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Evaluation of Yield and Pigment Content of Eleven Genotypes of Green and Purple Pod Yard Long Bean (*Vigna unguiculata* (L.) Walp.)

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Abstract

The consumption of yard long bean in Indonesia is high and it has been increasing continuously, but the production and harvest area has been decreasing. New, superior long bean varieties with higher productivity are required to meet the increasing demands. The aim of this study was to evaluate the morphological and yield characters of selected purple and green long bean genotypes. The research was conducted from February to May 2018 in the Madiun district, East Java, Indonesia. The experiment was laid out in a randomized complete block design with genotypes as the single factor treatment, replicated three times. Eleven yard long bean genotypes were tested, consisting of four new genotypes, F7-013014-4U-16-1-1, "F7-013014-4U-16-1-2", "F7-013014-4U-16-1-3", and "F7-013014-7P-4-1-1", and seven control genotypes, "KP13", "KP14", "KP Putih China", "KP Putih China", "Borneo", "Sabrina" and "Parade". The new genotypes, "F7-013014-4U-16-1-1, "F7-013014-4U-16-1-2", "F7-013014-4U-16-1-3", and "F7-013014-7P-4-1-1" had at least one superior characters compared to the control genotypes, i.e. earlier flowering and time to harvest, longer leaves, greater pod weight, longer pods, larger pod diameter, and higher contents of anthocyanin, carotene, chlorophyll a, chlorophyll b, and total chlorophyll.

Keywords: anthocyanin, genotype, pigment, carotene, chlorophyll

Introduction

Long bean consumption in Indonesia in 2016 was 1,158 million tons per year, ranked 4th of the most consumed vegetables (BPS, 2016). The average long bean production and harvest area had decreased significantly from 2009 to 2014, with an increase in productivity (Directorate General of Horticulture, Ministry of Agriculture, 2015). The increase productivity of long bean is due to the uses of superior varieties with higher productivity (Syukur et al., 2015). Superior long bean varieties were selected through plant breeding to improve the growth characters, yield, and adaptability (Syukur et al., 2015).

One of the desired characters in long bean breeding is to increase the pod pigment content, including anthocyanin, chlorophyll and carotenoids. Anthocyanin is classified as an antioxidant (Kuswanto et al., 2013), whereas carotenoid content is related to vitamin A activities (Syahputra et al., 2008). Carotenoid content in long bean correlated significantly with chlorophyll a, chlorophyll b and total chlorophyll content (Basrowi, 2017). The purple pod long bean are more tolerant to pests and diseases due to their thicker and harder skin pods which may repel pests, and can adjust well to limited soil water environment (Kuswanto et al., 2013). Higher nutritional content in long bean pods will increase the consumer demands for long beans (Ardian et al., 2016).

The long bean genotypes tested in this study were obtained from crossings between whitish green pod "KP 13" and purple pod "KP 14". The selection from the crossings had produced four genotypes, "F7-013014-4U-16-1-1" and "F7013014-4U-16-1-2" which have purple pods, the green pod "F7-013014-4U-16-1-3" and the whitish green pod "F7- 013014-7P-4-1-1". The genotypes tested are the 7th generation that will be ready to be released as new long bean varieties after evaluating the yield and pigment content of the pods.

The breeding of long beans is intended to produce varieties with a higher biomass, better nutritional content with acceptable taste, more attractive shapes and colors, and longer freshness (Syukur et al., 2015). The breeding lines long bean needs to be evaluated to determine the productivity and adaptability before releasing new long bean varieties. The yield evaluation is one of the plant breeding stages after selection which includes the preliminary evaluation, and an advanced evaluation (Syukur et al., 2015). According to Kuswanto (2005), long bean yield evaluation was determined based on fresh pod yield, pod quality and taste. This study was aimed evaluating the morphological and yield characters of purple and green long bean's genotypes as compared as compared to the existing long bean varieties and the parental genotypes, i.e. "KP13", "KP14", "KP Putih China", "KP Ungu China", "Borneo", "Sabrina" and "Parade".

Materials and Methods

This research was conducted in Madiun Regency, East Java with an altitude of 60 m above the sea level and located in -7.535 LS and 111.656 BT from February to May 2018, with monthly rainfall of 409.2, 440.8, 498.8 and 195.7 mm per month, respectively. The maximum temperature ranged from 27.8 to 29.5 °C with the relative humidity of 88.5 to 91.1% (BMKG, 2018).

Eleven yard long bean genotypes were tested, consisted of four test genotypes, "F7-013014-4U-16-1-1", "F7-013014-4U-16-1-2", "F7-013014-4U-16-1-3" and "F7-013014-7P-4-1-1", and seven control genotypes, "KP13" and "KP14" as parental genotypes, "KP Putih China" and "KP Ungu China" as the introductory genotypes, and "Borneo", "Sabrina" and "Parade" as commercial genotypes. The experiment was laid out in a randomized complete block design with long bean genotype as the single factor treatment. Each experimental unit is a 5 x 1 m^2 plots with 20 plants per plot, repeated three times.

