Morphological diversity and heritability of local sorghum (*Sorghum bicolor* L. Moench) landraces of ~~in~~ East Java~~, Indonesia~~

Abstract. Sorghum (*Sorghum bicolor* L. Moench) ~~was~~ is an essential food crop after wheat, rice, maize, and barley. ~~Sorghum~~ it has ~~a~~ wide adaptability. ~~Thus they have the potential to be developed in~~ grown on marginal lands as cheap sorce of carbohydrate. The~~se~~ present study aims ~~were obtained information about~~ at stdying the morphological diversity and heritability values of ~~several~~ major sorghum landraces ~~sorghum genotypes~~ in East Java. The research was conducted in Purutrejo village of ~~, Purworejo sub -district,~~ Pasuruan city. The local genotypes ~~of Sorghum used came~~ were derived from Jombang (SG-JBG), Tuban (SG-TBN), Pasuruan (GB-PSR), Lamongan 1 (SG-LMG 1), Lamongan 2 (SG-LMG 2), Sampang 1 (SG-SPG 1), Sampang 2 (SG-SPG 2), Tulungagung 1 (SG-TLG 1), Tulungagung 2 (SG-TLG 2). The results showed that the Sampang 2 genotype produced the longest panicles~~.~~, while the ~~The~~ Lamongan 2 ~~genotype~~ had the highest seed dry weight per panicle and ~~the~~ highest number of seeds per panicle (117.34 gram/panicle dry weight and 4581.80 seeds/panicle). The genotype of Tulungagung 2 produced the highest fresh ~~fresh weight of 1000 seeds~~ (41.43 g~~rams~~/1000 seeds) and ~~a~~ dry seed weight ~~of 1000 seeds~~ (31.96 g~~rams~~/1000 seeds). In addition, ~~Besides that~~, the~~se~~ results also showed that it was ~~not~~ genetically different from ~~the genotype of~~ Tulungagung 1 genotype. Similarly, the highest number of tillers was produced by Tulungagung 2 (4.20 tiller) and was not significantly different from Tulungagung 1 (3.33 tiller) and Jombang (2.07 tiller). Based on the result of nine local genotypes tested, the flowering ~~ages~~ ranged from 42 to 53 days after planting~~,~~ and days to ~~the~~ harvest ~~ages~~ ranged from 70 to 91 days after planting. The early maturity was observed ~~fastest harvest age is~~ in Tulungagung 2 (70 days after planting) as against others. ~~All parameters tested showed the criteria for a wide range of genotypes and phenotypes.~~ The phenotype variety's entire value on each variable was significant than the amount of the genotype range. The highest heritability value in all the observed exceedsed ~~parameters~~ 0.5.

Keywords: diversity, heritability, landrace, *Sorghum bicolor* Linn.

INTRODUCTION

The increasing population has increased the need for various agricultural commodities~~materials~~, especially cereals and pulses~~carbohydrate sources.~~.. Among the cereals, sSorghum (Sorghum bicolor L) is one of the world's essential crops as the primary source of carbohydrates after wheat, rice, corn, and barley. Sorghum could be developed as an alternative to local food besides rice to increase food needs. Besides, Sorghum also has the potential as animal feed and industrial material. Sorghum is an annual crop that was easy to cultivate, but its production is still lower than that of rice, maize, and other cereal crops. Sorghum has wide environmental adaptability and can be developed in areas with less adaptive environmental conditions to climate change (Sirappa, 2003; Mundia *et al*., 2019). These showed that Sorghum has more potential to be developed as an alternative to increasing local food on marginal lands compared to rice ~~crops~~ (Sulistyowati *et al*., 2019a). Besides, current research ~~results~~ indicated several local genotypes of Sorghum, which contain high carbohydrates and protein could be used for various food preparations (Sulistyowati *et al*., 2019b). Sorghum ~~development~~ improvement would upplement ~~was expected to support~~ government initiatives in reducing the burden of ~~-programs to suppress~~ rice and wheat import ~~policies~~ (Susilowati and Saliem, 2013).

Genetic ~~C~~characterization of germplasm lines ~~is an activity that~~ aims to identify important traits that have economic value or which ~~are~~ possess specific characteristics of the variety concerned. The characters could be ~~observed~~ morphological ~~characters~~ (qualitative and quantitative), agronomic ~~characters~~ (~~germination age~~Flowering and maturity time~~, harvesting age, ,etc.~~), physiological ~~characters, isoenzyme markers, and molecular markers~~. Characterization and evaluation ~~activities~~ prcesses have essential meanings and roles determining these materials' good value (Kusumawati *et al*., 2013). The differences in Sorghum's genotype could be recognized more clearly in the generative phase than in the vegetative phase (Elvira *et al*., 2015). The diversity among these accessions will help plant breeding activities, especially in providing plant breeding materials (Rifa'i *et al*., 2015).

Genetic diversity ~~served to~~ facilitates the selection process in field crops including sorghum~~ breeding~~. If the genetic variance were high, the heritability value would be high. Thus, the variable could be used as a selection criterion (Setiawan *et al.*, 2019). Heritability value could be interpreted as the proportion between genetic variance and phenotypic variance (Falconer & Mackay, 1996). The heritability value of a character did not indicate that the character is genetic or environmental (Maftuchah *et al.*, 2015).

Information ~~i~~on morphological diversity and heritability values help to breed for ~~on~~ local sorghum genotypes suitable ~~helped make sorghum varieties~~ as an alternative to food, feed, or fuel~~industry~~. In this context, Th~~is~~e present study aimed to obtain information about the morphological diversity and heritability values of ~~several~~ local sorghum genotypes ~~in~~of East Java.

MATERIALS AND METHODS

The research was conducted in Purutrejo village, Purworejo district, Pasuruan city. The planting material used in this study were consisted of ~~9~~nine genotypes of local sorghum plants derived from various regions in East Java, i.e., Jombang (SG-JBG), Tuban (SG-TBN), Pasuruan (GB-PSR), Lamongan 1 (SG-LMG 1), Lamongan 2 (SG-LMG 2), Sampang 1 (SG-SPG 1), Sampang 2 (SG-SPG 2), Tulungagung 1 (SG-TLG 1), Tulungagung 2 (SG-TLG 2).

The experiment ~~study used~~ was conducted as~~a~~ randomized block design with three replications. The design consisted of one factor (9 genotypes of local Sorghum) so that there was 27 experimental unit. The sorghum planting was carried out by seeding on a tray used a planting medium, i.e., soil and compost. Seedlings were planted in the field after ten days of planting with a planted distance of 75 cm x 15 cm at plots measuring 3 x 2.5 m. Thus, each plot consists of 21 sorghum plants. The fertilizers used organic fertilizers and inorganic fertilizers (SP 36, Urea, and KCL). Manure is an essential fertilizer given at the same time as tillage. Meanwhile, inorganic fertilizers are applied to the planting hole when the plants are 2 WAP and 4 WAP.

The variables observed were plant height, number of leaves, stem diameter, panicle length, total dry weight of grains per panicle, number of grains per panicle, fresh weight of 1000 grains, dry weight of 1000 grains, leaf length, leaf width, plant height at harvest, tillers, age, and harvest of flowering and harvest age. Data analysis was performed using variance analysis and continued with the 5% LSD test, analysis of variance~~,~~ and heritability testing.

RESULTS AND DISCUSSION

~~Vegetative~~ Morphological characters:

Formatted: English (U.S.)

