Morphology, yield, grain quality and minerals content (Fe and Zn) in white, brown and black rice lines

H Safitri, B Abdullah, I A Rumanti, Sularjo and Cahyono
Indonesian Center for Rice Research, Jl. Raya IX, Sukamandi Subang, Indonesia

E-mail: henisafitri2@gmail.com

Abstract. This study aims to determine the morphology, grain yield, grain quality, and minerals content (Fe and Zn) of white rice, brown rice and black rice lines produced by the Indonesian Center for Rice Research (ICRR). The research used 25 rice genotypes consisting of nine white rice lines, ten brown rice lines, four black rice lines and two check varieties (Aek Sibundong and Ciherang). The experiment was conducted in the Pusakanegara Experimental Station, Subang, West Java from January to April 2016. The experiment used a Randomized Completely Block Design (RCBD) with three replications. The results showed that three white rice lines yielded dry grain significantly higher than Ciherang (7.3 ton/ha) and four brown rice lines had grain yield significantly higher than Aek Sibundong (6.0 ton/ha). Four white rice and one black rice lines had high Fe content in endosperm (>15.0 ppm), while high Zn content (>25.0 ppm) was found in four white rice, two brown rice and one black rice lines. The lines that have high yield were not correlated by high Fe and Zn content, except for one brown rice line B13820E-MR-50-3-2 which had yield of 7.7 tons ha and a high Zn content (26.6 ppm).

1. Introduction
Rice (Oryza sativa L.) is the main food in Indonesia. Rice contributes 63% to total energy, 38% to total protein, and 21.5% to total iron adequacies [1, 2]. Therefore, rice is also called as functional food because it contains one or more components which have physiological functions and beneficial to health [3]. Su et al. [4] defines functional rice as rice which contains active substances in the endosperm, bran and embryo. Rice has added value to health with various functions in human physiological metabolism so that it can meet the demands of people who need these substances. For example, rice with iron content, rice with low glycemic index, and rice with iodine content, has been developed.

Recently, the demand for good quality of brown and black rice varieties is quite high in the community due to the nutrient content in the rice [5]. Several studies showed that rice and its contents determine people's health [2]. Pigments in rice can be beneficial for the body because they contain anti-oxidants or anti-inflammation [6, 2]. Rice is also a potential food for micronutrient fortification because rice is consumed regularly. Some studies have tried to add Fe and Zn in rice grains with the aim of overcoming the problem of nutritional deficiencies. Research conducted on Bangladeshi children shows that rice added to Zn in it provides 49% of Zn needs in children and 69% in women [7]. Myers et al. [8] suggested that the level of carbon dioxide will increase in the coming decades, the amount of rice production may survive in the same amount or slightly increase, but the nutrients content, especially iron and zinc, will decrease. Therefore, fortification steps are needed to increase the...
Fe and Zn content in rice. The breeding of rice varieties with the addition of micro nutrients such as Fe and Zn needs to be done. Both micro nutrients are needed by the body only <100 mg, but they are very important for the formation of hemoglobin which functions in the oxygen transport in the body, so that deficiency in Fe and Zn may cause anemia.

The quality of rice plays an important role in consumer acceptance. The quality of rice is one of the main goals in rice breeding programs. The quality of rice is assessed based on the quality of the milling, grain size, shape, appearance, aroma and cooking quality [9]. Rice seeds have a protective layer, underneath is the pericarp and endosperm. Grinding and polishing dry grain to get milled rice causes the loss of most of the nutritional components of grain which are mostly found in pericarp. Most rice varieties grown and consumed throughout the world has white pericarp. Therefore, more attention must be given to developing rice varieties with colored pericarp [10]. Removal of the pericarp layer can reduce the micro mineral content. Therefore, determining the right milling level can avoid loss of nutrients due to over-milling [11].

2. Methods

Field research was conducted at Pusakanegara Experimental Station, Indonesian Center for Rice Research (ICRR) in January-April 2016. The materials used were 23 lines and two check varieties (Aek Sibundong and Cipherang). The experiment was conducted using a Randomized Completely Group Design with three replications. The plot area was 2 x 5 m², with 20 cm x 20 cm spacing, one seedling per hole. The variables observed included plant height, number of productive tillers, days to flowering, ripening days, number of grains per panicle, 1000 grain weight, and dry milled grain yield. Data analysis was carried out using variance analysis and further tests were carried out using the Least Significantly Design test (LSD).

