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Evaluation of Agro-Morphological Traits of Some Introduced Okra [*Abelmoschus esculentus* (L) Moench] Varieties: Correlation, Variability and Heritability Studies

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Abstract

Okra is a functional vegetable due to its good nutritional content and medicinal benefits. A varietal introduction is one of the methods for obtaining and extent genetic material sources. The objectives of the research were to study agro-morphological traits of some introduced okra varieties and to determine correlation, variability and heritability of the traits. Genotypes evaluated were ten introduced okra varieties and two local cultivars, i.e. okra Merah and okra Hijau which were laid out in a RCB design with three replications. Results showed that genotypes were highly significant for all agro-morphological traits studied. The maximum picking day of introduced varieties was eight days after anthesis, which was longer than that of local cultivars. NongTruong and VN-1 produced the highest yield among the type 3 fruit shape varieties (1.74 and 1.42 kg per plant, respectively), while Ve-045 produced the highest (1.05 kg per plant) among the type 2 fruit shape varieties. The coefficient of genotypic correlation was consistently higher than that of phenotypic correlation. Plant height, number of branches, fruit weight and fruit length, which exhibited high heritability and positive association with yield at the phenotypic and genotypic level should be considered during selection for high yield in okra breeding programme.

Keyword: introduced variety, local cultivar, correlation, genetic variability, heritability

1. Introduction

Okra (*Abelmoschus esculentus* (L.) Moench) is one of fruit vegetable crop, commonly consumed when immature and tender in texture. Okra is known as okro or gumbo, local names in Java, belongs to family Malvaceae. The fruit is capsule-shaped and contains numerous of white seeds at young and black when ripe. The colour of the fruit is yellowish-green, green, dark green or red, while the shape of the fruit is straight, elongated or rounded depending on varieties (IBPGR, 1991).

Okra fruit has a high nutrient content. The nutritional content of edible fruit consists of protein, fat, carbohydrates, minerals and fibre (Gopalan et al., 2007). Vitamins and minerals found are vitamin A, thiamin, pyridoxine, vitamin C, riboflavin, calcium, potassium, zinc, iron, beta carotene and folic acid (Gopalan et al., 2007; Kumar et al., 2013), indicating the importance of okra in the human diet. The characteristic of fruit is mucilage in most fruit part associated with other substances such as tannins (Sengkhamparn et al., 2009) and potentially used as anti-cholesterol (Gamede et al., 2014). The okra fruit extract has hypoglycemic effects for the treatment of diabetic (Subrahmanyam et al., 2011; Amin, 2011; and Kumar et al., 2013). Besides, okra seeds are potential as anti-fatigue as the polyphenols and flavonoids content (Xia et al., 2015), while its oil has a hypocholesterolemic effect (Sanjeet et al., 2010). Due to nutritional and medicinal value, okra known as a functional food.

Okra has originated in tropical Africa and now widespread in tropical and sub-tropical regions around the world (Akanbi et al., 2010; Muhammad et al., 2013). There are less reports when okra began to cultivate and spread in Indonesia. Local okra cultivars, namely okra Merah and okra Hijau have introduced cultivars from other countries for years, then widely encountered and adapted in several places in Indonesia. Source of the seed derived from the previous generation cultivation, hence the uniformity of the crop and fruit quality becomes a limiting factor in obtaining good quality of okra. It is therefore vital that plant breeders need to develop improved varieties of okra in order to meet various consumer preferences at various levels.

The existence of genetic variability is essential for initiating genetic improvement program. One of the methods to obtain genetic sources is a varietal introduction. Evaluation of agro-morphological traits of introduced genetic materials provides recommendations of potential varieties having good traits for cultivation in the country. Information is also essential to determine potential genotypes employed as parents in the hybrid breeding programmes and improvement of local okra cultivars through hybridization. Assessing genetic variability and heritability of traits play a crucial role to obtain important traits used in selection. High genetic variability and heritability indicate the effectiveness of selection in the breeding programme. Proper knowledge of correlation among yield and other agro-morphological traits is vital in okra breeding programme (Das et al., 2012). The current research was undertaken to study agro-morphological traits of some introduced okra varieties and to determine correlation, variability and heritability of the traits; therefore their traits can be used for indirect selection to improve okra fruit quality.