Genotypic treatments showed significant differences in plant height at 21, 28, and 35 days after planting. Table 1 shows the average plant height and number of leaves several local sorghum genotypes in East Java at various observation ages Plant height is one of the growth parameters that is often used to determine environmental or genetic influences. The influence of the environment results in the genotype being able to display its character. The existence of inappropriate environmental influences results in the appearance of genetic traits that it was not optimal. Leaves are the primary organ for photosynthesis. The highest average number of leaves was shown by the genotypes of Jombang, Lamongan-1, and Tulungagung 1 (Table 2). In comparison, the largest average stem diameter is shown by Genotype Lamongan 2 (Table 3). The diversity of a plant's appearance is influenced by one genetic factor (Panjaitan *et al*., 2015).

Table 1. Plant height (cm) and number of leaves (strands) of several East Java local sorghum genotypes at various observation ages

Genotype	Plant Height (cm)								Number of Leaves (strands)							
	14 DAP		21 DAP		28 DAP		35 DAP		14 DAP		21 DAP		28 DAP		35 DAP	
SG-JBG	8,56	a	14,99	b	24,16	cd	63,30	e	4,80	d	6,80	d	7,93	c	8,53	e
SG-TBN	7,55	a	13,71	ab	22,10	ab	48,37	bcd	4,47	bc	6,47	cd	7,80	bc	8,13	de
SG-PSR	8,31	a	15,42	b	22,88	abc	55,55	cde	3,93	b	5,80	cd	7,07	bc	7,20	cd
SG-LMG 1	7,96	a	13,30	ab	22,65	abc	42,14	abc	4,27	bc	5,87	cd	7,87	c	8,33	e
SG-LMG 2	6,97	a	13,89	ab	20,43	ab	34,80	ab	4,07	bc	5,80	cd	7,27	bc	8,20	de
SG-SPG 1	7,13	a	11,03	a	17,27	a	29,55	a	2,53	a	2,87	a	4,67	a	5,13	a
SG-SPG 2	6,84	a	15,94	b	29,02	cd	46,60	bc	3,87	b	4,53	b	5,33	a	5,67	ab
SG-TLG 1	9,21	a	15,91	b	26,91	bc	62,04	de	4,00	bc	6,33	cd	7,47	bc	8,40	e
SG-TLG 2	8,43	a	15,77	b	33,87	d	63,97	e	4,00	bc	5,60	bc	6,73	bc	6,73	cd

Note: The numbers followed by the same letter in the same column show no significant difference in the 5% LSD test.

Table 2 shows the average leaf length and width of several genotypes of local Sorghum in East Java. In comparison, the average plant height at harvest and the number of tillers were shown in Table 3. The highest number of tillers was produced by genotype Tulungagung 2 (4.20 tillers) and did not differ significantly from genotype Tulungagung 1 (3.33 tillers) and genotype Jombang. The diversity of observations indicates that each genotype has different characteristics. Siswanto (2015) states that the genetic characteristics of varieties, the environment in which they are grown, and the cultivation treatment will affect Sorghum's yield potential. Genetic and environmental factors determine the number of chicks produced.

Table 2. Average stem diameter, length, the width of leaves, the value of plant height at harvest, and number of tillers of several East Java local sorghum genotypes

Genotype	Stem Diameter (cm)				Leaf length (cm)		Leaf Width (cm)		Plant Height at Harvest (cm)		Number of Tillers	
	28 DAP		35 DAP									
SG-JBG	1,27	bc	1,47	bcd	77,27	d	7,70	d	255,72	d	2,07	c
SG-TBN	1,29	bc	1,51	cd	79,15	d	7,82	de	262,33	d	2,13	ab
SG-PSR	1,14	abc	1,19	ab	78,40	d	6,75	c	202,40	c	2,27	ab
SG-LMG 1	1,26	abc	1,46	bcd	82,14	d	8,84	e	139,47	a	1,33	a
SG-LMG 2	1,37	c	1,83	e	76,01	cd	8,24	de	167,50	b	1,87	a
SG-SPG 1	1,19	abc	1,24	abc	69,96	bc	5,69	b	191,67	c	2,07	ab
SG-SPG 2	0,93	a	1,05	a	49,29	a	4,56	a	136,15	a	1,80	a
SG-TLG 1	1,37	c	1,56	de	80,11	d	7,84	de	274,23	d	3,33	bc
SG-TLG 2	1,02	ab	1,03	a	68,33	bc	4,79	ab	214,05	c	4,20	c

Note: The numbers followed by the same letter in the same column show no significant difference in the 5% LDS test

Formatted: English (U.S.)

~~Generative character~~Yield contributing traits:

The average panicle length, total seed dry weight per panicle, number of seeds per panicle, fresh weight, and dry weight 1000 seeds of several East Java local sorghum genotypes are shown in Table 3. The Sampang 2 genotype shows the longest panicle size, while Lamongan 2 produces the longest seed dry weight per panicle (117.34 grams). dry seeds/panicle) and the highest number of seeds per panicle (4581.80 seeds/panicle) (Table 3). Long panicles of plants are formed in the primordia phase. The difference in panicle length is due to different genotypes and inherited traits. Each genetic factor and the adaptability of each variety is different so that it affects the length of sorghum panicles (Sirappa and Waas, 2009).

Total dry weight is one measure to study further plant growth (Ferdian et al., 2015). The total dry weight per panicle is one of the criteria for the production of Sorghum. Genetic differences will result in a different panicle shape or weight of the seed unit so that each genotype has a different dry weight. Plants require sufficient nutrient content for seed formation. The highest total dry weight and the number of seeds per panicle were produced by the genotype Lamongan 2. The genotype of Tulungagung 2 produced the highest fresh weight and dry weight of 1000 seeds and was not significantly different from Tulungagung 1. The fresh weight of seeds in Tulungagung 2 was 41.43 grams / 1000 seeds, and the dry weight was 31.96 grams / 1000 seeds. Genotypic differences result in different shape and weight of seeds.

Table 3. The average length of panicle, total dry weight of seeds per panicle number of seeds, fresh and dry weight of 1000 seeds per panicle of several East Java local sorghum genotypes

Genotype	Panicle Length (cm)		Total Seed Dry Weight Per Panicle (g / panicle)		Number of Seeds per Panicle		Fresh Weight 1000 Seeds (g)		Dry Weight 1000 Seeds (g)	
SG-JBG	23,92	a	88,87	c	3081,80	de	37,86	cde	28,87	cd
SG-TBN	26,13	a	82,94	bc	3125,70	de	34,61	bc	26,50	bc
SG-PSR	34,69	b	68,68	b	2293,90	bc	37,25	cd	30,06	de
SG-LMG 1	25,50	a	86,68	bc	3563,90	e	34,07	bc	24,66	ab
SG-LMG 2	38,53	bc	117,34	d	4581,80	f	32,73	b	25,87	ab
SG-SPG 1	35,83	b	44,23	a	1962,10	ab	26,45	a	23,22	a
SG-SPG 2	47,75	d	48,70	a	1840,80	ab	32,65	b	26,51	bc
SG-TLG 1	41,29	c	86,69	bc	2746,60	cd	41,04	de	31,55	de
SG-TLG 2	41,73	c	45,72	a	1426,80	a	41,43	e	31,96	e

Note: The numbers followed by the same letter in the same column show no significant difference in the 5% LDS test

Table 4 shows that the flowering ages ranged from 42 to 53 days after planting. Meanwhile, the harvest age ranges from 70 to 91 days after planting. The fastest harvesting age was on genotype Tulungagung 2 (70 days after planting). The existence of the suitability of environmental conditions can stimulate the flowering and harvesting age faster. Besides, the nutrients absorbed by plants are used as a source of energy in plant growth (Setiyagama, 2017).