Analysis of minerals content (Fe and Zn) was carried out in the Laboratory of Flavor, ICRR, Sukamandi. These two minerals can be detected using XRF (X-Ray Fluorescence) method. The data will be obtained in the form of information on the content of the two minerals in the rice endosperm.

The amylose content and grain quality analysis were carried out at Laboratory of Rice Quality at ICRR Muara, Bogor. Amylose content analysis was carried out using spectrophotometry method which was used as a standard method for the analysis of amylose content in rice [12]. Amylose levels of rice samples are classified as sticky rice (0-2%), very low (3-9%), low (10-19%), medium (20-25%) and high (> 25%) [9].

3. Results and discussions

The characters that are widely used for the bedding of high yielding rice varieties are short and rigid stems, upright leaves, large number of tillers, early-medium ripening days, and dense panicles with low sterility. Short plant height is a characteristic of modern superior varieties of rice, this is related to the resistance to fall and the efficiency of biomass partitioning between grain and straw, which has a high harvest index [13]. According to IRRI [14], the height of rice plants can be classified into three categories, namely short (<110 cm), medium (110-130 cm) and high (>130 cm). Plant height of the lines tested ranged from 108.1-141.7 cm. Thus, the height of the lines tested varied from short to high. The shortest line is the white rice B14664E-MR-51, while the highest line is the white rice IR 97443-65-2-CRB-0-SKI-0-SKI-0 (Table 1).

The number of tillers is an important character in the breeding of rice varieties because they are directly related to grain yield. IRRI [14] classified the number of tillers of rice plant into five groups, namely very high (>25 tillers), good (20-25 tillers), medium (10-19 tillers), low (5-9 tillers) and very low (<5 tillers). Data showed that the number of productive tillers of the lines tested ranged from 14.5-22.1 which meant that they were classified as medium-good (Table 1). The number of tillers can change depending on the environment. Rice tillers will decrease if rice is planted in a sub-optimal environment, for example in saline, dry, acid or flooded environments.

In general, rice plants take 3-6 months from germination to harvest depending on the variety and growing environment. The ripening difference is caused by the length of the vegetative phase.
According to ICRR [15], rice ripening can be classified into five groups calculated from the day after seed sowing, namely ultra-early maturity (<90 days), very early maturity (90-104 days), early maturity (105-124 days), medium (125-150 days), and long maturity (>150 days). The ripening days of the lines tested ranged between 102-116 days (Table 1), which means that they are classified as very early-maturing. Variations in the ripening days of the lines tested were not too broad because the lines tested were promising lines that had passed the selection stage based on the maturing days. B13486D-4-1-PN-2-MR-3-3-3 and its sister line, B13486D-4-1-PN-2-MR-3-3-4, has the shortest ripening days. Both lines are black rice. Until now, superior varieties of black rice are still very limited, especially those who have very early maturing.

Table 1. Plant height, number of productive tillers, flowering and ripening days of rice lines tested on preliminary yield trial in Pusakanegara, DS 2016