Plant beds were prepared and added with 1 kg of manure and 200 g of dolomite per plot; mulch was applied one week before planting. Seeds were directly sown into the plots using a spacing of 50 cm x 50 cm. Plant maintenance includes weed control, fertilization with NPK Mutiara 16-16-16, tying up the tendrils, watering, and pest control when necessary. NPK fertilizer was diluted at 5 g per liter of water with a volume of 250 ml per plant, applied once a week. Harvesting was conducted at three day intervals according to the criteria used for fresh bean consumption, i.e. when the end of the pods have been fully filled, but before seeds in the pods became too large and protruded out of the pods.

Scoring was conducted on stem diameter (cm), length of a leaflet from trifoliate leaves (cm), length of petiole (cm), time to flower (DAP), time to harvest (DAP), pod length (cm), pod diameter (cm), seeds per pod, 1,000 seeds weight (g), pod weight (g), number of pods per plant (g), pod weight per plant (g), productivity ($t.ha^{-1}$), pod content of anthocyanin, carotene, chlorophyll a, chlorophyll b and total chlorophyll. Measurements were made on 10 randomly selected sample plants from each plot when the plants had entered the generative phase. Pigment content of the long bean pods were analyzed using the Sims, DA and Gamon method at IPB Postharvest Laboratory (Sim and Gamon, 2002). Samples for pigment content analysis were collected from two randomly selected pods of each genotype. Data were tested by ANOVA using SAS 9.0. Significant differences between means were further tested using Duncan Multiple Range Test (DMRT) at α 5%. Correlation and cluster analysis used single linkage, Euclidean distance with Minitab 18.

Soil analysis was tested at Laboratory of Soil Science and Land Resources Department, Faculty of Agriculture, IPB. Soil samples were collected from three different spots which were then mixed into one sample. Determination of particle size distribution, pH, organic-C, total N, electrical conductivity, water-soluble cations and anions, cation exchange capacity, free Fe oxides, available N, P and K, available Fe, Mn, Cu, Zn, Mo and B in soil used the methods described in Hardjowigeno (2004).

Result and Discussion

Analysis of variance of the 11 long bean genotypes is in Table 1. The highly significant characters were time to flower, time to harvest, pod weight, pod length, pod diameter, number of seeds per pod, the content of anthocyanin and chlorophyll b. Characters with significant results were the number of pod per plant, productivity, chlorophyll a, total chlorophyll and carotenoid content, while other characters were not significantly different (Table 1).

The coefficient variance (CV) shows the extent of environmental effects on the growth parameters, as also reported in Pradipta et al. (2010). Time to harvest character had the smallest CV value, whereas the largest CV value was in pod chlorophyll a content.

Time to Flower and Time to Harvest

Table 2 shows that the long bean genotypes flowered at 29 to 39 day after planting (DAP), which were quite early compared to those reported in Basrowi (2017). The white pod genotype had the earliest time to flower, whereas the green pod genotype had the longest time to flower.

Table 1. Analysis of variance of 11 long bean genotypes

No	Characters	Mean Square	Coefficient of Variance (%)
1	Stem diameter (cm)	1.33**	6.22
2	Trifoliate leaf length (cm)	2.09^{ns}	9.42
3	Length of leaflet (cm)	1.67^{ns}	7.74
4	Trifoliate leaf width (cm)	5.99^{ns}	7.35
5	Leaflet width (cm)	0.19^{ns}	10.84
6	Trifoliate petiole length (cm)	6.53**	14.16
7	Leaflet length (cm)	0.38**	7.72
8	Time to flower (DAP)	21.27**	3.69
9	Time to harvest (DAP)	9.15**	2.68
10	Number of pod per plant	50.29*	18.38
11	Weight of pod per plant (g)	7,808.25*	18.83
12	Pod weight (g)	43.65**	10.82
13	Pod length (cm)	153.98**	4.72
14	Pod diameter (cm)	0.46**	4.32
15	Number of seeds per pod	7.10**	5.81
16	Weight of 1,000 seeds (g)	2,306.29^{ns}	15.84
17	Anthocyanin content (mg.g^{-1})	0.00017**	16.01
18	Chlorophyll a content (mg.g^{-1})	0.00059*	41.86
19	Chlorophyll b content (mg.g^{-1})	0.00013**	37.70
20	Total chlorophyll content (mg.g^{-1})	0.00128*	40.18
21	Carotene content (mg.g^{-1})	0.00007*	31.77
22	Productivity (t.ha^{-1})	12.49*	18.83

Notes: * significant at α = 5%; ** highly significant at α = 1%; ns not significant at α = 5%

“F7-013014-7P-4-1-1” had the earliest time to flower, i.e. three days earlier compared to the introductory genotype “KP Putih China”. “Sabrina” and “Parade” were the latest time to flower. The time to flower of “F7-013014-4U-16-1-3” was earlier than “Sabrina” and “Parade”. “F7-013014-4U-16-1-2” had the similar time to flower with of “KP 14” and KP Putih China, and significantly earlier than “Sabrina” and “Parade”. The growers usually preferred crops with early flowering (Putri et al., 2015). Time to flower and time to harvest in this study were four and six days earlier than those reported in Basrowi (2017). According to Septeningsih et al. (2013), the difference in time to flower was affected by genetic and environmental factors. Cahyaningrum et al. (2014) reported that heavy rain conditions can lead to flower drops. Rainfall in Basrowi’s research (2017) was 78-116.8 mm higher than the research in Madiun.

