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Agro-morphological traits and harvest period assessment of winged bean (*Psophocarpus tetragonolobus*) genotypes for pods production

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Abstract. *Ishthifaiyyah SA, Syukur M, Trikoesoemaningtyas, Maharijaya A. 2021. Agro-morphological traits and harvest period assessment of winged bean* (Psophocarpus tetragonolobus) *genotypes for pods production. Biodiversitas 22: 1069-1075.* Winged bean (*Psophocarpus tetragonolobus*) is an underutilized crop in Indonesia. Winged bean varieties for pods productions not only must have high productivity and nutrient contents, but also have a long harvest period. This research aimed to evaluate agro-morphological traits and harvest period of eighth generation winged bean genotypes. Twenty genotypes of winged bean were evaluated using randomized complete block design (RCB) with three replications in Bogor, Indonesia. Several qualitative and quantitative traits were evaluated from each genotype. The results showed that there were variations among winged bean genotypes which were based on qualitative traits as well as the color of stem, calyx, corolla, pod, and pod wings. Purple coloration in the calyx of P1 and H3U genotypes was known to correspond with the purple color in stem, corolla, pod, and pod wings. The highest yield among F8 genotypes was found in H2 (6.69 to ha^{-1}), similar to P2. However, the longest harvest period among F8 genotypes was found in H1U-2 (78 days). This study revealed that harvest period had positive correlation with the leaflet size. Based on nutrient content, H3U and L2 were considered as the genotypes with the highest protein and fiber content respectively among F8 genotypes.

Keywords: Nutrient content, qualitative, quantitative, vegetable, yield

INTRODUCTION

Winged bean (*Psophocarpus tetragonolobus*) belongs to the Fabaceae or Leguminosae family which is widely dispersed in Indonesia. It is recognized as "supermarket on the stalk" because almost all parts of the plant can be exploited, such as pods, young leaves, flowers, dry seeds, and tuber (National Reasearch Council 1981). They contain many nutrients as well as protein, carbohydrate, fat, and fiber. Protein content of the pods is approximately 2.69%, while the young leaves and tubers respectively contain 6.14% and 2.80% protein (Laia 2019; Adegboyega et al. 2019). However, winged bean seed contains 33% protein, 22% carbohydrate, and 17.5% fat (Amoo et al. 2006). Among other legumes, winged bean seed is the most similar to soybean based on its nutrient content and seed morphology (Rif'atunidaudina 2018). Moreover, winged bean can grow better than soybean in Indonesia which has a wet tropical climate, so it is also called as "possible soybean for the tropics" (National Reasearch Council 1981; Eagleton 2019).

Despite its potential, winged bean is still underutilized and almost forgotten. It is traditionally cultivated in the backyard, so its utilization is limited to household consumption (Handayani 2013). Although there are many local winged bean accessions with agro-morphological variations in Indonesia, none have been released by Indonesian ministry of agriculture and disseminated as commercial varieties (Hidayat and Handayani 2009).

The development of winged bean can be directed to create varieties for seed or pod production. Beside yield parameter, there are some other requirements which must be considered in the breeding program to create varieties. Winged bean has indeterminate growth with several lateral branches (Tanzi et al. 2019a). This type of growth leads to continuous flower formation throughout its life cycle. For seed production, synchronous harvest is one of the most important criteria because asynchronous harvest can improve production input and post-harvest cost (Marwiyah et al 2020). On the other hand, asynchronous harvest is needed for pod production varieties due to continuous market demand for the fresh vegetable. Therefore, harvest period becomes an essential criteria that should be applied in selecting winged bean genotypes.

Plant breeding program begins with the establishment of a diverse population through exploration and introduction to collect desirable genes. Hybridization and mutation can be carried out to improve population diversity. A basic population with high diversity is useful for increasing selection effectiveness. The next steps in a plant breeding program are characterization, selection, and evaluation (Syukur et al. 2015). This study aimed to evaluate agro-morphological traits and harvest period in winged bean genotypes as a consideration in selecting the best genotype for pod production purposes.