| No. | Lines/varieties                          | Plant Height (cm) | Number of Productive Tiller | Flowering Days | Ripening Days |
|-----|-----------------------------------------|-------------------|-----------------------------|----------------|---------------|
| 1   | B13826D-RS*1-3-MR-25-1                  | 115.2             | 19.1                        | 81.0           | 111.0         |
| 2   | B13838D-RS*1-1-MR-13-1                  | 113.5             | 15.7                        | 82.0           | 112.0         |
| 3   | B14662E-MR-81                           | 124.3             | 21.5                        | 85.3           | 115.3         |
| 4   | B14664E-MR-44                           | 116.7             | 17.6                        | 80.0           | 110.0         |
| 5   | B14664E-MR-51                           | 108.1             | 17.7                        | 76.0           | 106.0         |
| 6   | B14667E-MR-50                           | 117.1             | 17.5                        | 82.0           | 112.0         |
| 7   | B14667E-MR-95                           | 117.2             | 17.1                        | 84.0           | 114.0         |
| 8   | B14672E-MR-37                           | 132.4             | 18.5                        | 84.0           | 114.0         |
| 9   | B13824D-RS*1-1-MR-20-1                  | 122.7             | 18.0                        | 78.0           | 108.0         |
| 10  | B13813D-RS*1-1-MR-8-1                   | 122.7             | 14.5                        | 86.0           | 116.0         |
| 11  | B14485E-MR-55-3-1                       | 113.5             | 21.7                        | 80.7           | 110.7         |
| 12  | IR97443-65-2-CRB-0-SKI-0-SKI-0          | 141.7             | 18.5                        | 82.0           | 112.0         |
| 13  | B13820E-MR-50-3-2                       | 120.0             | 20.3                        | 76.0           | 106.0         |
| 14  | B13824E-MR-18-3-3                       | 126.3             | 19.5                        | 78.0           | 108.0         |
| 15  | B13824E-MR-38-3-2                       | 125.7             | 19.9                        | 76.0           | 106.0         |
| 16  | B14508-RS*1-1 -MR-1-1-1-3               | 121.0             | 18.2                        | 74.0           | 104.0         |
| 17  | B13804C-MR-2-2-5-2-1                    | 130.5             | 19.5                        | 78.0           | 108.0         |
| 18  | B14483E-MR-43-2                         | 124.7             | 20.9                        | 78.7           | 108.7         |
| 19  | B14484E-MR-34-1                         | 129.5             | 20.2                        | 80.0           | 110.0         |
| 20  | B13486D-4-1-PN-2-MR-3-3-3               | 119.8             | 20.5                        | 72.0           | 102.0         |
| 21  | B13486D-4-1-PN-2-MR-3-3-4               | 117.9             | 20.2                        | 72.0           | 102.0         |
| 22  | B14947F-MR-1-1-2-16-1                   | 115.9             | 15.5                        | 76.0           | 106.0         |
| 23  | B13486D-4-1-PN-2-MR-3-2-1               | 120.3             | 19.9                        | 78.0           | 108.0         |
| 24  | Aek Sibundong                           | 125.7             | 22.1                        | 84.0           | 114.0         |
| 25  | Ciherang                                | 118.2             | 20.7                        | 76.0           | 106.0         |
|     | Mean                                    | 121.6             | 19.0                        | 79.2           | 109.2         |
|     | CV (%)                                  | 2.0               | 9.4                         | 0.5            | 0.4           |
|     | LSD (5%)                                | 3.9               | 2.9                         | 0.7            | 0.7           |

CV = Coefficient of variation, LSD = Least Significantly Different
Panicle characters are closely related to grain yield. Zhang et al. [16] stated that large panicles with more grain per panicle could increase grain density. According to Abdullah et al. [17], one of the characters that must be possessed by high yielding varieties (>9 tons ha\(^{-1}\) grain yield potential) is to have the number of grains per panicle 150-250 with 85-95% of fertility. Seven lines tested and two check varieties, namely Aek Sibundong and Ciherang had a small number of grains per panicle (<150 grains). Nevertheless, one line of brown rice, B13820E-MR-50-3-2, has a good fertility (83.8%), higher than Aek Sibundong (75.5%). From the lines tested, only one line had total grain per panicle >200 grains, namely white rice line B13813D-RS*1-1-MR-8-1 (226.4 grains) with 70% panicle fertility (Table 2).

Table 2. Number of grain/panicles, panicle fertility, 1000 grain weight, and grain yield of rice lines tested on preliminary yield trial in Pusakanegara, DS 2016