“KP Putih China” had the earliest time to harvest. “F7-013014-4U-16-1-2” and “F7-013014-4U-16-1-1” had later harvest than “KP 14” and “KP Ungu Cina”, whereas “F7-013014-7P-4-1-1” had similar time to harvest to “KP Putih China” and earlier compared to the other genotypes (Table 2). Genotypes with earliest harvesting time are expected to produce yield faster (Septeningsih et al., 2013) and can potentially be released as new varieties (Pradipta et al., 2010).

Stem Diameter, Length of Leaflet and Trifoliate Leaves

The stem diameter ranges from 9.17 to 6.87 mm (Table 3). “KP Putih China” had the largest stem diameter whereas “F7013014-4U-16-1-2” had the smallest. Test genotype “F7013014-4U-16-1-1” had a highly significantly larger stem diameter compared to “Sabrina”, “KP 13” and “Parade”, but it was not significantly different from other genotypes.

The character of trifoliate length had a range of 9.06 to 12.39 cm. Genotype with the longest petiole was “F7013014-4U-16-1-2”, while “F7013014-4U-16-1-3” had the shortest. The petiole length of “F7013014-4U-16-1-2” was not significantly different from that of “Sabrina” and “Borneo” but was significantly longer than those of other genotypes. The median value of the leaflet ranged from 5.1 to 4.00 cm, and “F7013014-

4U-16-1-2" had the longest (Table 3).

Pod Weight, Pod Length, Number of Seeds per Pod, Number of Pods per Plant, and Weight of Pod per Plant

The range of pod weights was 8.86 to 22.15 grams (Table 4). Pod weight of "F7-013014-4U-16-1-2" was significantly higher than all genotypes. "F7-013014-4U-16-1-3" pod weight was not significantly different from "Borneo", "Sabrina", "Parade" and "KP 13", but it was significantly different from the other control genotypes ("KP 14", "KP Putih China", and "KP Ungu China").

The median values of pod length were 40.16 to 56.55 cm (Table 4). The longest and shortest pod was "F7-013014-4U-16-1-2" and "KP Putih China", respectively. The pod length of "F7-013014-4U-16-1-2" and "F7-013014-4U-16-1-3" were not significantly different from the comparative genotypes of "Borneo", "Parade", "Sabrina" and "KP 13", but were significantly longer than the other genotypes. The pod lengths of all test genotypes were significantly longer than some control genotypes. One of the main criteria in the selection of superior long beans varieties was the character of pod length (Kuswanto et al., 2013). Consumers prefers long bean with pod lengths of 60 to 90 cm (Kuswanto et al., 2009). The length of pod can affect the weight of pod (Cahyaningrum et al., 2004), but longer pods do not necessarily had more seeds (Ardian et al., 2016).

The pod diameter ranged from 5.16 to 6.67 cm. The pod diameter of "F7-013014-4U-16-1-2" was significantly larger than those of the other genotypes, while "KP Putih China" was significantly smaller (Table 4). The result showed that the white pod such as "KP Putih China" and "F7-013014-7P-4-1-1" had pods with a relatively smaller diameter than the green and purple pods.

The number of seeds per pod ranged from 14 to 19 seeds. The control genotype of "KP 13" had the greatest number of seeds per pod, which was significantly more than all test genotypes. "F7-013014-4U-16-1-3" had the least number of seeds. "F7-013014-4U-16-1-2" had the fewest number of seeds per pod but it had the longest pods among the other genotypes. "KP 13" and "F7-013014-4U-16-1-3" although had a significantly more number of seeds per pod, had similar pod length.

Number of Pods per Plant, Pod Yield per Plant, and Productivity

The number of pods per plant ranged from 14.2 to 30 (Table 5). The number of pods of "F7-013014-4U-16-1-1" and "F7-013014-4U-16-1-3" was not significantly different from those from the control genotypes, therefore the yield of the tested genotype was comparable to yield of the existing commercial varieties. The number of pods per plant of "F7-013014-7P-4-1-1" was significantly lower than "KP 14", but it was not significantly different from the number of pods of the other control genotypes. The number of pods for the tested genotype "F7-013014-4U-16-1-2" was significantly lower than "KP Putih China", "KP 13", "KP Putih China" and "KP 14" (Table 5). This might have been caused by aphid (*Aphis craccivora*) infestation which was observed across all the replications so many of the pods from this genotype were not harvestable.