Table 4. Flowering age, flowering to harvest, and harvesting age of several East Java local sorghum genotypes

Genotype~~s~~	**Days to ~~F~~flower~~ing Age~~ (DAP)**	**Flowering ~~Age~~ to Harvest (Days)**	**Days to ~~Harvest Age~~ maturity (DAP)**
SG-JBG	53	38	91
SG-TBN	53	33	86
SG-PSR	49	28	77
SG-LMG 1	49	28	77
SG-LMG 2	51	35	86
SG-SPG 1	42	44	86
SG-SPG 2	42	49	91
SG-TLG 1	53	24	77
SG-TLG 2	38	32	70

The analysis of environmental diversity, genotype, and phenotype variability is shown in Table 9. These data indicate the criteria for broad genotype and phenotype variance. All values for the phenotype variety on each variable were more significant than the values for genotype variance. The indication of this is the influence of the genotype and the environment (Kotal *et al.*, 2010). Genotype diversity is a measure of genetic variation caused by the components of the genotype. In contrast, phenotype diversity is a variation of characters regulated by genotype factors and the growing environment and the two's interaction.

The wide variety of genotypes in the nine local sorghum genotypes in East Java indicates inequalities in genetic characters between genotypes. Dominant genotype variety is the main cause of the inequality of characters among plant relatives. High genetic diversity indicates a high potential for use in the improvement of plant traits. Genetic facts are inferred from phenotypic observations, which are the results of genotype interactions and the environment. The variability available in breeding material is the prime requirement for improving and selecting elite genotypes (Seetharam and Ganesamurthy, 2013).

Genetic variability and heritability

Table 5. Analysis of Environmental Variety, Genotype, and Phenotype

~~Peubah~~Traits	σ^2 e	σ^2 g	2σ g	Criteria	σ^2 p	2σ p	Criteria
Plant Height (cm)	26,56	2659,65	166.76	broad	2686,22	0,14	broad
Number of Leaves	0,52	138,75	7.97	broad	139,28	0,02	broad
Stem Diameter (cm)	0,07	4,99	0.34	broad	5,06	0,01	broad
Panicle Length (cm)	12,95	9206,55	515.25	broad	9219,5	0,10	broad
Number of Seeds per Panicle	405537	125860168,2	7186137.17	broad	126265705,06	17,83	broad
Seed / Panicle Dry Weight (g)	271,79	79463,18	4547.67	broad	79735	0,46	broad
Fresh Weight 1000 seeds (g)	11,32	2847,39	164.05	broad	2858,71	0,09	broad
Dry Weight 1000 seeds (g)	6,47	1213,8	71.15	broad	1220,28	0,07	broad
Leaf Length (cm)	29,47	13576,55	765.99	broad	13606	0,15	broad
Leaf Width (cm)	0,67	320	18.04	broad	320,67	0,02	broad
Plant Height at Harvest (cm)	414,57	356701,73	19913.49	broad	357116	0,57	broad
Number of Tillers	1,32	92,32	6.2	broad	93,64	0,03	broad

note: σ^2 e (Variety of Environment), σ^2 g (Variety of Genotypes), 2σ g(Standard Deviation of Genotype Variety), σ^2 *p*(Variety of Phenotypes), 2σ p(Standard Deviation of Phenotype Variety). σ^2 g < 2σ g (Narrow) dan σ^2 g > 2σ g (broad). σ^2 p < 2σ p (Narrow) dan σ^2 p > 2σ p (broad) .

Heritability value analysis shows that all tested parameters exceed 0.5 for each observed variable so that it is categorized as high heritability. Chaudhary (2001) concluded that the high coefficient of phenotype variety compared to

Formatted: English (U.S.)

the coefficient of genotype variance indicates a good effect on all genotypes' environment. The wide diversity of phenotypes comes from a wide diversity of genotypes, so that the requirement for the selection process to take place in the genotype selection process is wide genetic diversity. (Rahajeng and Rahayuningtyas, 2015).

In a broad sense, the heritability prediction value is the ratio between the total genetic variance and the phenotype variety, which shows the large proportion of genetic factors in a plant character's phenotype. The estimated high heritability means that plant genetic factors that affect plant phenotypes are very large compared to environmental factors (Ardiyanti et al., 2019). The phenotype variety analysis showed that the phenotype diversity in all observed genotypes was also high (Table 6). In general, high genotype diversity will be followed by high phenotype diversity. The diversity will be inherited can be measured using the heritability parameter. It was a broad sense, a comparison between the magnitude variety of genotypes and a character's phenotypes. The high heritability followed by wide genetic diversity in the nine East Java local sorghum genotypes indicates that genetic factors influence the characters. The high heritability of some local East Java sorghum genotypes is due to genetic factors. If genetic factors play a more important role, these characters can be inherited, and it is hoped that selection can be useful for the observed traits (Maftuchah et al., 2015). Besides, Jimmy et al. (2017) reported that high heritability was generated by all observed agronomic characters and indicated that additive genes played a more critical role in improving plant breeding more quickly. This study's results are also in line with Setiawan et al. (2016), who showed that the plant height variables of 20 sorghum genotypes showed high heritability. The selection criteria for Sorghum could be used as a biomass producer. However, this research needs to study the local Sorghum more deeply as an alternative food, animal feed, or industrial raw material.

Table 6. Heritability

~~Variable~~Traits	Heritability	Criteria
Plant Height (cm)	0,990	High
Number of Leaves	0,996	High
Stem Diameter (cm)	0,986	High
Panicle Length (cm)	0,999	High
Number of Seeds per Panicle	0,997	High
Seed / Panicle Dry Weight (g)	0,997	High
Fresh Weight 1000 seeds (g)	0,996	High
Dry Weight 1000 seeds (g)	0,995	High
Leaf Length (cm)	0,998	High
Leaf Width (cm)	0,998	High
Plant Height at Harvest (cm)	0,999	High
Number of Tillers	0,986	High

Description: High Heritability ($H \geq 50\%$ or $H \geq 0{,}5$ Medium heritability ($20\% < H < 50\%$ or $0{,}2 < H < 0{,}5$), low Heritability($H \leq 20\%$ or $H \leq 0{,}2$).

Formatted: English (U.S.)

The results showed that the Sampang 2 genotype produced the most extended panicle size. The Lamongan 2 genotype produced the highest seed dry weight per panicle and the highest number of seeds per panicle (117.34 grams of seed dry weight per panicle and 4581.80 seeds per panicle). The genotype of Tulungagung 2 produced the highest fresh weight and dry weight of 1000 seeds and was not different from Tulungagung 1. The fresh weight of 1000 seeds in Tulungagung 2 was 41.43 grams, and the dry weight of 1000 seeds was 31.96 grams. The highest number of tillers was produced by Tulungagung 2 (4.20 chicks) and was not significantly different from Tulungagung 1 (3.33 chicks) and Jombang (2.07 chicks). Of the nine genotypes tested, the flowering ages ranged from 42 to 53 days after planting, and the harvest ages ranged from 70 to 91 days after planting. The fastest harvest age is in Tulungagung 2 (70 days after planting). All parameters tested showed the criteria for a wide range of genotypes and phenotypes. The entire value of the phenotype variety on each variable was more significant than the value of the genotype range. Heritability test results show that all experimental parameters exceed 0.5 so that it is categorized as high heritability.

ACKNOWLEDGEMENTS

~~The~~ Author would like to thank~~s~~ the Directorate of Research and the Community Service University of Muhammadiyah Malang that has f~~o~~unded this research through the center of study's flagship program in 2017.

REFERENCES

Ardiyanti SE, Sopandie D, Wirnas D, Trikoesoemaningtyas. 2019. Ratoon Productivity of sorghum Breeding Lines (*Sorghum bicolor* (L.) Moench). IOP Conf. Series: Earth and Environmental Science 399 012030. Doi:10.1088/1755-1315/399/1/012030.