2. Materials and Methods

A. Plant Material

This research has been carried out in the Research Station, Faculty of Agriculture, Andalas University, Padang, in West Sumatra province, Indonesia, located at an altitude of 350 m above sea level. The order of soil was Ultisol which ameliorated with lime and chicken manure to improve the pH into 5.83 before evaluation. Rainfall during research ranges from 236-459 mm/month while daily temperatures range from 24.5 – 29.5^{o}C. The minimum and maximum temperatures within the period of study were 20^{o}C and 38.5^{o}C, respectively. The genotypes evaluated in this research consisted of ten introduced hybrid varieties and two local cultivars (Table 1).

B. Experimental Details

The genotypes evaluated in this research consisted of ten introduced hybrid varieties and two local cultivars (Table 1) were arranged in Randomised Complete Block Design with three replications. The experimental plot size was 250 cm x 120 cm, covered with mulch plastic. The plot consists of two rows with the inter-row spacing of 60 cm and intra-row spacing of 40 cm. Application of fertilizer consisted of 100 kg Urea, 200 kg SP-36 and 100 kg of KCl per hectare. Urea and KCl fertilizer were applied at 15, 30 and 45 days after planting, while the SP-36 applied at 15 days. Other agronomic practised followed as per standard recommendation to raise a healthy and good crop stand.

Table 1. Genotypes used in research and seed source of origin

No	Genotype	Source of seed
1	Ve-022	Malaysia
2	Ve-045	Malaysia
3	B-291	Malaysia
4	PhuNong	Vietnam
5	Bo-TN1	Vietnam
6	NongTruong	Vietnam
7	Do-TN2	Vietnam
8	VN-1	Vietnam
9	120-204	Taiwan
10	120-203	Taiwan
11	Okra Merah	Indonesia
12	Okra Hijau	Indonesia

C. Observations

The observed variables were plant height, the number of branches, flowering date, fruit weight, fruit diameter, fruit length and yield per plant. Plant height was length measurement using a meter ruler from base to the terminal node. The number of branch was total of branches which was more than 10 cm in length and produced fruit. The flowering date was days required by 50% of plants to start blooms. The observation of yield component traits coincided with the maximum day of picking, which fruit was tender and not fibrous. Fruit weight measured using an electrical balance, band ruler for fruit length and calibrated vernier calliper for fruit diameter. Yield per plant weighted from all fruits over trunk and branches harvested at maximum picking day. The data collected were from six sample plants in the plot, leaving border ones. Qualitative and quantitative observation traits of okra referred to the okra description guideline by IBPGR (International Board for Plant Genetic Resources) (1991) and UPOV (International Union for the Protection of New Varieties of Plants) (1999).

D. Statistical Analysis

Heritability estimates of each traits was calculated based on Singh and Caudhary (1979) using variance components of analyses of variance. A trait has a broad genetic variability when the genetic variance (σ^2g) is higher than two times its standard of deviation ($\sigma\sigma^2g$). Calculation of the standard of deviation of genetic variance referred to the formulae suggested by Anderson and Bancroft in 1952 cit. Susanto et al. (2001).

The data collected were subjected to the analysis of variance (ANOVA) using the General Linear Models (Proc GLM) and significant mean differences further tested with Tukey test of the Statistical Analysis System (SAS) version 9.1 (SAS/STAT®, 2003). Statistical analysis assisted with the SAS software. Partitioned of genotypic and phenotypic from analysis of variance and covariance referred to Dewi Hayati (2018).