| No.  | Lines/varieties                  | Number of Grain/ Panicle | Panicle Fertility (%) | 1000 Grain Weight (g) | Grain Yield (ton/ha) |
|------|--------------------------------|--------------------------|-----------------------|-----------------------|----------------------|
| 1    | B13826D-RS*1-3-MR-25-1          | 160.2                    | 65.6                  | 25.6                  | 5.9                  |
| 2    | B13838D-RS*1-MR-13-1            | 164.8                    | 76.1                  | 27.8                  | 5.7                  |
| 3    | B14662E-MR-81                   | 141.0                    | 72.6                  | 30.1                  | 6.0                  |
| 4    | B14664E-MR-44                   | 162.8                    | 74.9                  | 28.9                  | 7.9                  |
| 5    | B14664E-MR-51                   | 153.6                    | 75.0                  | 28.9                  | 6.9                  |
| 6    | B14667E-MR-50                   | 197.2                    | 66.2                  | 26.6                  | 6.1                  |
| 7    | B14667E-MR-95                   | 196.8                    | 70.7                  | 26.2                  | 6.0                  |
| 8    | B14672E-MR-37                   | 134.2                    | 61.6                  | 29.5                  | 7.6                  |
| 9    | B13824D-RS*1-MR-20-1            | 161.3                    | 76.5                  | 25.9                  | 6.2                  |
| 10   | B13813D-RS*1-MR-8-1             | 226.4                    | 70.0                  | 26.5                  | 6.1                  |
| 11   | B14485E-MR-55-3-1               | 165.1                    | 82.1                  | 28.1                  | 6.6                  |
| 12   | IR97443-65-2-CRB-0-SKI-0-SKI-0  | 156.0                    | 81.0                  | 27.8                  | 8.7                  |
| 13   | B13820E-MR-50-3-2               | 138.2                    | 83.8                  | 25.5                  | 7.7                  |
| 14   | B13824E-MR-18-3-3               | 149.5                    | 81.5                  | 28.7                  | 8.9                  |
| 15   | B13824E-MR-38-3-2               | 142.7                    | 78.3                  | 30.7                  | 8.7                  |
| 16   | B14508-RS*1-1-MR-1-1-1-3        | 161.5                    | 70.9                  | 25.1                  | 5.8                  |
| 17   | B13804C-MR-2-2-5-2-1            | 174.4                    | 68.2                  | 26.9                  | 6.6                  |
| 18   | B14483E-MR-43-2                 | 134.6                    | 75.3                  | 30.4                  | 8.7                  |
| 19   | B14484E-MR-34-1                 | 135.5                    | 79.3                  | 27.7                  | 8.3                  |
| 20   | B13486D-4-1-PN-2-MR-3-3-3       | 157.4                    | 69.5                  | 24.0                  | 5.8                  |
| 21   | B13486D-4-1-PN-2-MR-3-3-4       | 154.0                    | 72.6                  | 23.6                  | 5.4                  |
| 22   | B14947F-MR-1-1-2-16-1           | 151.4                    | 66.9                  | 29.8                  | 4.2                  |
| 23   | B13486D-4-1-PN-2-MR-3-2-1       | 152.6                    | 67.1                  | 22.4                  | 5.5                  |
| 24   | Aek Sibundong                   | 130.7                    | 75.5                  | 29.3                  | 6.0                  |
| 25   | Ciherang                        | 134.0                    | 83.7                  | 26.6                  | 7.3                  |

Mean 157.4  73.8  27.3  6.7  
CV (%)  8.4  5.6  5.1  11.8  
LSD (5%)  21.8  6.8  2.3  1.2

CV = Coefficient of variation, LSD = Least Significantly Different
The 1000 grain weight is the main character of a variety because it is related to the size of the grain. The 1000 grain weight of the lines tested ranged from 22.4-30.7 g (Table 2). Therefore, the grain size of the lines tested varied from small to large. Most rice varieties have 1000 grain weight 25-27 g [17]. From this study, three lines had a large grain size (>30 g), namely lines B14662E-MR-81 (30.1 g), B13824E-MR-38-3-2 (30.7 g) and B14483E-MR-43-2 (30.4 g).

Grain yield is the target character in the development of new superior varieties, because the new superior varieties are expected to have grain yield and yield potential higher than superior varieties that already exist and cultivated by farmers. Grain yield is the process of accumulation and distribution of dry matter. The total yield of dry matter is mainly determined by photosynthetic of the canopy, where canopy of each type of rice variety is different [18]. The grain yield was strongly influenced by the yield components, namely 1000 grain weight, number of productive tillers, number of grains per panicle, and panicle fertility [19]. The data showed that the grain yield of rice lines and varieties tested ranged between 4.2-8.9 tons/ha. Five lines tested had high grain yield (>8 tons/ha), consisting of three white rice lines, IR97443-65-2-CRB-0-SKI-0-SKI-0 (8.7 tons/ha), B13824E-MR-18-3-3 (8.9 tons/ha) and B13824E-MR-38-3-2 (8.7 tons/ha) and two brown rice lines B14483E-MR-43-2 (8.7 tons/ha) and B14484E-MR-34-1 (8.3 tons/ha). Three lines of white rice had significantly higher than Ciherang (7.3 tons/ha) and four lines of brown rice had grain yield significantly higher than Aek Sibundong (6.0 tons/ha) (Table 2).