MATERIALS AND METHODS

Study area and plant materials

The experiment was conducted in Leuwikopo experimental field, IPB University, Bogor, Indonesia between April and October 2020. The field site was located at an altitude 250 m asl, at latitude -6.563800S and longitude 106.726083E. Proximate analysis was carried out by technical staff in university center (Pusat Antar Universitas) laboratory, IPB University. Twenty genotypes used for this experiment consist of fifteen genotypes of F8 (eighth generation), two pure line parents, and three genotypes of local commercialized green winged bean as control (Table 1). Those F8 genotypes were generated from a bi-parental cross between purple winged bean from Thailand and green winged bean from Cilacap, Indonesia. The first parent is characterized by its purple pod and wing. It also has purple stem, calyx, and corolla. Otherwise the second parent has green pod and wing. Its stem and calyx are also green, while the corolla basic color is blue. The F1 plants were allowed to self-pollinate. Pedigree selection was conducted in F2 population, followed by self-pollination until F8.

Procedure

The experiment was arranged in a completely randomized complete block design (RCB) with three replications. Clusters of 20 plants were grown directly in a 4 m^2 mulch plot with plant spacing 40 cm x 50 cm. Each plant was supported by a 2 m bamboo pole and every four bamboos were tied up at the top. Two weeks before planting, the soil was treated with 20 tons ha^{-1} manure. The first fertilization was applied on the day of planting, using 50 kg ha^{-1} urea, 75 kg ha^{-1} SP-36, and 150 kg ha^{-1} KCl. The succeeding fertilizations were carried out once a week using 10 g L^{-1} NPK 16-16-16 with the dosage; 250 mL per-plant. Pest and plant diseases were controlled mechanically and chemically using insecticide (Deltametrin, 2 mL L^{-1}) and fungicide (Mankozeb 2g L^{-1}) when symptoms appeared. The pods were harvested 10-14 days after anthesis until 198 days after planting (DAP).

In order to characterize winged bean genotypes, several qualitative and quantitative traits were evaluated based on the guidance from International Board for Plant Genetic Resource (IBPGR 1982) and Technical Guide for winged bean BUSS test (PVTPP 2014). The observed qualitative traits were: (i) leaflet shape; (ii) stem color; (iii) calyx color; (iv) corolla color; (v) pod color; (vi) pod wings color; and (vii) pod shape in cross section. For color observation, RHS Color Chart was used to distinguish colors in detail. The recorded quantitative traits were: (i) leaflet length; (ii) leaflet width; (iii) stem diameter; (iv) internode length; (v) pod length; (vi) pod width; (vii) pod weight per-plot; (viii) pod weight per-plant; (ix) pod number per-plot; (x) pod number per-plant; (xi) pod productivity (ton ha^{-1}); and (xii) harvest period. The size of leaflet was observed on the terminal leaflet at the 15th node. The stem diameter was also recorded at the 15th node. The size of pod was measured from ten pods per-plot. The pod weight per-plot and pod number per-plot was calculated from the pods produced in each plot until 198 DAP. The data was then divided by the number of plants harvested in each plot to obtain pod weight per-plant and pod number per-plant. Pods productivity (pod yield) was calculated as below.

$$Pod\ yield\ (ton\ ha^{-1}) = \frac{10{,}000m^2}{plot\ length\ (m)} x \frac{plot\ width\ (m)}{plot\ width + plot\ spacing\ (m)} x \frac{pod\ weight\ per\ plot\ (g\ m^{-2})}{1{,}000{,}000}$$

The internode length was observed as the mean of the 6th, 10th, and 15th internode (Tanzi et al. 2019b), while the harvest period was recorded between the first and the last harvest time of pods. The harvest period was then classified according to Marwiyah et al. (2020) as below.

$$\Delta P = \frac{1}{n}(b - a),$$

Where:
ΔP: the change of harvest period,
n: number of classification class,
a: minimum harvest period,
b: maximum harvest period.

