the attachment of pollen can be dried up, pollen cannot stick on it, so there is no fertilization and formed empty grain. Each plant has a capability production themselves, also have different response to fertilizer or environment.

3.2.4. Crop Production Crops have their own agronomic characteristic in production. Crop production can be affected by the nature of crops as well as the treatment given to the empire itself. Spacing, the addition of certain fertilizers, or proper watering can support the productivity of rice.

Table 6. Average Crops Production at Different Elevation

Location	Production		
	Cempo Ireng	IPB	Gagak
Highland	2.30±0.14 a	4.44±0.15 b	4.40±0.05 b
Lowland		3.24±1.06 b	3.17±0.34 b
Mean	2.30 a	3.84 b	3.78 b

Addition: The figure is followed by different letters on the same line, significantly different (P < 0.05).

Results of analysis of variance showed a significant difference did not occur at treatment location, but significant difference occur on varieties those are nested within locations treatment. Although the analysis of variance treatment of different locations does not occur significantly, Table 6 above shows that highland rice production was higher than the lowlands. Table 6 shows that rice production in upland is higher than the lowlands. This can be due to on highland harvesting is done manually by removing the grain by hitting them, while in the lowlands harvesting using a thresher machine. Yield loss at harvest rice can be influenced by several factors, such as harvesting age, water content, and tools, and how to harvest. Besides overripe age with low water levels cause grain fall easily at harvest. [9] reported the results of postharvest loss is still quite high, more than 20%. The critical point of yield loss occurs at the stage of harvesting and threshing. With the loss rate is still quite high, and on the stages of harvesting loss is still around 9%, and at what stage threshing still more than 4%.

3.3. Treatment Effect on the Quality Produce

3.3.1. Anthocyanin Anthocyanin is secondary metabolites of the flavonoid formed due to environmental stress. The results are consistent with the statement [10] stated that light affects the setting of production of primary metabolites such as enzymes, carbohydrates, lipids and amino acids and secondary metabolites such as anthocyanins, flavonols and carotenoids [10]. [11] stated, the darker color of rice, the higher anthocyanin content and antioxidant. It makes high potential as a functional food.

Table 7. Average levels of anthocyanin in different elevation

Location	Anthocyanin (ppm)		
	Cempo Ireng	IPB	Gagak
Highland	521.9±8.27 c	113.99±6.30 a	131.31±7.47 b
Lowland		40.82±3.91 a	79.75±4.52 b
Mean	521.9 c	77.40 a	105.53 b

Addition: The figure is followed by different letters on the same line, significantly different (P < 0.05).

Results of analysis of variance showed that there was a significant difference in treatment location and varieties nested within the location. The highest total anthocyanin content owned by rice varieties Cempo Ireng, then Gagak, and the lowest IPB grown in the highlands with an average of 521.97 ppm, 131.31 ppm and 113.99 ppm (Table 7). Anthocyanin content was lower in Gagak and IPB varieties grown in the lowlands are 79.76 ppm and 40.82 ppm. The results are consistent with [12] in their research on the effect of temperature on anthocyanin, explained that at low temperatures anthocyanins can accumulate maximum compared with the high temperature treatment. The optimal temperature to accumulate anthocyanin is about 25-28 °C, whereas at 35 ° C anthocyanin in lower production.

[13] reported lower total anthocyanin content is a trait that is influenced by fewer genes (the qualitative nature). It is [14] appropriate opinion that the qualitative nature is controlled by one or two genes, are little affected the environment so that the election / selection can be done visually.

3.3.2. Iron Iron content in rice is at the aleurone pericarp and the rest are in the endosperm of the rice [15]. Aleurone layer thickness can affect the iron content in it.

Table 8. Mean of iron content on different elevation

Location	Anthocyanin (ppm)		
	Cempo Ireng	IPB	Gagak
Highland	62,83±14,26 a	59.06±11,63 a	75,35±30,05 a
Lowland		57,51±11,16 a	39,51±30,34 a
Mean	62,83 a	58,28 a	57,43 a

Addition: The figure is followed by different letters on the same line, significantly different (P < 0.05).

Result of analysis of variance showed the significant difference in location's treatment in iron content. However, the treatment is nested within location there is no significant difference in iron content. Varieties with low iron content obtained Gagak varieties on cultivation in the lowlands (39.51 ppm), and the highest in Gagak varieties on cultivating in highland (75.34 ppm). The differences of iron concentration is affected by plant genetic trait. Black rice has a high iron content compared to white rice or red. A high iron content can also be influenced by factors such as post-harvest handling milling degree also affect the iron content of rice, which is caused by the loss of aleurone layer during the milling and the iron minerals that dissolve during the washing process [13].

4. Conclusions

The conclusions from the study are, rice cultivation in highlands able to increase rice production which correlated with parameters number of total tillers, panicle length, and the number of grain per crops. The best on quantity (highest yield) were IPB and Gagak varieties, while the best variety on quality was Cempo Ireng. Difference elements of climate on the highland may increase the anthocyanin content and iron on black rice than in lowland

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