The range of pod weight was 227.55 to 376.80 gram per plant. "Borneo" had the greatest pod weight. Pod weight of "F7-013014-4U-16-1-2" and "F7-013014-7P-4-1-1" were significantly lower than "KP 13" and "Borneo", but it was not significantly different from the other control genotypes. Weight per pod of "F7-013014-4U-16-1-2" was quite low due to *Aphis craccivora* infestation which had affected the stem, leaves and pods in all blocks. Ziyadah (2016) reported that aphid infestation in long beans can decrease yield up to 62.35%.

The productivity of the 11 long bean genotypes ranged from 9.10 to 15.07 $t.ha^{-1}$ (Table 5). The yields of long bean in this study were smaller than the potential yields reported by The Indonesian Ministry of Agriculture and Basrowi (2017). Based on the description of long bean varieties released by the Ministry of Agriculture the yield of "Parade" (2006), "Borneo" (2010) and "Sabrina" (2012) was 12 to 25 $t.ha^{-1}$, 18 to 19.2 $t.ha^{-1}$ and 20 to 24 $t.ha^{-1}$, whereas in this study they were 11.47 $t.ha^{-1}$, 15.07 $t.ha^{-1}$ and 11.47 $t.ha^{-1}$, respectively. The yield evaluation study conducted in Bogor, West Java, (Basrowi 2017) reached 22.99 $t.ha^{-1}$ whereas in Madiun, East Java, the highest productivity was 15.07 $t.ha^{-1}$. The differences in the yield in the two locations were possibly due to the environment effects that were greater than the genetic effects, and interaction of both. Different environment might result in differences in the metabolic processes, including photosynthesis rate, which eventually affected yield (Cahyaningrum et al., 2014).

The low yields in this study were likely caused by *Sclerotium rolfsii* which had attacked since the crops were at the early generative phase. The disease infestation was made worse by the saturated soil environment due to high rainfall intensities in February to April 2018. Too wet media causes sub-optimal plant growth due to less oxygen availability (Hendriyani,

Table 2. Time to flower and to harvest of 11 yard long bean genotypes

Genotypes	Time to flower (DAP)	Time to harvest (DAP)
"F7-013014-4U-16-1-1"	37.3ab	44.0abc
"F7-013014-4U-16-1-2"	36.0b	42.0cd
"F7-013014-4U-16-1-3"	36.0b	46.0a
"F7-013014-7P-4-1-1"	32.6c	43.0bcd
"KP 13"	36.0b	44.0abc
"KP 14"	36.3b	46.0a
"KP Putih China"	29.6d	41.3d
"KP Putih Ungu"	36.0b	46.0a
"Borneo"	36.0b	45.0ab
"Sabrina"	39.0a	46.0a
"Parade"	39.0a	46.0a

Note: Values followed by the same letter within the same column were not significantly different according to DMRT α = 5%; DAP = days after planting

Table 3. Stem diameter, length of leaflet and trifoliate leaves of 11 yard long bean genotypes

Genotypes	Stem diameter (cm)	Trifoliate length (cm)	Leaflet length (cm)
"F7-013014-4U-16-1-1"	8.84ab	8.92c	4.47b
"F7-013014-4U-16-1-2"	6.87d	12.39a	5.16a
"F7-013014-4U-16-1-3"	7.63cd	8.06c	4.08b
"F7-013014-7P-4-1-1"	8.29abc	8.37c	4.04b
"KP 13"	7.87c	9.07bc	4.03b
"KP 14"	8.97ab	8.61c	4.14b
"KP Putih China"	8.34abc	8.12c	4.00b
"KP Putih Ungu"	9.17a	8.30c	4.02b
"Borneo"	8.37abc	10.61abc	4.27b
"Sabrina"	8.08bc	11.37ab	4.54b
"Parade"	7.73cd	8.43c	4.00b

Note: Values followed by the same letter within the same column were not significantly different according to DMRT α = 5%

Table 4. Pod weight, pod length, pod diameter and number of seeds per pod of 11 yard long bean genotypes

Genotype	Pod weight (g)	Pod length (cm)	Pod diameter (cm)	Number of seeds per pod
"F7-013014-4U-16-1-1"	10.33d	42.88b	5.57bc	17.0c
"F7-013014-4U-16-1-2"	22.15a	56.55a	6.67a	14.7d
"F7-013014-4U-16-1-3"	15.10b	55.13a	5.44bc	14.4d
"F7-013014-7P-4-1-1"	11.34cd	41.93b	5.48bc	17.1c
"KP 13"	13.90bc	54.35a	5.43bc	19.4a
"KP 14"	9.72d	41.30b	5.41bc	19.1ab
"KP Putih China"	10.00d	40.97b	5.16c	16.5c
"KP Putih Ungu"	8.86d	40.16b	5.37bc	16.8c
"Borneo"	15.47b	55.06a	5.60b	17.3bc
"Sabrina"	15.03b	54.43a	5.66b	17.5bc
"Parade"	13.28bc	54.89a	5.38bc	18.1abc