Harvest period classification class:
$x < \Delta P$: short
$\Delta P + a < x < (\Delta P + a) + \Delta P$: medium
$x > (\Delta P + a) + \Delta P$: long,
Where; x is the mean of harvest period for each genotype

Proximate analysis was also carried out using standard method (AOAC 2005) to measure water content, ash, fat, protein, and fiber percentage in pods. The sample used for this analysis was 100 g pods.

Table 1. Winged bean genotypes used for this study

Genotypes code	Note
L1	Selected (F8)
L2	Selected (F8)
L3	Selected (F8)
L4	Selected (F8)
H1U	Selected (F8)
H1P-19(3)	Selected (F8)
H1P-20(3)	Selected (F8)
H2	Selected (F8)
H3U	Selected (F8)
H4P	Selected (F8)
L1-2	Selected (F8)
L2-2	Selected (F8)
HIP-2	Selected (F8)
HIU-2	Selected (F8)
H4P-2	Selected (F8)
P1	Female parent (introduced purple winged bean from Thailand)
P2	Male parent (local green winged bean from Cilacap, Indonesia)
KH1	Local green winged bean
KH2	Local green winged bean
KH3	Local green winged bean

Data analysis

The qualitative data was analyzed descriptively. For quantitative traits, analysis of variance (ANOVA) was performed using SAS 9.0 software, followed by Duncan Multiple Range Test (DMRT). Pearson coefficient correlation was also calculated by SAS 9.0 software between quantitative traits.

RESULTS AND DISCUSSION

Qualitative traits

Qualitative observation for leaflet and pod shape in cross section showed similarity among genotypes. All of the genotypes had deltoid leaflet and rectangular pod shape. Based on RHS Color Chart, the stem color was commonly grouped into two classes i.e. greyish purple and yellowish green, but some plants showed reddish purple stem (Figure 1). However, the calyx color was greyish purple, yellowish green, and green with moderate anthocyanin color (Figure 2). The winged bean genotypes had purple and purplish blue corolla base-color. But in some genotypes with predominantly purplish blue corolla, there were some plants that had brighter blue corolla grading into white (Figure 3).

Furthermore, the winged bean pods had three basic colors i.e. purple, green, and yellowish green. The purple pod also had purple wings, while the green and yellowish green pods had varied colors of wings namely green, grey, and purple (Figure 4). Purple color in winged bean pod and wings showed its high antioxidant capacity as reported by Calvindi et al. (2020). In this study, some genotypes showed correspondence between purple coloration in calyx with pigmentation in stem, corolla, pod, and wings. The genotypes that had purple calyces as well as H3U and P1 also showed purple stem, corolla, pod, and wings consistently. Otherwise the genotypes that had green calyces commonly had green stem, blue corolla-base color, and green pod with green wings as shown by H1P-19(3), H2, and local genotypes (P2, KH1, KH3). This evidence was also shown in the previous studies conducted by Thompson and Haryono (1980), and Yulianah et al. (2020). Erskine and Khan (1977) reported linkage between stem and calyx color, and also between pod and wing color. They found that the color of stem, calyx, pod wings, and pod specks was controlled by individual gene with complete dominance of purple over green color. A single gene also controlled pod shape as seen in cross section with complete dominance of rectangular over flat pod shape. Yulianah et al. (2020) highlighted that the phenotypic expression of a simple inherited trait depends on the genetic background within the particular population in which the trait is observed. Among those characters, stem color can be used as genetic marker in selecting winged bean genotypes because it is inherited and able to be observed at the early stage of plant growth.

Quantitative traits

Analysis of variance showed that there were significant differences ($P<0.05$) among genotypes on all recorded quantitative traits except pods width with coefficient of variation between 4.82% - 41.17% (data not shown). The mean value of vegetative traits in 20 winged bean genotypes are presented in Table 2. The leaflet length varied from 7.27 cm – 10.73 cm, while the width varied from 5.68 cm – 8.01 cm. On both characters, L4 had the highest mean value, but was not significantly different from some other genotypes. Correlation analysis on both characters using Pearson method revealed that those characters were strongly correlated with coefficient correlation up to 92.94%.