3. Results and Discussion

A. Results

Results of the analysis of variance showed that genotype had a significant effect on all growth, flowering, yield and yield component traits. Plant height of introduced varieties ranged from 108.5 cm – 195.5 cm. Two varieties originating from Vietnam performed the highest; conversely, varieties originating from Taiwan have the shortest. Plant branches ranged from 1.33 to 4.33. Plant height and number of branches of okra Merah and okra Hijau cultivars were in the range. Meanwhile, flowering time of introduced varieties varied from 51.3 – 62.5 days after planting. The local cultivars of okra Hijau and the introduced variety of Bo-TN1 were early in the flowering, while the variety of 120-204 become the latest (Table 2).

Observation of the fruit traits, which includes fruit weight, diameter, and length, as presented in Table 2 used fruits harvest at the maximum picking day. The maximum picking day was different in each genotype. NongTruong and VN-1 that originated from Vietnam were the highest in yield (1.74 and 1.43 kg, respectively). These varieties also possed heavier weight fruit (42.6 and 38.6 g, respectively) compared to other okra varieties, whereas Do-TN2 and okra Hijau were the lightest (24.6 and 24.0 g, respectively). Do-TN2 consistently produced the lowest yield.

The highest diameter of fruit was obtained in okra Merah and B-291, while Do-TN2 was the smallest in fruit diameter. The fruit length of PhuNong and Bo-TN1 was the greatest and had similar length with VN-

1 and NongTruong. Otherwise, okra Hijau performed the shortest.

Correlation analysis showed the relationship between two traits. Yield exhibited a significant and positive phenotypic and genotypic correlation with plant height, number of branches, fruit weight and fruit length. Significant phenotypic correlation among those traits was also in line with the significant genotypic correlations (Table 3). All significant genotypic correlation coefficient was consistently higher than the phenotypic correlation coefficient.

The genetic variance value of growth, flowering, yield and yield component traits showed a higher value compared to two times the deviation standard of genotypic variance (Table 4). All agro-morphological traits also performed high heritability estimates that were in line with broad genetic variability.

Table 2. Agro-morphological traits of ten introduced okra varieties and two local okra cultivar

Genotypes	Plant height (cm)	Branch number	Flowering time	Fruit weight (g)	Diameter Buah (mm)	Fruit lenght (cm)	Yield/plant (kg)
VN-1	195.0±9.7 a	3.17±0.29 bc	59.3±1.5 ab	38.6±3.2 ab	20.6±0.3 ab	19.0±1.6 ab	1.43±0.28 ab
NongTruong	145.5±4.0 bc	3.67±0.29 ab	57.0±1.7 b-d	42.6±1.8 a	20.8±0.7 ab	18.9±0.8ab	1.74±0.02 a
Ve-045	124.3±15.5 cd	2.33±0.58 cd	53.0±1.0 de	30.9±1.8 cd	21.2±1.8 ab	15.7±0.4 cde	1.05±0.08 c-e
Do-TN2	133.5±2.3 b-d	3.33±0.58 abc	56.5±1.3 b-d	24.0±3.3 e	17.1±0.8 c	17.2±0.5 bcd	0.58±0.05 f
120-204	112.9±2.4 d	2.67±0.58 bc	62.5±2.0 a	35.1±3.4 bc	21.0±1.0 ab	17.9±1.1 a-c	0.68±0.17 f
120-203	108.5±5.6 d	1.33±0.29 d	57.3±0.6 b-d	31.5±0.6 cd	21.5±0.4 ab	14.6±0.4 de	0.85±0.01 d-f
Ve-022	190.7±11.5 a	1.33±0.58 d	55.2±0.8 b-e	27.3±0.9 de	18.3±0.9 bc	17.8±0.1 a-c	0.84±0.05 d-f
PhuNong	149.7±12.4 bc	3.50±0.50 ab	58.2±1.0 a-c	43.8±1.6 a	21.3±0.3 ab	20.4±0.4 a	1.20±0.17 bc
Bo-TN1	197.9±5.5 a	4.33±0.58 a	51.3±2.5 e	36.3±2.4 bc	21.3±1.0 ab	19.9±1.1 a	1.16±0.12 b-d
B-291	153.3±10.0 b	1.50±0.50 d	53.0±1.0 de	28.6±0.8 de	22.0±0.9 a	16.2±0.9 b-d	0.75±0.04 ef
Okra Merah	134.7±10.2 b-d	2.83±0.76 bc	54.3±1.5 c-e	26.7±0.2 de	22.9±2.5 a	14.9±1.4 de	0.84±0.03 d-f
Okra Hijau	153.9±5.2 b	3.00±0.50 bc	51.3±2.1 e	24.6±1.8 e	20.1±0.3 a-c	12.9±0.5 e	0.89±0.03 c-f
Average	150.0	2.8	55.8	32.5	20.7	17.1	1.00
c.v.	6.53	12.76	2.82	5.96	5.44	5.48	11.06