### Table 3. Fe and Zn content in endosperm of white, brown and black rice lines

| No. | Lines/varieties      | Fe (ppm) | Zn (ppm) | Information  |
|-----|---------------------|----------|----------|-------------|
| 1   | B13826D-RS*1-3-MR-25-1 | 10.5     | 20.2     | Brown rice  |
| 2   | B13838D-RS*1-MR-13-1  | 11.9     | 23.4     | Brown rice  |
| 3   | B14662E-MR-81         | 12.4     | 24.0     | Brown rice  |
| 4   | B14664E-MR-44         | 12.4     | 22.9     | Brown rice  |
| 5   | B14664E-MR-51         | 16.1     | 22.8     | Brown rice  |
| 6   | B14667E-MR-50         | 16.4     | 26.4     | Brown rice  |
| 7   | B14667E-MR-95         | 17.9     | 27.8     | Brown rice  |
| 8   | B14672E-MR-37         | 11.9     | 23.3     | Brown rice  |
| 9   | B13824D-RS*1-1-MR-20-1| 11.2     | 23.7     | Brown rice  |
| 10  | B13813D-RS*1-1-MR-8-1 | 17.8     | 29.7     | Brown rice  |
| 11  | B14485E-MR-55-3-1     | 10.7     | 22.3     | Brown rice  |
| 12  | IR97443-65-2-CRB-0-SKI-0-SKI-0 | 13.9 | 24.9 | Brown rice  |
| 13  | B13820E-MR-50-3-2     | 14.5     | 26.6     | Brown rice  |
| 14  | B13824E-MR-18-3-3     | 11.9     | 24.0     | Brown rice  |
| 15  | B13824E-MR-38-3-2     | 10.9     | 22.9     | Brown rice  |
| 16  | B14508-RS*1-1-MR-1-1-1-3 | 12.2 | 26.2 | Black rice  |
| 17  | B13804C-MR-2-2-5-2-1  | 14.6     | 25.9     | Brown rice  |
| 18  | B14483E-MR-43-2       | 12.0     | 22.9     | Brown rice  |
| 19  | B14484E-MR-34-1       | 11.9     | 22.9     | Brown rice  |
| 20  | B13486D-4-1-PN-2-MR-3-3-3 | 12.4 | 23.7 | Black rice  |
| 21  | B13486D-4-1-PN-2-MR-3-3-4 | 14.0 | 26.0 | Black rice  |
| 22  | B14947F-MR-1-1-2-16-1 | 14.0     | 28.5     | Brown rice  |
| 23  | B13486D-4-1-PN-2-MR-3-3-2-1 | 15.0 | 25.5 | Black rice  |
| 24  | Aek Sibundong         | 11.8     | 24.6     | Brown rice  |
| 25  | Ciherang              | 11.7     | 22.0     | Brown rice  |

Note: Fe is considered high if >15 ppm, Zn is considered high if >25 ppm
The result of this experiment showed that three lines namely B14667E-MR-50, B14667E-MR-95 and B13813D-RS*1-1-MR-8-1 had high Fe and Zn content in the endosperm. The three lines were white rice. Meanwhile the white rice line B14664E-MR-51 had a high Fe content in the endosperm although the Zn content was low, on the contrary the B13820E-MR-50-3-2, B14508-RS*1-1-MR-1-1-1-3, B13486D-4-1-PN-2-MR-3-3-4, B14947F-MR-1-1-2-16-1 and B13486D-4-1-PN-2-MR-3-2-1 had a high Zn content with low Fe (Table 3). The five lines with high Zn consisted of one white rice, one brown rice and three black rice lines. Fe and Zn are needed by the body in very small amounts (<100 mg), however these two elements are very important for the formation of hemoglobin which functions in the oxygen transport in the body, so that deficiency of Fe and Zn could cause anemia. Anemia in children will interfere with the process of growth and development, while in pregnant women cause bleeding.

Tabel 4. Milling rendement, amylose content and rice texture of white, brown and black rice lines