The stem diameter of 20 winged bean genotypes varied from 3.07 mm – 3.95 mm with maximum value recorded in L2-2 genotypes. On the other hand, the internode length ranged between 6.74 cm and 8.64 cm. For pod size, the pod length of winged bean varied from 13.39 cm – 20.22 cm, while the pod width ranged between 1.94 cm and 2.49 cm. In previous studies, evaluation on some winged bean accessions showed that the pod length varied from 13.70 cm – 38.40 cm with the pod width between 0.82 cm and 2.90 cm.

A B C

Figure 1. Stem color of winged bean genotypes. A. Reddish purple, B. Greyish purple, C. Yellowish green

Based on the pod length, winged bean genotypes in this study belong to pod classification as being moderate pods in size except for accessions KH2 and KH3 (Yulianah et al. 2020; Sari et al. 2018; Sukma et al. 2017). Yulianah et al. (2020) also reported that the pod length could affect pod weight (g per-pod), where the genotype with shorter pods produced lower pod weight, otherwise the genotype with the longest pod produced the highest pod weight. The evidence also related with the high number of seed per pod.

A B C

Figure 2. Calyx color of winged bean genotypes. A. Greyish purple, B. Yellowish green, C. Green with moderate anthocyanin

A B C D

Figure 3. Corolla color of winged bean genotypes. A. Purple, B. Purplish blue, C. Blue, d. White

A B C D E

Figure 4. Variation of pod and pod wings color of winged bean genotypes. A. Purple pod and wings, B. Green pod and wings, C. Yellowish green pod and wings, D. Green pod with grey wings, E. Yellowish green pod with purple wings

Table 2. Mean value of six quantitative traits in 20 winged bean genotypes

Genotypes code	LL (cm)	LW (cm)	SD (mm)	IL (cm)	PL (cm)	PW (cm)
L1	9.68bc	7.21bc	3.40a-d	6.74d	15.79b-d	2.12ab
L2	9.33c	7.13b-d	3.74a-c	7.79a-c	18.77ab	**2.49a**
L3	9.64bc	7.68a-c	3.94a	7.60b-d	18.95ab	2.32ab
L4	**10.73a**	**8.01a**	3.44a-d	6.81d	17.79a-c	2.22ab
H1U	9.67bc	7.46a-c	3.64a-c	8.15a-c	18.54ab	2.44a
H1P-19(3)	10.65a	7.82ab	3.91a	7.96a-c	16.18b-d	2.15ab
H1P-20(3)	9.65bc	7.56a-c	3.72a-c	7.83a-c	17.94a-c	2.42a
H2	9.12c	7.26a-c	3.60a-d	7.22cd	17.26a-c	2.33ab
H3U	10.41ab	7.90ab	3.20cd	7.60b-d	**20.22a**	2.31ab
H4P	9.49c	7.45a-c	3.53a-d	7.48b-d	18.40ab	2.26ab
L1-2	9.54bc	7.27a-c	3.60a-d	7.25cd	18.09ab	2.09ab
L2-2	9.61bc	7.22bc	**3.95a**	7.22cd	16.92bc	2.36ab
HIP-2	9.61bc	7.35a-c	3.51a-d	7.76a-c	18.83ab	2.31ab
HIU-2	9.72bc	7.24a-c	3.81ab	**8.64a**	19.00ab	2.42a
H4P-2	9.85bc	7.51a-c	3.67a-c	7.56b-d	18.09ab	2.38ab
P1	9.25c	7.01cd	3.07d	7.82a-c	17.80a-c	1.94b
P2	7.89d	6.46de	3.85a	8.53a	18.54ab	2.44a
KH1	7.89d	5.68f	3.30b-d	7.57b-d	18.72ab	2.17ab
KH2	7.27d	5.78ef	3.45a-d	8.23ab	13.39d	2.08ab
KH3	7.97d	6.44de	3.75a-c	8.53a	14.84cd	2.32ab

Note: LL, leaflet length; LW, leaflet width; SD, stem diameter; IL, internode length; PL, pods length; PW, pods width. Values in each column followed by the same letters do not differ significantly ($P<0.05$).

