



Yield and Quality of Two Varieties of Winged Bean (*Psophocarpus tetragonolobus* L.) with Different Harvest Ages of Young Pods

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Abstract. Winged bean is a tropical vegetable crop that has the potential to be developed as legumes. The age of harvest can determine the quality of the young pod of winged bean. This study aims to determine the yield and quality of two varieties of winged bean pods with different harvest ages. The experiment was carried out from September 2020 to February 2021 at IPB experimental field, Dramaga, Bogor. The experiment used a factorial completely randomized complete block design with three replications, namely two-winged bean varieties (Fairuz IPB and Sandi IPB) and harvest age (8, 10, 12, and 14 days after anthesis (DAA)). The results showed that the two varieties had different yield and quality of young pods. Fairuz had a higher number of flowers, the number of pods, total weight, and the productivity of young pods compared to Sandi. Young pods harvested at 8 DAA were the softest and had the lowest thickness, and had relatively young pod maturity, and can be recommended to harvest the young pod.

Keywords: Anthocyanin · Days after anthesis · Fairuz · Pod · Sandi

1 Introduction

Winged bean (*Psophocarpus tetragonolobus* L.) is one of the potential tropical vegetable crops in Indonesia [1]. Winged bean belongs to the family *Fabaceae* (beans) and has the potential to be developed as legumes, and this plant is also known as “supermarket on the stalk” [2]. In addition to stems and roots, almost all parts of the winged bean plant can be consumed, including young leaves, flowers, young pods, dried seeds, and tubers, and contain various nutrients such as protein, energy, carbohydrates, fat, fibre, ash and water [3, 4]. The protein content in each part of the plant that can be consumed is flowers 2.8–5.6 g; dry seeds 29.8–39 g [3], while winged young leaves and pods have protein of 6.14% and 2.69% [5], and winged tubers have protein of 17–19% with water content ranging from 2.80 to 7.81% [6]. This plant with good adaptation is estimated to be able to become a food substitute for soybeans because it can grow better than soybeans in the tropics, so the winged bean is known as “a possible soybean for the tropics” [2, 3].

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Seeing the potential of winged bean plants from their adaptability in the tropics can be an alternative plant and a good source of protein. In Indonesia, winged bean cultivation is traditionally carried out in the yard and used for household consumption [2], and the protein content can help the body resist the current Covid-19 condition. Therefore, plant breeding research has developed winged bean varieties that are adaptive in the local environment, early in age, and have high productivity [5]. The development of winged bean varieties can be directed to producing young pods and dry seeds [7]. The potential yield of winged bean pods ranges from 2.58 tons/ha to 8.94 tons/ha and is used as a vegetable [8]. The different winged bean varieties are used based on the colour of winged bean pods, namely green pods and purple pods.

The quality of pods is essential in a horticultural product, the quality of young winged bean pods determines the yield of good pods for consumption. The pods are harvested when they are young, soft, and green [9]. According to Bramastyo et al. [10] young pods that consumers want have a slightly sweet pod taste, crunchy pod hardness, and young pod maturity. To get good quality young pods obtained with the proper cultivation system, one of which harvest age. In addition to the high production and quality of winged beans, some characters need to be considered, one of which is the age of harvest. Young pods can be harvested as green vegetables at the first stage because they still contain many fibres, to produce soft seeds can be done in the second stage, or dry pods can be harvested for hard seeds [3]. Delay in harvesting can cause the pods to be hard and unfit for consumption [2]. Winged bean flowers appear periodically so that the harvest of young pods occurs continuously. A long harvest period is required to produce young pods due to market demand for fresh vegetables [7]. Therefore, this study aimed to determine the yield and quality of young winged pods with differences in harvest age.

2 Materials and Methods

2.1 Experiment Time and Place

The research was carried out from September 2020 to February 2021 at IPB experimental field at Leuwikopo Dramaga, Bogor, Indonesia. The experimental site is located at 220 m asl, with coordinates -6.563800 LS and 106.726083 BT. Observations were also carried out at the Postharvest Laboratory of the Department of Agronomy and Horticulture, IPB. The analysis of dietary fiber was carried out at the Bogor Agro-Industry Center.