Note: Note: Values followed by the same letter within the same column were not significantly different according to DMRT at α = 5%

Table 5. Number of pod per plant, weight of pod per plant and productivity of 11 yard long bean genotypes

Genotype	Number of pods per plant	Weight of pods per plant (g)	Productivity ($t.ha^{-1}$)
"F7-013014-4U-16-1-1"	22.5abcd	252.14bc	10.08bc
"F7-013014-4U-16-1-2"	14.2d	227.55c	9.10c
"F7-013014-4U-16-1-3"	22.5abcd	366.21ab	14.64ab
"F7-013014-7P-4-1-1"	21.0bcd	233.30c	9.33c
"KP 13"	25.3abc	364.86ab	14.59ab
"KP 14"	30.0a	297.70abc	11.90abc
"KP Putih China"	23.2abc	261.06bc	10.44bc
"KP Putih Ungu"	26.8ab	309.43abc	12.37abc
"Borneo"	21.3bcd	376.80a	15.07a
"Sabrina"	19.5bcd	316.93abc	12.67abc
"Parade"	17.3cd	286.96abc	11.47abc

Note: Values followed by the same letter within the same column were not significantly different according to DMRT at α = 5%

2009). In addition, soil Fe in the experimental site was quite high (Table 6). In rice, high concentration of soil Fe reduced growth, especially in the number of tillers and shoot dry weight (Lubis and Noor, 2012).

The control genotype "Borneo" had the highest productivity, but it was not significantly different from "F7-013014-4U-16-1-3". The productivity of "F7-013014-4U-16-1-3" was the highest (14.64 $t.ha^{-1}$) among the tested genotypes. According to Cahyaningrum et al. (2014), the yield average is influenced by the environment, but the lines which had the ability to adapt to the growing environment could have good productivity. "F7-013014-4U-16-1-1" productivity was not significantly different from "KP Putih China", "Parade", "KP 14", KP Putih China, "Sabrina" and "KP 13" (Table 6). "F7-013014-4U-16-1- 2" and "F7-013014-7P-4-1-1" productivity was significantly lower than that of "KP 13" and "Borneo", but it was not significantly different from the control genotypes (Table 5).

A similar study conducted in Bogor (Basrowi, 2017) showed that "F7-013014-7P-4-1-1" had the highest productivity of 22.99 $t.ha^{-1}$, whereas in this research the yield only reached 9.33 $t.ha^{-1}$. The difference in the productivity was likely due to the different harvest criteria, because the pods of "F7-013014-7P-4-1-1" hardened and the seeds enlarged quickly upon ripening.The swollen pods are heavier, which in turn increased productivity.

Chlorophyll a, Chlorophyll b, Total Chlorophyll, Carotene and Anthocyanin Content of Long Bean Pods

The chlorophyll a in "F7013014-4U-16-1-2" seeds was significantly higher than that of the other genotypes,and chlorophyll b in "F7013014-4U-16-1-2" and "F7013014-4U-16-1-3" was significantly higher compared to the other genotypes (Table 7). "KP Putih China" had the lowest content of chlorophyll b.The high content of chlorophyll a or chlorophyll b indicates efficiency in photosynthesis (Mescht et al., 1999).

The total chlorophyll of "F7013014-4U-16-1-2" seeds was the highest and it was significantly higher than those from the other genotypes. The total chlorophyll of "F7013014-4U-16-1-3" was not significantly different from the control genotypes "Borneo", "Parade", "Sabrina" and "KP 14", but it was significantly higher than the other genotypes. The genotype of "KP Putih China" had the lowest chlorophyll content.

The genotype with the highest carotenoid content was "F7-013014-4U-16-1-2", whereas the lowest was in "KP Putih China". The carotenoid level of "F7-013014-4U-16-1-3" seeds was not significantly different from "Borneo", but it was significantly higher than other genotypes. There were 10 types of carotenoids in vegetables that play important roles in human's health, including improving visual function, immune system and resistance to infection (Merdekawati and Susanto, 2009). Mortensen (2006) reported that beta carotene is a precursor of vitamin A.

Table 7 shows that long beans with purple pod have high anthocyanin content, whereas the whitish-green pods had the lowest. "KP 14" had the highest anthocyanin content, whereas "KP Putih China" had the lowest. The high anthocyanin content in "KP 14" correlated positively with the darker color of the pods. A similar result was reported by Kuswanto et al. (2013) that the intensity of purple seeds correlates with anthocyanin content.

The anthocyanin content of "F7-013014-4U-16-1-1" and “F7-013014-4U-16-1-2” was significantly lower than “KP 14” and “KP Putih China” but higher than the other genotypes. The result of this study was different from the findings of Baswori (2017) where the anthocyanin content of “F7-013014-4U-16-1-2” was higher with a difference of 0.0152 $mg.g^{-1}$. The different result was possibly due to the long duration of transport when shipping samples to Bogor prior to pigment analysis. Sample shipment took about two days; during which the samples were not stored in cold storage. According to Hayati et al. (2012), anthocyanins stability is influenced by temperature and storage environment. The high temperatures cause anthocyanin degradation that effect on the loss of color in anthocyanins, e.g. longer storage duration causes a decrease in anthocyanin color and stability of the petals extract of rosella flower (*Hibiscus sabdariffa* L.).