Table 3. Mean value of agronomy traits in 20 winged bean genotypes

Genotypes code	NP	NPT	WP (g)	WPT (g)	YP (ton ha^{-1})
L1	16.00f	2.31g	172.40e	24.00e	0.57e
L2	108.67a-d	12.93b	1569.60a-c	192.76b	5.23a-c
L3	90.67b-d	8.38b-g	1253.40-c	115.63b-e	4.17bc
L4	55.00c-f	5.95c-g	777.50c-e	86.21c-e	2.59c-e
H1U	89.00bcd	9.29b-f	1219.40b-d	130.13b-d	4.06b-d
H1P-19(3)	42.00def	**19.44a**	633.00c-e	**290.27a**	2.11c-e
H1P-20(3)	51.67c-f	4.60d-g	693.40c-e	61.83c-e	2.31c-e
H2	**160.00a**	11.78bc	**2007.50ab**	146.96bc	**6.69ab**
H3U	20.33ef	4.45e-g	315.40de	67.86c-e	1.05de
H4P	105.00a-d	8.78b-g	1362.00a-c	113.96b-e	4.54a-c
L1-2	102.67a-d	10.81b-e	1337.10a-c	140.48b-d	4.45a-c
L2-2	96.67a-d	8.77b-g	1216.80b-d	110.69b-e	4.05b-d
HIP-2	72.33c-f	11.96bc	932.00c-e	153.22bc	3.10c-e
HIU-2	85.67c-e	11.00b-e	1179.80b-d	151.37bc	3.93b-d
H4P-2	86.33c-e	11.75bc	1068.60c-e	145.65bc	3.56c-e
P1	16.00f	3.50fg	193.50e	42.33de	0.64e
P2	154.67ab	13.47b	**2192.10a**	190.72b	**7.30a**
KH1	112.67a-c	11.61bc	1384.80a-c	142.17b-d	4.61a-c
KH2	69.67c-f	8.33b-g	671.80c-e	80.25c-e	2.23c-e
KH3	76.00c-f	11.33b-d	775.40c-e	116.88b-e	2.58c-e

Note: NP, number of pod per-plot; NPT, number of pod per-plant; WP, pod weight per-plot; WPT, pod weight per-plant; YP, yield (pod productivity). Values in each column followed by the same letters do not differ significantly ($P<0.05$).

The maximum mean of pod number per-plot in this study was found in H2. Meanwhile, the maximum mean of pod weight per-plot was P2, but it was not significantly different from H2. On the other hand, the highest number of pods per-plant was found in H1P-19(3), likewise the pod weight per-plant. Based on the pod weight per-plot, the expected yield of pod in winged bean genotypes in this study ranged between 0.57 ton ha^{-1} and 7.30 ton ha^{-1}. P2 had the highest yield, but it didn't differ significantly from H2. According to the previous studies, yield in winged bean was affected by the number of pods and harvest period where the increase in both characters would increase the yield of pods (Mohamadali et al. 2004; Handayani et al. 2015). In this study, H2 was the best genotype that had the highest yield of pods among F8 genotypes.