| No.  | Lines/varieties         | Rendement (%) | Amylose (%) | Rice Texture | Information |
|------|------------------------|---------------|-------------|--------------|-------------|
| 1    | B13826D-RS*1-3-MR-25-1 | 70.8          | 18.6        | soft         | Brown rice  |
| 2    | B13838D-RS*1-MR-13-1   | 70.1          | 23.1        | medium       | Brown rice  |
| 3    | B14662E-MR-81          | 71.9          | 26.0        | hard         | Brown rice  |
| 4    | B14664E-MR-44          | 72.0          | 25.6        | hard         | Brown rice  |
| 5    | B14664E-MR-51          | 71.2          | 21.0        | soft         | Brown rice  |
| 6    | B14667E-MR-50          | 68.1          | 26.0        | medium       | Brown rice  |
| 7    | B14667E-MR-95          | 64.6          | 23.1        | medium       | Brown rice  |
| 8    | B14672E-MR-37          | 74.2          | 23.3        | medium       | Brown rice  |
| 9    | B13824D-RS*1-1-MR-20-1 | 66.2          | 23.4        | medium       | Brown rice  |
| 10   | B13813D-RS*1-1-MR-8-1  | 63.8          | 22.8        | medium       | Brown rice  |
| 11   | B14485E-MR-55-3-1      | 68.8          | 23.3        | medium       | Brown rice  |
| 12   | IR97443-65-2-CRB-0-SKI-0-SKI-0 | 59.0 | 20.0 | soft | Brown rice |
| 13   | B13820E-MR-50-3-2      | 75.6          | 23.9        | medium       | Brown rice  |
| 14   | B13824E-MR-18-3-3      | 66.8          | 19.3        | soft         | Brown rice  |
| 15   | B13824E-MR-38-3-2      | 67.2          | 27.0        | hard         | Brown rice  |
| 16   | B14508-RS*1-1-MR-1-1-1-3 | 67.8      | 26.2        | hard         | Black rice  |
| 17   | B13804C-MR-2-2-5-2-1   | 70.6          | 21.0        | soft         | Brown rice  |
| 18   | B14483E-MR-43-2        | 73.6          | 26.3        | hard         | Brown rice  |
| 19   | B14484E-MR-34-1        | 69.8          | 23.3        | medium       | Brown rice  |
| 20   | B13486D-4-1-PN-2-MR-3-3-3 | 62.8      | 22.8        | medium       | Black rice  |
| 21   | B13486D-4-1-PN-2-MR-3-3-4 | 65.4      | 23.3        | medium       | Black rice  |
| 22   | B14947F-MR-1-1-2-16-1  | 64.2          | 22.8        | medium       | Black rice  |
| 23   | B13486D-4-1-PN-2-MR-3-2-1 | 67.0      | 24.2        | medium       | Black rice  |
| 24   | Aek Sibundong          | 68.8          | 22.3        | medium       | Brown rice  |
| 25   | Ciherang               | 70.4          | 23.2        | medium       | Brown rice  |

The quality of rice plays an important role in consumer acceptance. The quality of rice is one of the main goals in rice breeding programs. At present, consumer demand for functional rice is increasing. Brown rice, black rice and rice with minerals content are needed by consumers, so the need for rice varieties is increasing. Variations in the color of rice from the lines tested can be seen in Figure 1. In addition to high yield, the quality of rice is also very important in rice varieties breeding program.
Varieties with good rice quality will be acceptable to farmers and consumers. For farmers and traders, milled rendement is very important, because it relates to rice yield produced from dried grain that has been harvested. The milled rendement of the lines tested ranged from 59.0-75.6% (Table 4). The brown rice line B13820E-MR-50-3-2 has a high yield (75.6%), higher than Aek Sibundong (68.8%). The higher milled rendement, the more rice is obtained, and the less rice husk is produced. In general, high yielding rice varieties have thin grain skin.

Functional rice is demanded by special markets, including glutinous rice and aromatic rice [20]. Glutinous rice is the rice that has low amylose content (0-8%), while the amylopectin content is high. Although this type of rice is not the main food ingredient for Indonesian population, this rice is important in the lives of Indonesian people. Amylose content determines the texture of rice more than other properties, such as gelatinization temperature and gel consistency. Rice that has a low amylose content when cooked produces sticky, glazed, does not expand, and keeps clumping after cold. Rice with high amylose content when cooked in rice is not sticky, expand, and becomes hard when it's cold, while rice with medium amylose content generally has soft rice texture. It is known that the amylose content of rice has a positive correlation with the taste of rice, the higher amylose content, the harder the rice texture [21]. Amylose levels of the lines tested ranged from 18.6-27.0%, with variations in soft, medium and hard rice textures. Data showed that rice with amylose content <22% has soft rice texture. Five lines tested had soft rice texture, consisting of three white rice lines, namely B14664E-MR-51 (21.0%), IR 97443-65-2-CRB-0-SKI-0-SKI-0 (20.0%) and B13824E-MR-18-3-3 (19.3%), and two brown rice lines, namely B13826D-RS*1-3-MR-25-1 (18.6%) and B13804C-MR-2-2-5-2-1 (21.0%). Meanwhile, the brown rice variety, Aek Sibundong, has medium rice texture with 22.3% of amylose content (Table 4). Recently, brown rice and black rice with soft rice texture are highly needed by consumers. This is because brown rice only undergoes one polishing process in the milling process to avoid the loss of pigments. Brown and black pigments are widely found in rice pericarp which is lost during the process of polishing. In the market, there is already one brown rice variety that has soft rice texture, namely Inpari 24 which was released in 2012 [22], while the superior variety of black rice has not been produced. Therefore, the breeding of superior varieties of brown rice and black rice is still very necessary to enrich the choice of farmers and consumers, in addition to enriching the genetic wealth of rice.