The soil base saturation of this study was 23% (Table 6). According to the Soil Research Center (1983) in Hardjowigeno (2010) soil base saturation of >20 % was classified as low category. The content of C-organic, N, P, K, Na, Mg, Ca, and CEC in the study was low according to Hardjowigeno (2010). Soil with low saturated base usually had high levels of leaching, so the cations (Ca ++, Mg ++, K +, Na +) of the soil were low (Hardjowigeno, 2010). The soil Fe and Mn in this study was 85.18 and 95.69 ppm (Table 6), which according to the Soil Research Center (2005) is classified as very high. High soil Fe content is likely due to the ferrolysis which occurred due to the reduction and oxidation processes as a result of repeated flooding and drying (Hardjowigeno, 2004). High soil Mn content is usually found in poorly drained and inundated land (Makarim, 2005) which is similar to the soil condition in this study. High content of Fe and Mn could reduce plant productivity (Makarim, 2005).

Correlation Analysis

Correlation analysis was conducted to determine

Table 6. Soil chemical and physical properties

pH H_2O	pH KCL	C-org 1)	Total N 2)	P 3)	P 4)	Ca	Mg	K	Na	CEC
		(%)	(%)	(ppm)		($cmol^{(+)}kg^{-1}$)				
6.08	5.42	1.53	0.11	12.43	114.92	2.50	0.65	0.14	0.16	15.19
SB	Al	H	Fe	Cu	Zn	Mn	Sand 5)	Clay 5)	Dust 5)	
(%)	($cmol^{(+)}kg^{-1}$)		(ppm)				(%)	(%)	(%)	
23	tr	0.11	85.18	4.43	2.96	96	14.02	33.18	52.80	

Note: 1)Walkley and Black method; 2)Kjeldahl method; 3)P Bray and 4)HCl method; 5) pipette method; all methods are described in Hardjowigeno (2004). SB: saturated base; CEC: cation exchange capacity.

Table 7. Pod chlorophyll a, chlorophyll b, total chlorophyll and anthocyanin of 11 long bean genotypes

Genotypes	Chlorophyll a content ($mg.g^{-1}$)	Chlorophyll b content ($mg.g^{-1}$)	Total chlorophyll content ($mg.g^{-1}$)	Carotene content ($mg.g^{-1}$)	Anthocyanin content ($mg.g^{-1}$)
“F7-013014-4U-16-1-1”	0.015c	0.007cd	0.023c	0.007c	0.019b
“F7-013014-4U-16-1-2”	0.065a	0.031a	0.097a	0.026a	0.016b
“F7-013014-4U-16-1-3”	0.051ab	0.023ab	0.074ab	0.018ab	0.004c
“F7-013014-7P-4-1-1”	0.016c	0.006cd	0.023c	0.008c	0.003c
“KP 13”	0.014c	0.008cd	0.023c	0.008bc	0.004c
“KP 14”	0.021c	0.010cd	0.032c	0.010bc	0.025a
“KP Putih China”	0.014c	0.007cd	0.021c	0.006c	0.003c
“KP Putih Ungu”	0.012c	0.005d	0.018c	0.007c	0.025a
“Borneo”	0.034bc	0.018cb	0.052bc	0.016bc	0.005c
“Sabrina”	0.031bc	0.013bcd	0.044bc	0.014bc	0.004c
“Parade”	0.032bc	0.014bcd	0.046bc	0.014bc	0.004c

Note: Values followed by the same letter within the same column were not significantly different according to DMRT at α = 5%

the relationship between the main growth characters in order to improve selected traits (Nasution, 2010). The time to flower character has a positive correlation with time to harvest, meaning that earlier flowering will result in earlier production. Crops with earlier production are preferable (Putri et al., 2015). Genotypes with earlier harvest were “F7-013014-7P-4-1-1”, “F7-013014-4U-16-1-2”, “F7-013014-4U-16-1-1”, “KP Putih China” and “KP 13”; these results are consistent to those reported by Basrowi (2017).

Pod length, pod diameter, the content of chlorophyll a, chlorophyll b, total chlorophyll and carotenoids were highly correlated with the weight per pod. Pod with long and large size would have a greater weight per pod compared to short and small pods. Similar result was reported by Cahyaningrum et al. (2014) that pod weights were affected by pod length. The heavier pods also contain higher chlorophyll a, chlorophyll b, total chlorophyll and carotenoid. This result is inversely proportional to the character of the number of pods per plant which had a negative correlation to pod length, pod diameter, weight per pod, and level of chlorophyll a, chlorophyll b, total chlorophyll, and carotenoid. A larger number of pods per plant will have less weight of seeds per pod, smaller pod size and pod diameter, and a lower content of chlorophyll and carotenoids.