Chaudhary R. R., 2001. Genetic Variability and Heritability in Sugarcane. Nepal Agric. Res. J., Vol. 5.

Elvira SD, Yusuf M, Maiyuslina. 2015. Karakter Agronomi Beberapa Varietas Sorgum pada Lahan Marginal di Aceh Utara. Jurnal Agrium 12(1): 1-4.

Falconer, D.S., T.F.C. Mackay. 1996. Quantitative to Genetics. The Roland Press Company. New York 356p

Ferdian B, Sunyoto, Karyanto A, Kamal M. 2015. Akumulasi Bahan Kering Beberapa Varietas Tanaman Sorgum (Sorghum bicolor (L.) Moench) Ratoon 1 Pada Kerapatan Tanaman Berbeda. J.Agrotek Tropika 3 (1): 41-48.

Jimmy ML, Nzuve F, Flourence O, Manyasa E, Muthomi J. 2017. Genetic variability, heritability, genetic advance and trait correlatons in selected Sorghum (*Sorghum bicolor* L. Moench) varieties. Int.J.Agron. Agri. R. 11 (5): 47-56.

Kotal BD, Das A, Choudhury BK. 2010. Genetic Variability and Association of Characters in Wheat (*Triticum aestivum* L.). Asian Journal of Crop Science 2(3):155-160. http://dx.doi.org/10.3923/ajcs.2010.155.160

Kusumawati A, Putri NK, Suliansyah I. 2013. Karakterisasi dan Evaluasi Beberapa Genotipe Sorgumn (*Sorghum bicolor* L) di Sukarami Kabupaten Solok. Jurnal Agroteknologi 4(1): 7-12. http://dx.doi.org/10.24014/ja.v4i1.57

Maftuchah, Reswari HA, Ishartati E, Zainudin A, Sudarmo H. 2015. Heretability and Correlation of Vegetative and Generative Character on Genotypes of Jatropha (*Jatropha curcas* Linn.). Energy Procedia 65 : 186-193. https://doi.org/10.1016/j.egypro.2015.01.058

Mundia CW, Secchi S, Akamani K, Wang G. 2019. A Regional Comparison of Factor Affecting Global Sorghum Production: The Case of North America, Asia and Africa's Sahel. Sustainability 11 (2135) doi:10.3390/su11072135

Panjaitan R, Zuhry E, Deviona. 2015. Karakterisasi dan Hubungan Kekerabatan 13 Genotipe Sorgum (Sorghum Bicolor (L.) Mouch Koleksi Batan. Jurnal JOM Faperta. Vol. 2 No. 1.

Rahajeng W, Rahayuningtyas A. 2015. Pendugaan Komponen Ragam, Heritabilitas dan Korelasi Klon-Klon Harapan Ubijalar Berkadar Betakaroten Tinggi. Jurnal Ilmu Pertanian Vol. 18 No.1. https://doi.org/10.22146/ipas.6177

Rifa'i H, Ashari S, Damanhuri. 2015. Keragaman 36 Aksesi Sorgum *(Sorghum bicolor L.)*. Jurnal Produksi Tanaman. 3(4): 330-337.

Seetharam K, Ganesamurthy K. 2013. Characterization Of Sorghum Genotypes For Yield And Other Agronomic Traits Through Genetic Variability And Diversity Analysis. Electronic Journal of Plant Breeding 4(1): 1073-1079.

Setiawan K, Kamal M, Hadi MS, Sungkono, Maulana I. 2016. Keragaan beberapa kandidat genotip sorgum sebagai penghasil biomasa. hlm 373-380. *Dalam Prosiding Seminar Nasional dan Kongres 2016 Perhimpunan Agronomi Indonesia (PERAGI)*. Departemen Agronomi dan Hortikultura, Institut Pertanian Bogor, Bogor.

Setiawan K, Restiningtias R, Utomo SD, Ardian, Hadi MS, Yuliadi E. 2019. Keragaman Genetik, Fenotip, dan Heritabilitas Beberapa Genotipe Sorghum pada Kondisi Tumpangsari dan Monokultur. Jurnal Agro 6 (2): 95-109. https://doi.org/10.15575/4568

Setiyagama MJ, Arifin AZ, Sulistyawati. 2017. Karakterisasi Beberapa Genotip Sorgum *(Sorghum bicolor* L.) Lokal Jawa Timur. Dalam jurnal Agroteknologi Merdeka Pasuruan 1 (2):18-22.

Sirappa MP, Waas ED. 2009. Kajian Varietas dan Pemupukan Terhadap Peningkatan Hasil Padi Sawah di Dataran Pasahari, Maluku Tengah. Jurnal pengkajian dan pengembangan teknologi pertanian Vol. 12 No. 1.

Sirappa MP. 2003. Prospek Pengembangan Sorghum di Indonesia sebagai Komoditas Alternatif untuk Pangan, Pakan, dan Industri. Jurnal Litbang Pertanian 22 (4).

Sulistyowati, Roeswitawati D, Ibrahim JT, Maftuchah. 2019. Agronomic Character of Several Local Genotypes of Sorghum (*Sorghum bicolor* L.) at East Java. IOP Conf. Series : Materials Science and Engineering 532. doi:10.1088/1757-899X/532/1/012023

Sulistyowati, Roeswitawati D, Ibrahim JT, Maftuchah. 2019. Genetic Diversity of Local Sorghum (*Sorghum bicolor*) Genotypes of East Java, Indonesia for Agro-Morphological and Physiological traits. Biodiversitas 20 (9) : 2503-2510. https://doi.org/10.13057/biodiv/d200911

Susilowati SH, Saliem HP. 2013. Perdagangan Sorgum di Pasar Dunia dan Asia serta Prospek Pengembangannya di Indonesia. Dalam: Sumarno, et al. (eds). Sorgum: Inovasi Teknologi dan Pengembangan. IAARD Press, Jakarta.

Morphological diversity and heritability of nine local sorghum (*Sorghum bicolor*) genotypes (*Sorghum bicolor* in East Java

Abstract. Sorghum (*Sorghum bicolor* L. Moench) is an essential food crop after wheat, rice, maize, and barley. IIt has –wide adaptability. to various environmental conditions, including can be grown on marginal lands, so that it is potential to be developed as cheap soource of carbohydrate. The present study aims at stdyingaimed to obtain information about the morphological diversity and heritability values of local sorghum genotypes occurred in East Java Province, Indonesia.the morphological diversity and heritability values of major sorghum landraces in East Java. The research was conducted in Purutrejo village, of -Pasuruan city using nine . The local genotypes, namely -were derived from Jombang (SG-JBG), Tuban (SG-TBN), Pasuruan (GB-PSR), Lamongan 1 (SG-LMG 1), Lamongan 2 (SG-LMG 2), Sampang 1 (SG-SPG 1), Sampang 2 (SG-SPG 2), Tulungagung 1 (SG-TLG 1), and Tulungagung 2 (SG-TLG 2). The results showed that the genotype of the SampangSG-SPG 2 genotype produced the longest panicles, while the SG-LMGLamongan 2 had the highest seed dry weight per panicle and highest number of seeds per panicle (117.34 gram/panicle dry weight and 4581.80 seeds/panicle). The genotype of SG-TLGTulungagung 2 produced the largest weight of seeds, either in highest fresh seed (41.43 g/1000 seeds) orand dry seed weight (31.96 g/1000 seeds). In addition, , the results also showed that it was genetically different from Tulungagung 1 genotype. Similarly, the highest number of tillers was produced by Tulungagung 2 (4.20 tiller) and was not significantly different from Tulungagung 1 (3.33 tiller) and Jombang (2.07 tiller). Based on the result o Of the nine genotypes tested, the flowering ages ranged from 42 to 53 days after planting, and the harvest ages ranged from 70 to 91 days after planting with the fastest harvest age was achieved by SG-TLG 2 (70 days after planting). f nine local genotypes tested, the flowering ranged from 42 to 53 days after planting and days to harvest ranged from 70 to 91 days after planting. The early maturity was observed in Tulungagung 2 (70 days after planting) as against others. The entire value of the phenotype variety on each variable was more significant than the value of the genotype range. Heritability test results show that all experimental parameters exceed 0.5 so that it is categorized as high heritability.