2.2 Experimental Material

The material used in this study was winged bean seed with two varieties, namely Fairuz IPB with green pods and Sandi IPB with purple pods. Compound fertilizer NPK 15-15-15 was used in the experiment.

2.3 Procedure

The study used a factorial completely randomized complete block design (RCBD) with three replications. The first treatment was Fairuz IPB and Sandi IPB. The second treatment was harvest age consisted of 8, 10, 12, 14 days after anthesis (DAA). The seeds

were soaked in warm water for one day, then sown using a nursery tray for 14 days. The plot size was 5 m × 1 m. There were 24 plots. The seedlings with two full leaves were transplanted into plot with planting distance of 50 cm × 30 cm. Plots have been added with 25 kg cow manure/plots. Each plant was supported by the 2-m stake; four stakes were tied together. Additional fertilization was carried out once a week with NPK with a concentration of 10 g/L was as much as 250 mL/plant. Pests and plant diseases were controlled manually and chemically with insecticides (Siamethrin 2 mL/24 L water), (Decis 4 mL/24 L water) and fungicides (Dithane 4 g/24 L water). Harvesting of young pods was carried out according to the treatment of harvest age, namely 8, 10, 12, and 14 DAA regularly.

The variables observed were on yield and quality of young pods during 18 weeks of production. Although it can be harvested for a long time but in this study, it was limited because the plant was attacked by false rust disease. Yield variables were 1) number of flowers per plant, 2) number of young pods per plant, 3) percentage of fruit set, 4) pod weight per plant, 5) total pod weight per plot, and 6) pod yield. Variables of quality of young pods were 1) pod colour, 2) pod wing colour, 3) pod length, 4) pod width, 5) pod moisture content, 6) pod softness, 7) pod thickness, 8) pigment analysis, and 9) food fiber content.

2.4 Data Analysis

Data were analyzed by using analysis of variance (ANOVA), using Rstudio 4.0.3 software. If the treatment has a significant effect, continue with the Duncan multiple range test (DMRT) at a level of 5%.

3 Results and Discussion

The climate data during the experiment were average temperatures 25.71 °C with average humidity 83.50%, average solar radiation intensity 359.48 cal cm² with average irradiation time 43.28%, and average rainfall 2060.20 mm for six months and an average rainfall per year. The moon ranges from 343.3 mm with a maximum wind speed of 4.60 m/s and an average wind speed of 1.58 m/s.

3.1 Young Pods Production

The yield of young winged pods differed between varieties except for the fruit set variable (Table 1). Fairuz had a higher value than Sandi. The flower number and pod numbers of Fairuz was 50.89%, and 51.59% higher than those of Sandi respectively. However, the formation of flowers into fruit or fruit sets of Sandi was higher than of Fairuz. It is also possible that environmental factors cause the occurrence of flower loss. According to previous studies [11], climatic stress and internal limitations from lack of pollination, adverse hormonal levels, or competition for carbohydrates and nutrients can cause fruit set failure (physiological decline).

Total pod weight per plot of Fairuz was 57.20% higher, and the pod yield of Fairuz was 57.20% higher than Sandi. Lower pod weight per plot and pod productivity of Sandi

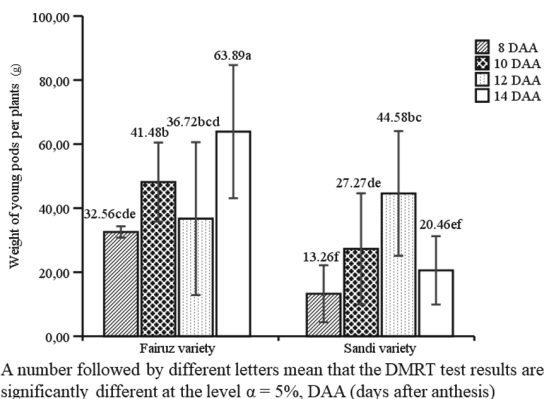


Fig. 1. Effect of interaction between varieties and harvest age on the weight of young pods per plant.

than Fairuz was due to the lower number of surviving plants. The Sandi variety results from plant breeding introduced from Thailand, so the ability of Sandi to grow varieties is not yet adaptive enough in the Indonesian agro-climate [5]. The significant interaction between two factors on weight of young pods per plant showed that the highest value was found of Fairuz harvested at 14 DAA (Fig. 1).