The pod length character does not correlate significantly with number of seeds per pod, but

Table 8. Correlation analysis between quantitative characters of 11 long bean genotypes

	SD	TSL	SSL	FT	HT	NPP	PW	PL
TL	-0.50^{nc}							
LL	-0.49^{nc}	0.87**						
FT	-0.09^{nc}	0.34^{nc}	0.29^{nc}					
HT	0.30^{nc}	-0.16^{nc}	-0.30^{nc}	0.73*				
NPP	0.77**	-0.59^{nc}	-0.60^{nc}	0.20^{nc}	0.31^{nc}			
PW	-0.88**	0.80**	0.74**	0.26^{nc}	-0.19^{nc}	-0.75**		
PL	-0.79**	0.57^{nc}	0.38^{nc}	0.49^{nc}	0.17^{nc}	-0.61*	0.83**	
PD	-0.61*	0.86**	0.93**	0.25^{nc}	-0.30^{nc}	-0.64*	0.85**	0.49^{nc}
NSP	0.45^{nc}	-0.21^{nc}	-0.44^{nc}	0.15^{nc}	0.27^{nc}	0.50^{nc}	-0.46^{nc}	-0.19^{nc}
CA	-0.79**	0.60*	0.66*	0.30^{nc}	-0.01^{nc}	-0.66*	0.88**	0.72*
CB	-0.78**	0.62*	0.66*	0.27^{nc}	-0.04^{nc}	-0.63*	0.89**	0.73*
AC	0.48^{nc}	0.01	0.24^{nc}	0.23^{nc}	0.20^{nc}	0.41^{nc}	-0.25^{nc}	-0.47^{nc}
CC	-0.77**	0.68*	0.69*	0.36^{nc}	0.02^{nc}	-0.67*	0.90**	0.75**
TC	-0.79**	0.61*	0.66*	0.29^{nc}	-0.02^{nc}	-0.65*	0.89**	0.72*
WPP	0.05^{nc}	-0.07^{nc}	-0.37^{nc}	0.26^{nc}	0.58^{nc}	0.34^{nc}	0.03^{nc}	0.44^{nc}
PRD	0.05 ^{nc}	-0.07^{nc}	-0.37^{nc}	0.26^{nc}	0.58^{nc}	0.34^{nc}	0.03^{nc}	0.44^{nc}

	PD	NSP	CA	CB	AC	CC	TC	WPP
NSP	-0.45^{nc}							
CA	0.75**	-0.66*						
CB	0.77**	-0.63*	0.99**					
AC	0.18^{nc}	0.05^{nc}	-0.10^{nc}	-0.08^{nc}				
CC	0.79**	-0.58^{nc}	0.98**	0.98**	-0.06^{nc}			
TC	0.76**	-0.65*	0.99**	0.99**	-0.09^{nc}	0.98**		
WPP	-0.29^{nc}	0.21^{nc}	0.02^{nc}	0.05^{nc}	-0.25^{nc}	0.05^{nc}	0.03^{nc}	
PRD	-0.29^{nc}	0.21^{nc}	0.02^{nc}	0.05^{nc}	-0.25^{nc}	0.05^{nc}	0.05^{nc}	1.00**

Notes: * = correlated at α = 5%; ** = highly correlated at α = 1%; nc = no at α = 5%; SD = stem diameter; TL = trifoliate length; LL = leaflet length; FT = flowering time; HT = harvesting time; NPP = number of pods per plant; PW = pod weight; PL = pod length; PD = pod diameter; NSP = number of seeds per pod; CA = chlorophyll a content; CB = chlorophyll b content; TC = total chlorophyll content; AC = anthocyanin content; CC = carotene content; WPP = weight of pod per plant; PRD = productivity.

correlated with chlorophyll and carotene content. The length of pods did not affect the number of seeds per pod. These results are different from Basrowi (2017) who reported that the length of pod affected the number of seeds per pod. The character of pod weight per plant correlated significantly (~100%) with productivity, as productivity values are the result of conversion from pod weight per plant.

The total chlorophyll content correlated significantly with chlorophyll a, chlorophyll b and the carotene content. According to Pradnyawan et al. (2015), chlorophyll a and chlorophyll b are parts of the chlorophyll which will affect the photosynthesis. The total chlorophyll content had no significant effect on anthocyanin content, whereas the anthocyanin content did not show any significant correlation with all characters. Pods with high total chlorophyll content will likely to have high content of chlorophyll a, chlorophyll b and carotene (Pradnyawan et al., 2015).