The phenotype variety's entire value on each variable was significant than the amount of the genotype range. The highest heritability value in all the observed exceeded 0.5.

Keywords: diversity, heritability, landrace, *Sorghum bicolor* Linn.

INTRODUCTION

The increasingHuman population growth globally has increased the need for various agricultural commodities, especially cereals and pulses.. Among the cereals, sSorghum (*Sorghum bicolor* L) is one of the world's essential crops as the primary source of carbohydrates after wheat, rice, corn, and barley. Sorghum could be developed as an alternative to substitute and/or to complement local food consumption besides rice to enhanceincrease food needsdiversification. Besides,In addition to human food source, Ssorghum also has also the potential as animal feed and raw materials for various industriesal material.

Sorghum is an annual crop that iswas easy to cultivate, but its production is still lower than that of rice, maize, and other cereal crops. Sorghum has wide environmental adaptability and can be developed in areas with less adaptive environmental conditions to climate change (Sirappa, 2003; Mundia *et al*., 2019). These As such,showed that S sorghum has more potential to be developed as an alternative crop on marginal lands compared to rice as an alternative to increaseing local food supplies on marginal lands compared to rice (Sulistyowati *et al*., 2019a). Besides, current research indicated that several local genotypes of sSorghum, which contain high carbohydrates and protein, could be used for various food preparations (Sulistyowati *et al*., 2019b). Any efforts in– Ssorghum improvement would upplement help government initiatives in reducing the burden of rice production and wheat import (Susilowati and Saliem, 2013).

Genetic characterization of germplasm lines aims to identify important traits that have economic value or specific characteristics which possess specific characteristics of the variety concernedto be targeted and retained. The characters could be morphological (both in in term of (qualitative, such as…. and quantitative, such as…), agronomic (e.g. fFlowering and maturity time,), and physiological, (e.g.….). The processes of Ccharacterization and evaluation precesses have essential meanings and roles to obtain the genetic lines that have excellence determining these materials' good

Comment [A1]: All in all, what genotype is the most promising one to be developed?

Formatted: Font: Italic

Comment [A2]: If any, please provide the total production of each crop (either globally or at national scale) along with the reference source(s).

Comment [A3]: It is not clear what you mean quantitative and qualitative, so providing an example would give a better understanding.

Comment [A4]: Please provide example of such characters.

traits~~value~~ (Kusumawati *et al*., 2013). In the context of sorghum, ~~T~~the differences in ~~Sorghum's~~ genotype could be recognized more clearly in the generative phase than in the vegetative phase (Elvira *et al*., 2015).

The diversity in ~~among~~ ~~these~~ crop varieties and accessions will help plant breeding activities, especially in providing plant breeding materials (Rifa'i *et al*., 2015).

Genetic diversity facilitates the selection process in field crops including sorghum. If the genetic variance ~~were~~ is high, the heritability value would be high. Thus, the variable could be used as a selection criterion (Setiawan *et al.*, 2019). Heritability value could be interpreted as the proportion between genetic variance and phenotypic variance (Falconer & Mackay, 1996). The heritability value of a character do~~id~~ not necessarily indicate that the character inherited is affected by genetic factors or environmental conditions (Maftuchah *et al.*, 2015).

Similarly, ~~I~~information on morphological diversity and heritability values in sorghum would help breeders to obtain ~~breed for~~ local sorghum genotypes with preferred characteristics suitable for particular purpose, for example as an alternative food source for~~to~~ human consumption~~food~~, animal feeding ~~feed,~~, or raw material of fuel production~~fuel~~. ~~In this context,~~ The present study aimed to obtain information about the morphological diversity and heritability values of local sorghum genotypes occurred in ~~of~~ East Java Province, Indonesia. We expected the results of this study could serve as baseline information for future research and development of sorghum cultivation, especially in East Java.

MATERIALS AND METHODS

Plant materials

The research was conducted in Purutrejo village, Purworejo Sub-district, Pasuruan ~~c~~City, East Java Province. ~~The~~ ~~p~~Plant~~ing~~ materials used in this study were ~~consisted of~~ nine genotypes of local sorghum plants derived from various regions in East Java, i.e., Jombang (SG-JBG), Tuban (SG-TBN), Pasuruan (GB-PSR), Lamongan 1 (SG-LMG 1), Lamongan 2 (SG-LMG 2), Sampang 1 (SG-SPG 1), Sampang 2 (SG-SPG 2), Tulungagung 1 (SG-TLG 1), Tulungagung 2 (SG-TLG 2).

Experimental design

The experiment was conducted as randomized block design with three replications. The design consisted of one factor (i.e. ~~9~~nine genotypes of local ~~S~~sorghum) so that there was 27 experimental units in total. The planting of sorghum ~~planting~~ was carried out by ~~seeding~~ sowing sorghum seeds on a tray used a planting medium containing~~, i.e.,~~ soil and compost. Seedlings were then planted in the field after ten days of ~~planting~~ sowing with a planting~~ed~~ distance of 75 cm x 15 cm at plots measuring 3 x 2.5 m. Thus, each plot consist~~ed~~s of 21 sorghum plants. The fertilizers used were organic fertilizers and ~~inorganic~~ chemical fertilizers (SP 36, Urea, and KCL). Manure is an essential fertilizer given at the same time ~~as~~ when conducted tilling~~age~~. Meanwhile, ~~inorganic~~chemical fertilizers were~~are~~ applied to the planting hole when the plants were~~are~~ 2 weeks ~~W~~after ~~AP~~planting (WAP) and 4 WAP.

Data collection and analysis

The variables observed were plant height, number of leaves, stem diameter, panicle length, total dry weight of grains per panicle, number of grains per panicle, fresh weight of 1000 grains, dry weight of 1000 grains, leaf length, leaf width, plant height at harvest, tillers, age, and harvest of flowering and harvest age. Data analysis was performed using variance analysis and continued with the 5% LSD test, analysis of variance and heritability testing.

RESULTS AND DISCUSSION

Morphological characters~~:~~

Genotypic factor~~treatments~~ showed significant differences in plant height and number of leaves at 21, 28, and 35 days after planting. Table 1 shows the average plant height and number of leaves of the nine ~~several~~ local sorghum genotypes in East Java at various observation ages. Our results indicate that the genotype of SG-TLG 2 had the highest plant height with 63.97 cm, followed by SG-JBG and SG-TLG 1 with 63.30 and 62.04 cm, respectively. On the other hand, the highest average number of leaves was shown by the genotype of SG-JBG with 8.53 strands, followed by SG-TLG 1 and SG-LMG 1 with 8.40 and 8.33 strands, respectively.

Plant's appearance is influenced by one genetic factor (Panjaitan *et al*., 2015). ~~-~~Plant height is one of the growth parameters that is often used to determine environmental or genetic influences. Leaves are the primary organ for photosynthesis. The influence of the environment results in the genotype being able to display in its character. The existence of inappropriate environmental influences results in the appearance of genetic traits that is~~t was~~ not optimal. ~~Leaves are the primary organ for photosynthesis. The highest average number of leaves was shown by the genotypes of Jombang, Lamongan 1, and Tulungagung 1 (Table 2). In comparison, the largest average stem diameter is shown by Genotype Lamongan 2 (Table 3). The diversity of a plant's appearance is influenced by one genetic factor (Panjaitan *et al.*, 2015).~~

Formatted: English (U.S.)