Similar notations within column are significant based on Tukey at P≤0.05

Table 3. Phenotypic and genotypic correlation coefficient some of agro-morphological traits of ten introduced okra varieties and two local okra cultivars

		Phenotypic correlation						
Genotypic correlation	**Traits**	Plant height	Branch number	Flowering time	Fruit weight	Fruit diameter	Fruit length	Yield
	Plant height		0.28	-0.25	0.15	-0.21	0.45*	0.37*
	Branch number	0.28		-0.02	0.42*	-0.01	0.45*	0.46*
	Flowering time	-0.33	-0.02		0.43*	-0.01	0.36*	0.07
	Fruit weight	0.17	0.48*	0.48*		0.30	0.73*	0.76*
	Fruit diameter	-0.20	-0.01	-0.13	0.35		-0.11	0.19
	Fruit length	0.48*	0.54*	0.41*	0.77*	-0.09		0.45*
	Yield	0.38*	0.49*	0.07	0.79*	0.25	0.52*	

Above and below diagonal is phenotypic and genotypic correlation coefficient respectively. "" is significant at P≤0.05*

Table 4. Phenotypic and genotypic variance components and heritability estimates of agro-morphological traits of ten introduced okra varieties and two local okra cultivars

Value	Plant height	Branch number	Flowering time	Fruit weight	Fruit diameter	Fruit length	Yield
σ^2_g	945.6	0.9	10.6	44.2	2.0	4.9	107201
$\sigma_{\sigma^2_g}$	383.4	0.4	4.5	17.8	1.0	2.1	43666
σ^2_p	1040.3	1.0	13.1	48.0	3.3	5.8	119457
$H_{(BS)}$	0.91	0.88	0.81	0.92	0.61	0.85	0.90

σ^2_g = *variance of genotype,* $\sigma\sigma^2_\sigma$ = *standard of deviation of genotype variance, and* σ^2_e = *variance of error*

B. Discussion

Agro-morphological Performance

Characterization and identification of genetic variability among genotypes are the preliminary requirements for the exploitation of genotypes in the breeding programme. Agro-morphological traits are useful to differentiate germplasms in considering their genetic fashion and their interaction with environments. Agro-morphological characterization becomes the initial step to be undertaken prior to more in-depth biochemical or molecular studies in okra germplasm (Oppong-Sekyere et al., 2011).

Plant height and number of branches determine the performance of the whole plant of okra. Tall plant performance with dense branches all over stem formed a robust degree of branching compared to the tall plant with small branches at the base. In general, the introduced okra varieties and the local cultivars had several small branches located at the base of the stem. The branches protruding of nodus at the base of stems widened to the side before upwards and built procumbent and robust performance. Generally, there were variations among genotypes and plants within such genotypes in the degree of branching. Medium and strong in branching were predominant, while weak was least frequent.

Fruits located on small branches generally showed smaller fruit weight and size compared to the fruits located on the main trunk. Even though erect or orthotropic plants type have uniform fruit weight and size, their performance was usually weak due to the thin stem. The delayed seed emergence might affect inferior plants performance. Generally, the plant height of introduced hybrid okra varieties evaluated was higher than that of reported by Ali et al. (2014), Bello et al. (2015) and Shivaramegowda et al. (2016).