Cluster Analysis

Cluster analysis was used to determine grouping based on the closeness in the character or inter character relationships (Suketi et al., 2010). The distance between clusters shows the high order between clusters (Vailapalli et al., 2014). Figure 1 show the similarity based on 16 quantitative characters of long bean genotype which ranges from 67.54 to 95.60%. The highest similarity level was 95.60%. The highest similarity level of 95.60% was between “KP 13” and “F7-013014-4U-16-1-3”. According to Hadi et al. (2014), this high percentage indicates the similarities of a number of characters between the variables. This high similarity was possibly because the “KP 13” was one the “F7-013014-4U-16-1-3” parents. The difference in the character between the two genotypes was only on the number of seeds per pod, the content of chlorophyll a and b and total chlorophyll.

Based on the character correlation analysis (Table 8) “F7-013014-4U-16-1-3” and “KP Putih China” had a similarity of 92.37%. The similarities were based on pod diameter, time to flower and to harvest, trifoliate stalk length, single stalk length and pigment contents. The test genotype “F7-013014-4U-16-1-1” had a similarity of 91.79% with “Parade”, while “F7-013014-4U-16-1-2” and “F7-013014-7P-4-1-1” had similarity levels of 85.87% and 86.93%, respectively, with “Parade” (Figure 1).

Conclusion

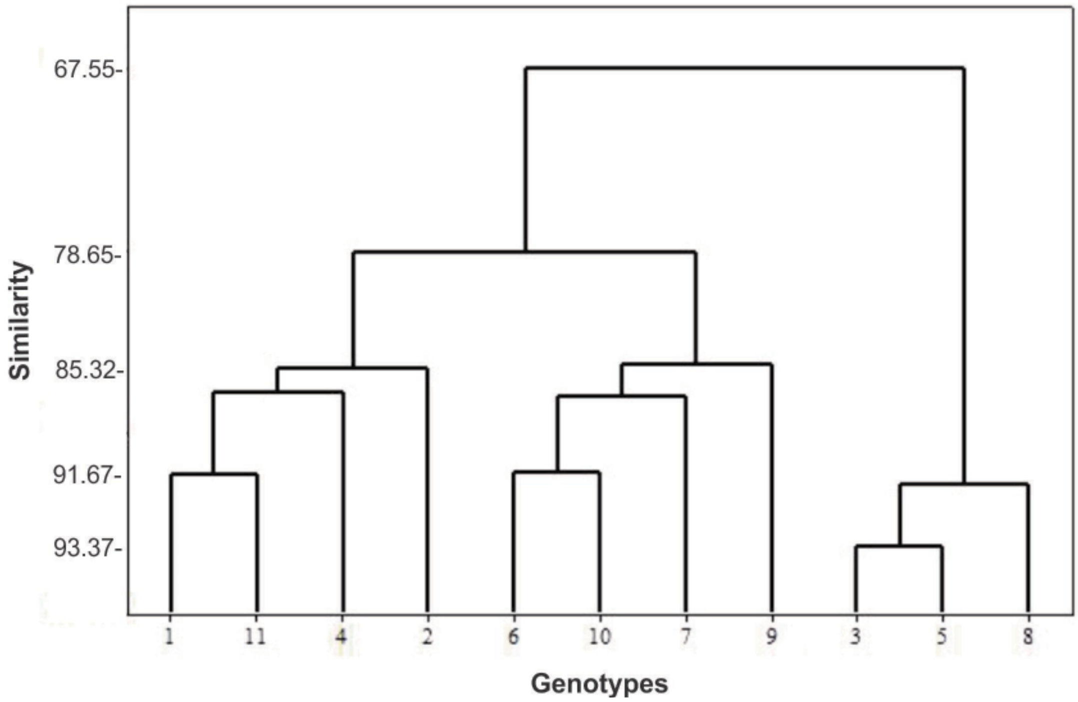

Figure 1. Dendogram of similarity based on quantitative characters of 11 long bean genotypes; 1=”F7-013014-4U-16-1-1”; 2=”“F7-013014-4U-16-1-2”; 3=“F7-013014-4U-16-1-3”; 4=“F7-013014-7P-4-1-1”; 5=“KP 13”; 6=“KP 14”; 7=“KP Putih China”; 8=”KP Putih Ungu”; 9=“Borneo”; 10=“Sabrina”; 11=“Parade”

The number of pods, pod weight and productivity of genotype "F7-013014-4U-16-1-1", "F7-013014-4U-16-1-2", "F7-013014-4U-16-1-3", and "F7-013014-7P-4-1-1" were comparable to the control genotypes and the parental genotypes. "F7-013014-4U-16-1-1", "F7-013014-4U-16-1-2", "F7-013014-4U-16-1-3" and "F7-013014-7P-4-1-1" have potentials to be released as new long bean superior varieties due to their earlier flowering and harvesting, longer leaves, higher pod weight, longer pods, larger pod diameter, higher seed content of anthocyanin, carotene, chlorophyll a, chlorophyll b and total chlorophyll. Genotype "F7-013014-4U-16-1-1" has high anthocyanin content. "F7-013014-7P-4-1-1" had the earliest time to flower and to harvest. "F7-013014-4U-16-1-1" has a high of pod weight per plant and productivity with higher chlorophyll content compared to the other green pod long beans.

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