Formatted: English (U.S.)

Formatted: Font: Bold

Formatted: Indent: First line: 0 cm

Formatted: Font: Bold

Formatted: Indent: First line: 0 cm

Comment [A5]: It is a bit confusing to imagine. I would suggest to a diagram presenting the experimental design.

Formatted: Indent: First line: 0 cm

Comment [A6]: It is not clear what methods you used to test genetic variability and heritability. So, I would suggest you to elaborate how you did those analysis in the Methods.

Comment [A7]: Please be systematic when presenting the Results and Discussion. In the current version, it is very confusing to follow as the explanation of the results and discussion were jumping around. For each table presented in the Results and Discussion, please add one paragraph describing the results and one paragraph elaborating the discussion. I provided an example how to do that in the paragraph explaining the result of Table 1. Please do it similarly for the rest of the tables.

Comment [A8]: Please be in line when expressing the genotype in text and in the table so that the readers not confused. For example, if you used SG-JBG in the table, please use similar term in the text (SG-JBG), and not Jombang.

Comment [A9]: The elaboration of the results was very limited. I would suggest to add the most interesting results as the example I provided.

Comment [A10]: It is hard to imagine the morphology of the plants if only described by text. I would suggest to add photograph of each genotype in which for each genotype at least presenting the whole body of the plant and the panicle/grain.

Table 1. Plant height (cm) and number of leaves (strands) of several East Java local sorghum genotypes at various observation ages

Genotype	Plant h~~H~~eight (cm)								Number of l~~L~~eaves (strands)							
	14 DAP		21 DAP		28 DAP		35 DAP		14 DAP		21 DAP		28 DAP		35 DAP	
SG-JBG	8,56	a	14,99	b	24,16	cd	63,30	e	4,80	d	6,80	d	7,93	c	8,53	e
SG-TBN	7,55	a	13,71	ab	22,10	ab	48,37	bcd	4,47	bc	6,47	cd	7,80	bc	8,13	de
SG-PSR	8,31	a	15,42	b	22,88	abc	55,55	cde	3,93	b	5,80	cd	7,07	bc	7,20	cd
SG-LMG 1	7,96	a	13,30	ab	22,65	abc	42,14	abc	4,27	bc	5,87	cd	7,87	c	8,33	e
SG-LMG 2	6,97	a	13,89	ab	20,43	ab	34,80	ab	4,07	bc	5,80	cd	7,27	bc	8,20	de
SG-SPG 1	7,13	a	11,03	a	17,27	a	29,55	a	2,53	a	2,87	a	4,67	a	5,13	a
SG-SPG 2	6,84	a	15,94	b	29,02	cd	46,60	bc	3,87	b	4,53	b	5,33	a	5,67	ab
SG-TLG 1	9,21	a	15,91	b	26,91	bc	62,04	de	4,00	bc	6,33	cd	7,47	bc	8,40	e
SG-TLG 2	8,43	a	15,77	b	33,87	d	63,97	e	4,00	bc	5,60	bc	6,73	bc	6,73	cd

Note: The numbers followed by the same letter in the same column show no significant difference in the 5% LSD test.

Comment [A11]: Throughout the text, please use dot point when expressing decimal and not comma as in current version.

Table 2 shows the average stem diameter at 28 DAP and 35 DAP, leaf length and width, ~~-~~the average plant height at harvest and the number of tillers. ~~of several genotypes of local Sorghum in East Java. In comparison, the average plant height at harvest and the number of tillers were shown in Table 3.~~ The biggest stem diameter was obtained by the genotypes of SG-LMG 2 and SG-TLG 2 with….., followed by SG-TBN with…... The genotype of SG-LMG 2 had the longest leaf with….., followed by SG-TLG 1 and SG-TBN with …..and…..respectively, while the genotype with the biggest leaf width was SG-LMG 1 with…., followed by SG-LMG 2 and SG-TLG 1 with……and……., respectively. When harvested, SG-TLG 1 had the highest height with…….., followed by SG-TBN and SG-JBG with……and…….respectively, while the genotype with the largest number of tillers was SG-TLG 2 with….., followed by SG-TLG 1 and SG-PSR with …..and……, respectively. Nonetheless, ~~T~~the highest number of tillers ~~was~~ which was produced by genotype ~~Tulungagung~~ SG-TLG 2 ~~(4.20 tillers) and~~ did not differ significantly from ~~genotype~~ SG-TLG 2.

~~Tulungagung 1 (3.33 tillers) and genotype Jombang.~~ The ~~diversity o~~varying ~~f~~ observations results indicate~~s~~ that each genotype has different characteristics. Siswanto (2015) states that the genetic characteristics of varieties, the environment in which they are grown, and the cultivation treatment will affect s~~S~~orghum's yield potential. Genetic and environmental factors determine the number of ~~chicks~~ tillers produced.

Comment [A12]: Please add the value of each variable mentioned here as an example provided for Table 1.

Table 2. Average stem diameter, length, the width of leaves, the value of plant height at harvest, and number of tillers of several East Java local sorghum genotypes

Genotype	Stem d~~D~~iameter (cm)				Leaf length (cm)		Leaf w~~W~~idth (cm)		Plant h~~H~~eight at h~~H~~arvest (cm)		Number of t~~T~~illers	
	28 DAP		35 DAP									
SG-JBG	1,27	Bc	1,47	bcd	77,27	d	7,70	d	255,72	d	2,07	c
SG-TBN	1,29	Bc	1,51	cd	79,15	d	7,82	de	262,33	d	2,13	ab
SG-PSR	1,14	Abc	1,19	ab	78,40	d	6,75	c	202,40	c	2,27	ab
SG-LMG 1	1,26	Abc	1,46	bcd	82,14	d	8,84	e	139,47	a	1,33	a
SG-LMG 2	1,37	C	1,83	e	76,01	cd	8,24	de	167,50	b	1,87	a
SG-SPG 1	1,19	Abc	1,24	abc	69,96	bc	5,69	b	191,67	c	2,07	ab
SG-SPG 2	0,93	A	1,05	a	49,29	a	4,56	a	136,15	a	1,80	a
SG-TLG 1	1,37	C	1,56	de	80,11	d	7,84	de	274,23	d	3,33	bc
SG-TLG 2	1,02	Ab	1,03	a	68,33	bc	4,79	ab	214,05	c	4,20	c

Note: The numbers followed by the same letter in the same column show no significant difference in the 5% LDS test

Comment [A13]: As per comment above, please use dot point when expressing decimal.

Yield contributing traits~~:~~

Observed parameters related to yield contributing traits include ~~The~~ average panicle length, total seed dry weight per panicle, number of seeds per panicle, fresh weight, and dry weight 1000 seeds. The results of such parameters for each sorghum genotype studied here are presented in Table 3 ~~of several East Java local sorghum genotypes are shown in Table 3~~. The genotype of ~~Sampang 2~~SG-SPG 1 ~~genotype shows~~ had the longest panicle size with….cm, followed by SG-TLG 2 and SG-TLG 1. ~~while~~ The genotype of SG-LMG ~~Lamongan~~ 2 produce~~d~~s the ~~longest~~ largest seed dry weight per panicle (117.34 grams), followed . ~~dry seeds/panicle) and the highest number of seeds per panicle (4581.80 seeds/panicle)~~by

…..and…..with…., respectively…AND SO ON>>>PLEASE DEVELOPED SIMILAR AS THE EXAMPLEs ABOVE FOR ALL PARAMETERS IN TABLE 3.