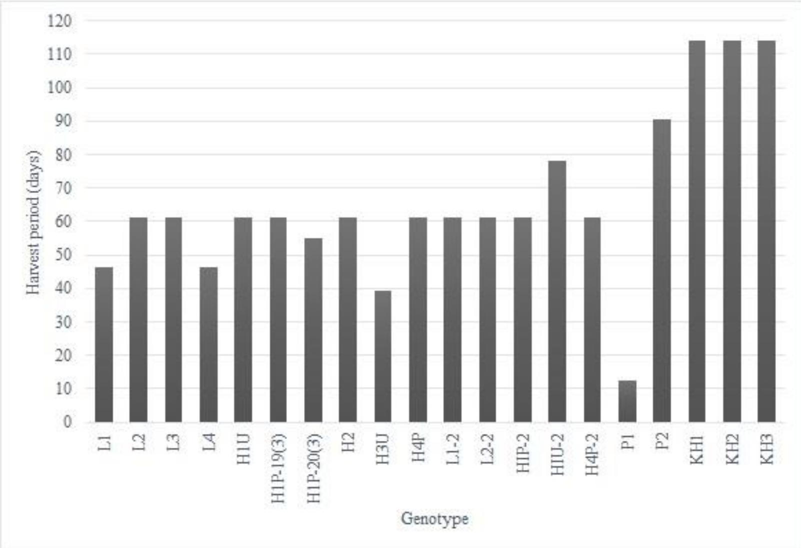

Figure 5. Harvest period mean of 20 winged bean genotypes

Table 4. Percentage of proximate analysis component in 20 winged bean genotypes

Genotypes code	Water content (%)	Ash (%)	Fat (%)	Protein (%)	Fiber (%)
L1	90.10i	0.64ef	**0.23a**	2.36d	1.52bc
L2	90.72h	0.65de	0.12de	2.30ef	**2.06a**
L3	91.32e	0.56j	0.11d-g	2.31d-f	1.31d-f
L4	90.97g	0.59hi	0.09e-i	2.08i	1.14g-i
H1U	**92.04b**	0.60gh	0.19b	2.09i	1.23d-h
H1P-19(3)	91.96bc	0.60gh	0.09f-i	2.00j	1.32d-f
H1P-20(3)	88.90k	0.71c	0.16c	2.34de	1.60b
H2	91.92c	0.61gh	0.13cd	2.01j	1.18f-i
H3U	89.63j	**0.78b**	0.16c	**2.57b**	1.17f-i
H4P	90.96g	0.76b	0.05jk	2.49c	1.48bc
L1-2	90.96g	0.62fg	0.08d-i	2.15h	1.38cd
L2-2	89.64j	0.59hi	0.10d-i	2.28f	1.50bc
HIP-2	91.20f	0.67d	0.11d-h	2.16h	1.34de
HIU-2	91.90c	0.67d	0.12d-f	2.22g	1.05i
H4P-2	91.68d	0.62e-g	0.02k	2.17gh	1.27d-g
P1	88.33l	**0.94a**	0.13cd	**2.90a**	1.29d-g
P2	91.96bc	0.48k	0.07ij	2.01j	1.22e-h
KH1	91.97bc	0.46k	0.07ij	1.97j	1.10hi
KH2	90.80h	0.57ij	0.08ghi	2.35de	1.05i
KH3	**92.75a**	0.64ef	0.08hij	2.58b	0.87j

Note: Values in each column followed by the same letters do not differ significantly (P<0.05)

Harvest period in this study classified into three classes i.e. short ($x < 46$ days), medium ($46 \leq x \leq 80$ days), and long (> 80 days). H3U and P1 belonged to short harvest period genotypes, while P2, KH1, KH2, and KH3 belonged to long harvest period genotypes. Meanwhile, another F8 genotypes had medium harvest period. Among the medium harvest period genotypes, H1U-2 shown the longest harvest period (78 days).

However, there was no correlation between harvest period and pod yield in this study. H2 with the highest yield among F8 genotypes showed medium harvest period, while H1U-2 with the longest harvest period among the F8 genotypes showed lower pod yield. Likewise, KH1, KH2, and KH3 as controls had the longest harvest period among genotypes but their yields were lower than the others. However, harvest period was known to correlate negatively with leaflet size (data not shown).

Proximate analysis showed that water content among genotypes ranged between 88.33% - 92.75% where KH3 had the highest water content, followed by H1U. Meanwhile, P1 had the highest ash and protein content followed by H3U. L1 and L2 had the highest fat and fiber content respectively. Maturity level of the edible parts in winged bean could affect protein, fiber, and fat content especially in pods (Claydon 1983; Ningombam et al. 2012). Late harvest of pods causes the increase in fiber content (Handayani et al. 2015).

In conclusion, this study showed differences among twenty genotypes of winged bean based on qualitative and quantitative traits. The best genotype for pod production based on yield parameter was H2. Otherwise, H2 had medium harvest period and lower nutrient content than other genotypes. Selection process in order to obtain the best winged bean genotypes for pod production needs to consider criteria both of qualitative and quantitative traits. Weighted index can be used as the selection method.

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