Genetic and environment exposed influenced flowering time of plants. The flowering time of introduced varieties from 51.3 – 62.5 days after planting indicates variation in the flowering period among okra varieties. Variation in the flowering time was also reported by Ige and Eludire (2014) between long and short okra variety. The variation also existed among plants within a variety, ranged from 1 – 4 days. Differences in the flowering time among the varieties imply to variation in the commercial harvest time and maturity when pod used as a source of seeds.

Plants that bloom earlier is more desirable because it allows for getting harvest crops faster. Variety of 120-204 bloomed the latest, might due to the interaction between genetic and sub-tropical environments where this variety produced plays a role. Generally, the first flower emerged on the sixth axillar. The daily temperature conditions in the field that are around 27^{o}C during the end of the vegetative period were the same as the temperature conditions reported by Tripathy et al. (2009). This temperature condition induced the emergence of flowers at the sixth axilla.

Flower buds appear on the leaf axilla (flos axillaris). Both the introduced varieties and the local okra cultivars have five to six group flowers. The flowers within-group are not inflorescence but separate each other (flores sparsi) due to the short internodes. Not all flower buds in groups evolve into flowers, especially buds of the group located at the terminal nodes of the stem. A similar phenomenon happens in fruit set. Hence, the success of flower buds develops into flower and fruits determines the fruit production in each variety.

Okra Merah and okra Hijau possessed a flowering group span. The internodes had been shorter than the introduced varieties. Consequently, fruit emerges over the stem was very densely from base to tip of a stem. Meanwhile, Ve-022 performed different flowering span due to length of internodes. These internodes caused flowers emerged from the group to look like a single span of flowering.

Okra fruit harvested on the maximum picking day when the fruit texture is still tender and not fibrous. Tender fruit was characterized by a fruit condition that still easily split into two parts by hand. All introduced varieties were picked at eight days after anthesis. Fruit from Ve-022 and B-291 varieties had a thin pericarp; hence the fruit texture was still tender although picking into the ninth day. Meanwhile, picking day of okra Merah and okra Hijau cultivars was at seven days after anthesis. These indicate that delayed picking day varieties could be used as genetic source material in the improvement of harvest trait of a local cultivar.

Based on the fruit shape, NongTruong (1.74 kg), VN-1 (1.42 kg) and Phunong (1.20 kg) were the top-three varieties with the highest yield. The characteristics of the varieties were grouped as type 3 fruit shape based on IBPGR descriptor (1991). Meanwhile, based on the type 2 fruit shape, Ve-045 was the highest in the fruit weight (1.05 kg). NongTruong, VN-1 and PhuNong were also the top-three heaviest varieties. All three varieties have yellowish-green in colour, many ridges and locules (more than 5), while Ve-045 has a green colour fruit, five ridges and locules.

Okra fruit was picked when immature before highly fibrous (Ige and Eludire, 2014). Varieties that have high production and more extended picking day is an indispensable genetic material source for the improvement of local cultivars of okra Merah and okra Hijau. The maximum picking at harvest of okra Merah and okra Hijau cultivars was at seven days after anthesis (DAA). Farmer prefers to harvest okra Hijau cultivar at six DAA because fruit at sixth day consistently gives a tender texture. Fruit picking of okra Hijau on the seventh day revealed the texture varies among plants within okra Hijau cultivars from tender to medium-fibrous. A fibrous texture indicated over-aged fruits on okra Hijau. Over-aged fruit due to delayed picking interval reduced fruit quality of okra as reported by Talukder et al. (2003), Saha et al. (2005) and Maurya (2013).

The increase in weight, diameter and length of fruit from six to seven DAA were 35.3, 11.8 and 6.2% in the okra Merah cultivar and 50.1, 15.9 and 24.3% in the okra Hijau cultivar, respectively. The increase in those traits from seven to eight DAA were 38.3, 12.4 and 8.5% in okra Merah, and 20.6, 7.3 and 2.9% in okra Hijau, respectively. These data show that earlier picking day reduced yield component traits, while late picking is very significant in the increase of yield in okra crops. However, delayed picking into over-aged produced low fruit quality due to highly fibrous of texture.