Harvest age did not affect the number of flowers, pods, and fruit sets (Table 1). The average number of flowers at 8 DAA was higher than at other harvest ages because pod harvest will trigger the formation of the new flower. When young pods are harvested later, it will affect source and sink relationship. Strong sinks are in seeds, fruit, and young leaves, if the sinks are much more robust, the assimilate will be transferred to the seeds to inhibit the formation of new flowers [12]. The sink organ can take up assimilation, which is influenced by the activity and size of the sink [13]. The number of pods at 14 DAA had a higher number of pods, and this was because, at other harvest ages, not all flowers managed to become pods. Flowers will fall out during high winds so that the formation of pods from flowers fails [14].

The delay in harvesting age affected the total pod weight and pod productivity (Table 1). It is because the longer the harvest, the younger pods will be bigger, longer, and heavier, which will affect the pods' weight and the young pods' productivity. The length of the pod affects the weight of the pod (g/pod). The winged with the shortest pod has the lowest pod weight, while the winged with the most extended pod has the highest [15].

3.2 Young Pods Quality

The results showed that the crown colour of the winged flower in the Fairuz variety had a purplish-blue colour while the wing crown of the Sandi variety was purple (Fig. 2). The results of previous studies stated that the winged has the primary colour of purple and blue-purple flower crowns [7].

Fairuz and Sandi varieties are the results of plant breeding. Fairuz has green pods and wings, while Sandi has purple pods, especially on the wing pods. There is a match between the purple or reddish-purple flower crown with the purple colour on the wings

Table 1. The average value of crop yield in two-winged bean varieties and harvest age

Treatment	Number of flowers	Number of pods	Fruit set (%)	Total pod weight per plot (g/plot)	Productivity of pods (kg/ha)
Varieties					
Fairuz (green pods)	8.9 ^a ± 0.6	3.7 ^a ± 0.2	44.54 ± 4.43	841.76 ^a ± 123.40	1683.53 ^a ± 246.81
Sandi (purple pods)	4.3 ^b ± 0.5	1.8 ^b ± 0.3	47.50 ± 11.27	360.26 ^b ± 66.98	720.52 ^b ± 133.97
Harvest age (DAA)					
8	7.8 ± 1.0	2.6 ± 0.6	38.38 ± 6.71	396.24 ^d ± 80.99	792.49 ^d ± 161.99
10	6.7 ± 0.8	2.8 ± 0.5	50.48 ± 4.77	463.46 ^c ± 63.46	926.92 ^c ± 126.93
12	6.7 ± 1.3	2.4 ± 0.3	36.31 ± 9.71	742.07 ^b ± 197.28	1484.15 ^b ± 394.56
14	5.3 ± 1.7	3.2 ± 0.6	58.91 ± 20.25	802.27 ^a ± 243.65	1604.54 ^a ± 487.30

A number followed by different letters in the same column means that the DMRT test results are significantly different at the level $\alpha = 5\%$, the mean is followed by the standard error (SE), DAA (days after anthesis).



Fig. 2. The colour and shape of the flowers of both varieties. (A) flowers of Fairuz variety, (B) flowers of Sandi variety.

of the pods, and there are anthocyanins in the pods with weak to moderate intensity [15]. The purple colour of the pods and wings of the pods has high antioxidant activity [16]. Sandi at harvest age of 8 DAA has green pods and purple wings, but the longer it is harvested, the green colour will fade, and the purple colour will be darker. The colour of the pods and wings of the pod is shown in (Fig. 3).

Differences in winged bean varieties and harvest age had a significant effect on the length of young pods. Sandi has the most extended pods compared to Fairuz. Delaying harvest age by 2 days (8 to 10 days) caused pods lengths increased by 2 cm, while delaying harvest age by 6 days (8 to 14 days) caused winged bean pods length increased by 4 cm (Table 2).