4. Conclusion
The white, brown and black rice lines tested had variations between lines in morphological characters, yield, mineral content and quality of rice. Three white rice lines had grain yield significantly higher than Ciherang (7.3 tons/ha) and four brown rice lines had grain yield significantly higher than Aek Sibundong (6.0 tons/ha). Three white rice lines have high Fe and Zn content in the endosperm. One white line has a high Fe content (>15 ppm) with a low Zn content, whereas five lines have high Zn content (> 25 ppm) with low Fe. The high yielding lines are not always related by high Fe and Zn content. One brown rice line B13820E-MR-50-3-2 has 7.7 tons/ha of grain yield and a high Zn content (26.6 ppm).
References

[1] Indrasari S D, Wibowo P and Damardjati D S 1997 Food consumption pattern based on the expenditure level of rural communities in several parts in Indonesia (Sukamandi : unpublished Balai Penelitian Tanaman Padi)

[2] Rohman A, Helmiyati S, Hapsari M and Setyaningrum D L 2014 Int. Food Research J. 21 13–24

[4] Su N, Wan X Y, Zhai H Q and Wan J M 2008 Agr. Sci. in China. 7 1–9

[5] Sumczynski D, Kotásková E, Druzbíková H and Mleck J 2016 Food Chemistry 211 339–46

[6] Anderson J W 2004 American J. Clinical Nutrition 80 1459–60

[7] Arsenault J E, Yakes E A, Hossain M B, Islam M M, Ahmed T, Hotz C, Lewis L, Rahman A S, Jamil K M and Brown K H 2010 Journal of Nutrition 140 1683–90

[9] Cruz D N and Khush G S 2000 Rice grain quality evaluation procedures ed Singh R K, Singh U S et al (New Delhi : Oxford & IBH Publishing Co. Pvt. Ltd.) pp 16–28

[10] Zhang H, Shao Y, Bao J and Beta T 2015 Food Chemistry 172 630–9

[11] Liu K, Zheng J and Chen F 2017 Food Science and Technology 82 429–36

[12] Juliano B O 1993 Rice in human nutrition (Rome : IRRI-FAO)

[13] Manurung S O and Ismunadji M 1988 Morfologi dan fisiologi padi ed Ismunadji M, Partohardjono S et al (Bogor : Badan Penelitian dan Pengembangan Pertanian) pp 55–102

[14] International Rice Research Institute 2004 Rice Knowledge Bank CD ROM Version 3.1 [15 April 2004].

[15] Balai Besar Penelitian Tanaman Padi 2016 Klasifikasi Umur Padi [Downloaded 11 March 2016] http://bbpadi.litbang.pertanian.go.id/index.php/tahukah-anda/120-klasifikasi-umur-padi

[17] Abdullah B, Tjokrowidjojo S and Sularjo 2008 J Litbang Pert. 271–9

[18] Wahyuti T B 2012 Hubungan karakter morfologi dan fisiologi dengan hasil dan upaya meningkatkan hasil padi varietas unggul (Bogor : Disertasi Institut Pertanian Bogor)

[19] Ishimaru K, Kashiwangi T, Hirotsu N and Madoka Y 2005 J Exp Bot. 56 2745–53

[20] Calingacion M, Laborte A, Nelson A and Resurreccion A 2014 PLoS ONE 9 85–106

[21] Zhang H, Tan G L, Xue Y G, Liu L J and Yang J C 2010 Acta Agron Sin. 36 133–40

[22] Balai Besar Penelitian Tanaman Padi 2017 Deskripsi Varietas Unggul Baru Padi (Subang : BB Padi) p 87