Genotypic and Phenotypic Correlation

Information about the association between yield and related traits are prerequisites for selection of superior genotypes and improvement of any trait (Singla et al., 2018). Selection for a single trait may increase the trait values of positively correlated traits and decline the values for negatively correlated traits. A yield had a phenotypic correlation with the yield component traits viz. fruit weight (r=0.76) and fruit length (r=0.45), and growth traits viz. plant height (r=0.37) and number of branches (r=0.46). Highly and positively correlations among those traits indicate that varieties that have long fruit length such as type 3 fruit shape have heavier fruit weight and high yield. A longest of fruit length means a broader place for the development of ovule and accommodates more ovule inside the ovary. More number of seeds in the locules contribute to the more weight of fruit. Type 3 shape fruit also has a thicker layer of pericarp so that it also contributes to more weight of the fruit. Plants with high-performance have a higher chance fulfilled with more nodes and branches. Short internodes contribute to the increasing number of flowers and fruits. Similar conditions also meet the growth and development of flower buds on branches.

Fruit weight was not correlated with the fruit diameter (r=0.30), but positively correlated with the fruit length (r=0.73) (Table 3). This association indicates that the fruit length of the type 3 fruit variety was consistently longer and heavier than that of type 2 variety. There was no correlation between fruit diameter and fruit length (r=-0.11). This result was not in line with Ali et al. (2014) who reported negatively and significant phenotypic correlation between the traits.

Parallel to the phenotypic correlation coefficient, the yield was also genetically correlated with fruit weight (r=0.79), fruit length (r=0.52), plant height (r=0.38) and the number of branches (r=0.49)(Table 3). The action of the pleiotropic genes and linkage or both play a role with the significant correlation between traits (Falconer, 1996). The genotypic correlation coefficients between the traits are consistently higher than the phenotypic correlation coefficient. Higher coefficient of genotypic correlation indicates that there is a close relationship between the two traits genetically. Similar genes are responsible in controlling the traits, while environment only have small portion in the expression of the traits. These results go in the favors of findings made by Das et al. (2012); however not in line with Ibrahim et al. (2013) and Agbowuro et al. (2019) who obtain a higher of phenotypic correlation coefficient than genotypic correlation coefficient. The population of okra studied, and an environment imposed become the reason of the difference result.

Heritability Estimates

The success of breeding programme for the improvement of the trait depends to a large extent of the genetic variability existing in the germplasm (Das et al., 2012; Bello et al., 2015). Growth, flowering time, yield and yield component traits exhibited a great extent of genetic variability (Table 4), indicating the diverse genetic background of varieties used in the evaluation. The higher value suggests a large portion of genetic in governing variability in all agro-morphological traits evaluated.

Broad genetic variability contributes to high heritability estimate values. It is a portion of the genetic variance to a total variance expressed as a phenotypic variance (broad-sense heritability). Hence, a large extent of genetic variability contributes to the high heritability value (Table 4), indicating the amount of genetic portion in producing variance observed as phenotypic variance compared to the portion of the environment.

In exception with fruit diameter, all agro-morphological traits showed a very high magnitude of broad sense heritability (Table 4). High heritability estimates in many characters of growth, flowering, yield and yield components were also reported by several researchers with variation in magnitude (Das et

al.., 2012; Nwangburuka et al., 2012; Bello et al., 2015; Agbowuro et al., 2019). As additive gene effects predominant in genotypic variance, high heritability estimates revealed in the study indicate that most genetic variances in such traits were due to additive gene effects. The existence of high heritability estimates of the traits indicate that the breeding program through simple selection can take place efficiently

4. Conclusions

The maximum picking day in harvest of introduced varieties was eight days after anthesis, which was longer than local cultivars, while Ve-022 and B-291 exhibited the longest (9 days). NongTruong and VN-1, and Ve-045 revealed the highest yield among type 3 and type 2 fruit shape varieties, respectively. All significant genotypic correlation coefficient was consistently higher than the corresponding phenotypic correlation coefficient. High heritability estimates were performed by all agro-morphological characteristics that were in line with a broad genetic variability of the traits.

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