In this study, the variables of pod width, pod moisture content, and pod thickness did not differ between varieties, but the age at harvest treatment affected the thickness of young pods. The thickness of the young pods was measured in three parts, namely the tip, middle, and base of the pod. The longer the young pods are harvested, the higher

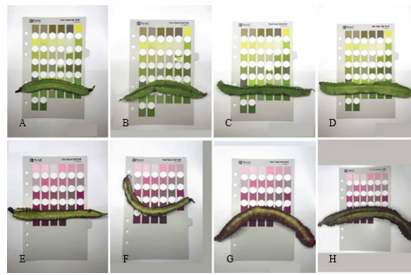


Fig. 3. Color of young pods and wings. (A) Fairuz variety 8 DAA, (B) Fairuz variety 10 DAA, (C) Fairuz variety 12 DAA, (D) Fairuz variety 14 DAA, (E) Sandi variety 8 DAA, (F) Sandi variety 10 DAA, (G) Sandi variety 12 DAA, (H) Sandi variety 14 DAA.

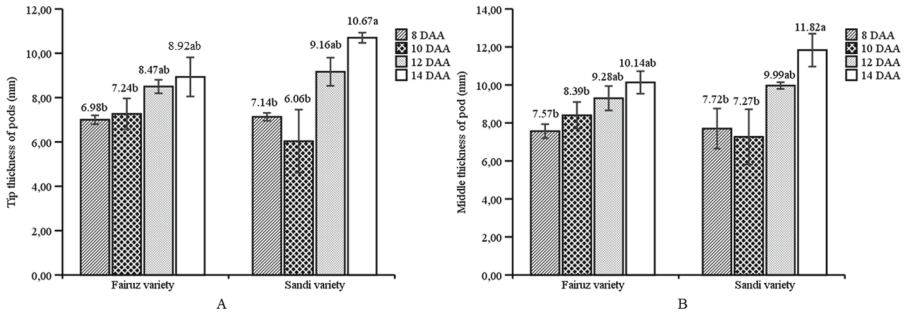
Table 2. The average value of plant quality in two-winged bean varieties and harvest age

Treatment	Pod length (cm)	Width of pods (cm)			Pod water content (%)	The thickness of the base of the pods (mm)
		Tip	Middle	Base		
Varieties						
Fairuz (green pods)	16.36 ^b ± 0.27	1.75 ± 0.04	1.97 ± 0.05	1.78 ± 0.05	91.96 ± 0.20	8.41 ± 0.25
Sandi (purple pods)	19.08 ^a ± 0.86	1.80 ± 0.15	2.16 ± 0.11	2.04 ± 0.13	91.21 ± 0.47	8.67 ± 0.57
Harvest age (DAA)						
8	15.63 ^b ± 0.79	1.72 ± 0.09	1.89 ± 0.08	1.79 ± 0.13	91.43 ± 0.49	7.41 ^b ± 0.21
10	17.44 ^{ab} ± 0.99	1.64 ± 0.13	2.07 ± 0.05	1.96 ± 0.11	91.54 ± 0.74	7.44 ^b ± 0.48
12	18.44 ^a ± 1.00	1.71 ± 0.13	1.04 ± 0.05	1.84 ± 0.06	91.70 ± 0.65	9.26 ^a ± 0.24
14	19.38 ^a ± 0.96	2.03 ± 0.22	2.25 ± 0.22	2.06 ± 0.23	91.67 ± 0.16	10.06 ^a ± 0.57

A number followed by different letters in the same column means that the DMRT test results are significantly different at the level $\alpha = 5\%$, the mean is followed by the standard error (SE), DAA (days after anthesis).

the thickness of the base of the young pods. Fruit thickness increases with increasing harvest age [17]. The interaction between variety and harvest age significantly affected young pods' tip and middle thickness (Fig. 4).

An increase in fruit thickness will make the pods less crunchy and undesirable. Changes in the size of the larger fruit associated with the delay in harvest age cause a decrease in fruit tenderness. In this study, fruit tenderness was measured in three parts: the pod's tip, middle, and base. Varieties treatment and harvest age affect the softness of the fruit (Table 3). It is possible because the older the pods, the more pod fibres will form. The loss of fruit tenderness leads to a consequence of increased fibre content [18].