~~(Table 3).~~ Long panicles of plants are formed in the primordia phase. The difference in panicle length is due to different genotypes and inherited traits. Each genetic factor and the adaptability of each variety is different so that it affects the length of sorghum panicles (Sirappa and Waas, 2009).

Total dry weight is one measure to study further plant growth (Ferdian et al., 2015). The total dry weight per panicle is one of the criteria for the production of s~~S~~orghum. Genetic differences will result in a different panicle shape or weight of the seed unit so that each genotype has a different dry weight. Plants require sufficient nutrient content for seed formation. ~~The highest total dry weight and the number of seeds per panicle were produced by the genotype Lamongan 2. The genotype of Tulungagung 2 produced the highest fresh weight and dry weight of 1000 seeds and was not significantly different from Tulungagung 1. The fresh weight of seeds in Tulungagung 2 was 41.43 grams / 1000 seeds, and the dry weight was 31.96 grams / 1000 seeds.~~ Genotypic differences result in different shape and weight of seeds.

Table 3. The average length of panicle, total dry weight of seeds per panicle number of seeds, fresh and dry weight of 1000 seeds per panicle of several East Java local sorghum genotypes

Genotype	Panicle ~~L~~length (cm)		Total ~~S~~seed d~~D~~ry ~~W~~weight p~~P~~er ~~P~~panicle (g-/-panicle)		Number of s~~S~~eeds per p~~P~~anicle		Fresh w~~W~~eight 1000 s~~S~~eeds (g)		Dry ~~W~~weight 1000 s~~S~~eeds (g)	
SG-JBG	23,92	a	88,87	c	3081,80	de	37,86	cde	28,87	cd
SG-TBN	26,13	a	82,94	bc	3125,70	de	34,61	bc	26,50	bc
SG-PSR	34,69	b	68,68	b	2293,90	bc	37,25	cd	30,06	de
SG-LMG 1	25,50	a	86,68	bc	3563,90	e	34,07	bc	24,66	ab
SG-LMG 2	38,53	bc	117,34	d	4581,80	f	32,73	b	25,87	ab
SG-SPG 1	35,83	b	44,23	a	1962,10	ab	26,45	a	23,22	a
SG-SPG 2	47,75	d	48,70	a	1840,80	ab	32,65	b	26,51	bc
SG-TLG 1	41,29	c	86,69	bc	2746,60	cd	41,04	de	31,55	de
SG-TLG 2	41,73	c	45,72	a	1426,80	a	41,43	e	31,96	e

Note: The numbers followed by the same letter in the same column show no significant difference in the 5% LDS test

Table 4 shows that the flowering ages ranged from 42 to 53 days after planting. Meanwhile, the harvest age ranged~~s~~ from 70 to 91 days after planting with~~.~~ ~~T~~the fastest harvesting age was on genotype SG-TLG~~Tulungagung~~ 2 (70 days after planting), followed by SG-PSR, SG-LMG 1 and SG-TLG 1 with 77 days after planting. The existence of the suitability of environmental conditions can stimulate the flowering and harvesting age faster. Besides, the nutrients absorbed by plants are used as a source of energy in plant growth (Setiyagama, 2017).

Table 4. Flowering age, flowering to harvest, and harvesting age of several East Java local sorghum genotypes

Genotype	Days to flower (DAP)	Flowering -to h~~H~~arvest (days~~Days~~)	Days to maturity (DAP)
SG-JBG	53	38	91
SG-TBN	53	33	86
SG-PSR	49	28	77
SG-LMG 1	49	28	77
SG-LMG 2	51	35	86
SG-SPG 1	42	44	86
SG-SPG 2	42	49	91
SG-TLG 1	53	24	77
SG-TLG 2	38	32	70

Note: Days to maturity is the sum of days after planting to flower and days of flowering to harvest.

Formatted: Font color: Red

Formatted: Font color: Red

Comment [A14]: As per comment above, please use dot point when expressing decimal.

Formatted: Indent: First line: 0,5 cm

Formatted: English (U.S.)

Genetic variability and heritability

The analysis of environment~~al diversity~~, genotype, and phenotype variability is shown in Table 9. These data indicate the criteria for broad genotype and phenotype variance. All values for the phenotype variety on each variable were more significant than the values for genotype variance. The indication of this is the influence of the genotype and the environment (Kotal *et al.*, 2010). Genotype diversity is a measure of genetic variation caused by the components of the genotype. In contrast, phenotype diversity is a variation of characters regulated by genotype factors and the growing environment and the two's interaction.

The wide variety of genotypes in the nine local sorghum genotypes in East Java indicates inequalities in genetic characters between genotypes. Dominant genotype variety is the main cause of the inequality of characters among plant relatives. High genetic diversity indicates a high potential for use in the improvement of plant traits. Genetic facts are inferred from phenotypic observations, which are the results of genotype interactions and the environment. The variability available in breeding material is the prime requirement for improving and selecting elite genotypes (Seetharam and Ganesamurthy, 2013).

~~Genetic variability and heritability~~

Table 5. Analysis of e~~E~~nvironmental v~~V~~ariety, g~~G~~enotype, and p~~P~~henotype

Traits	σ^2 e	σ^2 g	2σ g	Criteria	σ^2 p	2σ p	Criteria
Plant Height (cm)	26,56	2659,65	166.76	broad	2686,22	0,14	broad
Number of Leaves	0,52	138,75	7.97	broad	139,28	0,02	broad
Stem Diameter (cm)	0,07	4,99	0.34	broad	5,06	0,01	broad
Panicle Length (cm)	12,95	9206,55	515.25	broad	9219,5	0,10	broad
Number of Seeds per Panicle	405537	125860168,2	7186137.17	broad	126265705,06	17,83	broad
Seed / Panicle Dry Weight (g)	271,79	79463,18	4547.67	broad	79735	0,46	broad
Fresh Weight 1000 seeds (g)	11,32	2847,39	164.05	broad	2858,71	0,09	broad
Dry Weight 1000 seeds (g)	6,47	1213,8	71.15	broad	1220,28	0,07	broad
Leaf Length (cm)	29,47	13576,55	765.99	broad	13606	0,15	broad
Leaf Width (cm)	0,67	320	18.04	broad	320,67	0,02	broad
Plant Height at Harvest (cm)	414,57	356701,73	19913.49	broad	357116	0,57	broad
Number of Tillers	1,32	92,32	6.2	broad	93,64	0,03	broad

N~~n~~otes: σ^2 e (Variety of Environment)~~;~~ σ^2 g (Variety of Genotypes), 2σ g (Standard Deviation of Genotype Variety), Criteria for genotype variety: σ^2 g < 2σ g (narrow) dan σ^2 g > 2σ g (broad); σ^2 p (Variety of Phenotypes), 2σ p (Standard Deviation of Phenotype Variety). ~~,~~ Criteria for phenotype variety: ~~σ^2 g < 2σ g (Narrow) dan σ^2 g > 2σ g (broad).~~ σ^2 p < 2σ p (n~~N~~arrow) dan σ^2 p > 2σ p (broad) .

Heritability value analysis shows that all tested parameters exceed 0.5 for each observed variable so that it is categorized as high heritability. Chaudhary (2001) ~~concluded~~ stated that the high coefficient of phenotype variety compared to the coefficient of genotype variance indicates a good effect on all genotypes' environment. The wide diversity of phenotypes comes from a wide diversity of genotypes, so that the requirement for the selection process to take place in the genotype selection process is wide genetic diversity. (Rahajeng and Rahayuningtyas, 2015).