A number followed by different letters mean that the DMRT test results are significantly different at the level $\alpha = 5\%$, DAA (days after anthesis)

Fig. 4. Interaction of two winged bean varieties and harvest age. (A) the thickness of the tip of the young pods, (B) the thickness of the middle of the young pods.

Table 3. Effect of harvest age on the tenderness of young pods in two-winged bean varieties

Treatment	Softened pods (mm/g/5s)		
	Tip	Middle	Base
Varieties			
Fairuz (green pods)	27.00 ^b ± 0.93	25.02 ^b ± 0.92	24.19 ^b ± 1.06
Sandi (purple pods)	29.93 ^a ± 1.50	29.17 ^a ± 1.58	27.17 ^a ± 1.75
Harvest age (DAA)			
8	33.30 ^a ± 1.20	32.07 ^a ± 1.54	32.41 ^a ± 1.32
10	30.71 ^b ± 1.42	28.67 ^b ± 1.89	26.49 ^b ± 1.43
12	25.89 ^c ± 0.79	24.71 ^c ± 0.89	22.21 ^c ± 0.74
14	23.97 ^c ± 0.64	22.94 ^c ± 1.19	21.63 ^c ± 1.04

A number followed by different letters in the same column means that the DMRT test results are significantly different at the level $\alpha = 5\%$, the mean is followed by the standard error (SE), DAA (days after anthesis).

The softness of the pods between the tip, middle, and base had the same decrease. At harvest age 8 DAA had softer pods, while at harvest age 14 DAA had more rigid pods.

The chlorophyll content and carotenoid content in young pods did not show differences between varieties but showed differences in anthocyanin levels (Table 4). Young pods in Sandi have higher anthocyanin levels than Fairuz, possible because Sandi which is a winged bean with purple pods, contains anthocyanin levels. Anthocyanin pigments are commonly found in purple, red, or blue fruits and vegetables [19, 20]. Anthocyanins are also a class of flavonoid derivatives that function as antioxidants and antimicrobials [21]. The benefits of anthocyanins are free radical scavengers and can prevent diabetes [22]. The treatment of harvest age in this study did not show a significant difference in total dietary fiber.

Table 4. Pigment content in two-winged bean varieties and harvest age

Treatment	Pod pigment content (mg/g)					Total dietary fiber (%) (TDF)*	
	Chlorophyll A	Chlorophyll B	Total chlorophyll	Anthocyanin	Carotenoids	Fairuz	Sandi
Varieties							
Fairuz (green pods)	0.24 ± 0.01	0.10 ± 0.005	0.34 ± 0.01	0.01 ^b ± 0.001	0.08 ± 0.005	–	–
Sandi (purple pods)	0.21 ± 0.01	0.09 ± 0.006	0.31 ± 0.02	0.03 ^a ± 0.002	0.09 ± 0.005	–	–
Harvest age (DAA)							
8	0.21 ± 0.01	0.09 ± 0.007	0.31 ± 0.02	0.02 ± 0.003	0.07 ± 0.006	4.50	4.71
10	0.22 ± 0.02	0.09 ± 0.011	0.32 ± 0.03	0.02 ± 0.002	0.08 ± 0.012	4.03	5.99
12	0.21 ± 0.01	0.09 ± 0.003	0.31 ± 0.01	0.02 ± 0.007	0.09 ± 0.005	5.04	4.62
14	0.26 ± 0.01	0.11 ± 0.007	0.38 ± 0.02	0.02 ± 0.004	0.10 ± 0.006	4.58	4.70

Numbers of anthocyanin content followed by different letters in the same column mean significantly different, DAA (days after anthesis), *TDF: not statistically analyzed.

4 Conclusion

Fairuz has high yields on yield variables such as the number of flowers, number of pods, the total weight of young pods per plot, and productivity of young pods. Sandi had a high value on quality variables such as pod length, pod thickness, pod softness, and high anthocyanin content. The harvest age of 8 days has the highest yield on the number of flowers, pod tenderness but has a smaller pod size than other harvest ages. Harvest age of 8 DAA has lower pod thickness, which means that the seeds have not yet entered the mature phase and are more crunchy. The interaction between the two winged bean varieties with harvest age was found in the weight of young pods per plant and the thickness of the tips and middle of young pods.

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