In a broad sense, the heritability prediction value is the ratio between the total genetic variance and the phenotype variety, which shows the large proportion of genetic factors in a plant character's phenotype. The estimated high heritability means that plant genetic factors that affect plant phenotypes are very large compared to environmental factors (Ardiyanti et al., 2019). The phenotype variety analysis showed that the phenotype diversity in all observed genotypes was also high (Table 6). In general, high genotype diversity will be followed by high phenotype diversity. The diversity will be inherited can be measured using the heritability parameter. It is ~~was~~ a broad sense, a comparison between the magnitude variety of genotypes and a character's phenotypes.

The high heritability followed by wide genetic diversity in the nine East Java local sorghum genotypes indicates that genetic factors influence the characters. The high heritability of some local East Java sorghum genotypes is due to genetic factors. If genetic factors play a more important role, these characters can be inherited, and it is hoped that selection can be useful for the observed traits (Maftuchah et al., 2015). Besides, Jimmy et al. (2017) reported that high heritability was generated by all observed agronomic characters and indicated that additive genes played a more critical role in improving plant breeding more quickly. This study's results are also in line with Setiawan et al. (2016), who showed that the plant height variables of 20 sorghum genotypes showed high heritability. The selection criteria for Sorghum could be used as a biomass producer. However, this research needs to study the local s~~S~~orghum ~~more deeply~~further as ~~an~~ alternative food, animal feed, or industrial raw material.

Table 6. Heritability

Traits	Heritability	Criteria

Comment [A15]: While the findings are very interesting, it is not clear what methods you used to test genetic variability and heritability as per comment above in the Method. So I would suggest you to elaborate how you did those analysis in the Methods.

Comment [A16]: It is not clear which table you referred to here. Do you mean Table 5? Please check again and correct it.

Formatted: Normal

Formatted Table

Comment [A17]: As per comment above, please use dot point when expressing decimal.

Comment [A18]: The table caption is very short and not clear describing what. Please write the table caption properly and clearly.

Plant Height (cm)	0,990	High
Number of Leaves	0,996	High
Stem Diameter (cm)	0,986	High
Panicle Length (cm)	0,999	High
Number of Seeds per Panicle	0,997	High
Seed / Panicle Dry Weight (g)	0,997	High
Fresh Weight 1000 seeds (g)	0,996	High
Dry Weight 1000 seeds (g)	0,995	High
Leaf Length (cm)	0,998	High
Leaf Width (cm)	0,998	High
Plant Height at Harvest (cm)	0,999	High
Number of Tillers	0,986	High

Description: High Heritability ($H \geq 50\%$ or $H \geq 0,5$ Medium heritability ($20\% < H < 50\%$ or $0,2 < H < 0,5$), low Heritability ($H \leq 20\%$ or $H \leq 0,2$).

In summary, ~~T~~the results showed that the ~~Sampang~~SG-SPG 2 genotype produced the longest~~most extended~~ panicle size, while ~~. The~~ SG-LMG ~~Lamongan~~ 2 genotype produced the highest seed dry weight per panicle and the highest number of seeds per panicle (117.34 grams of seed dry weight per panicle and 4581.80 seeds per panicle). The genotype of SG-TLG~~Tulungagung~~ 2 produced the highest fresh weight (41.43 grams) and dry weight (31.96 grams) of 1000 seeds, but it ~~and~~ was not different from SG-TLG~~Tulungagung~~ 1. ~~The fresh weight of 1000 seeds in Tulungagung 2 was 41.43 grams, and the dry weight of 1000 seeds was 31.96 grams.~~ The highest number of tillers was produced by SG-TLG~~Tulungagung~~ 2 (4.20 chicks) and was not significantly different from ~~Tulungagung~~ SG-TLG 1 (3.33 chicks) and SG-JBG~~Jombang~~ (2.07 chicks). Of the nine genotypes tested, the flowering ages ranged from 42 to 53 days after planting, and the harvest ages ranged from 70 to 91 days after planting. The fastest harvest age ~~is~~ was achieved by SG-TLG~~in Tulungagung~~ 2 (70 days after planting). All parameters tested showed the criteria for a wide range of genotypes and phenotypes. The entire value of the phenotype variety on each variable was more significant than the value of the genotype range. Heritability test results show that all experimental parameters exceed 0.5 so that it is categorized as high heritability.

ACKNOWLEDGEMENTS

Author would like to thank the Directorate of Research and the Community Service University of Muhammadiyah Malang that has funded this research through the center of study's flagship program in 2017.

REFERENCES

Ardiyanti SE, Sopandie D, Wirnas D, Trikoesoemaningtyas. 2019. Ratoon Productivity of sorghum Breeding Lines (*Sorghum bicolor* (L.) Moench). IOP Conf. Series: Earth and Environmental Science 399 012030. Doi:10.1088/1755-1315/399/1/012030.

Chaudhary R. R., 2001. Genetic Variability and Heritability in Sugarcane. Nepal Agric. Res. J., Vol. 5.

Elvira SD, Yusuf M, Maiyuslina. 2015. Karakter Agronomi Beberapa Varietas Sorgum pada Lahan Marginal di Aceh Utara. Jurnal Agrium 12(1): 1-4.

Falconer, D.S., T.F.C. Mackay. 1996. Quantitative to Genetics. The Roland Press Company. New York 356p

Ferdian B, Sunyoto, Karyanto A, Kamal M. 2015. Akumulasi Bahan Kering Beberapa Varietas Tanaman Sorgum (Sorghum bicolor (L.) Moench) Ratoon 1 Pada Kerapatan Tanaman Berbeda. J.Agrotek Tropika 3 (1): 41-48.

Jimmy ML, Nzuve F, Flourence O, Manyasa E, Muthomi J. 2017. Genetic variability, heritability, genetic advance and trait correlatons in selected Sorghum (*Sorghum bicolor* L. Moench) varieties. Int.J.Agron. Agri. R. 11 (5): 47-56.

Kotal BD, Das A, Choudhury BK. 2010. Genetic Variability and Association of Characters in Wheat (*Triticum aestivum* L.). Asian Journal of Crop Science 2(3):155-160. http://dx.doi.org/10.3923/ajcs.2010.155.160

Kusumawati A, Putri NK, Suliansyah I. 2013. Karakterisasi dan Evaluasi Beberapa Genotipe Sorgumn (*Sorghum bicolor* L) di Sukarami Kabupaten Solok. Jurnal Agroteknologi 4(1): 7-12. http://dx.doi.org/10.24014/ja.v4i1.57

Maftuchah, Reswari HA, Ishartati E, Zainudin A, Sudarmo H. 2015. Heretability and Correlation of Vegetative and Generative Character on Genotypes of Jatropha (*Jatropha curcas* Linn.). Energy Procedia 65 : 186-193. https://doi.org/10.1016/j.egypro.2015.01.058

Mundia CW, Secchi S, Akamani K, Wang G. 2019. A Regional Comparison of Factor Affecting Global Sorghum Production: The Case of North America, Asia and Africa's Sahel. Sustainability 11 (2135) doi:10.3390/su11072135

Panjaitan R, Zuhry E, Deviona. 2015. Karakterisasi dan Hubungan Kekerabatan 13 Genotipe Sorgum (Sorghum Bicolor (L.) Mouch Koleksi Batan. Jurnal JOM Faperta. Vol. 2 No. 1.

Comment [A19]: All in all, what genotype is the most promising one to be developed?

Rahajeng W, Rahayuningtyas A. 2015. Pendugaan Komponen Ragam, Heritabilitas dan Korelasi Klon-Klon Harapan Ubijalar Berkadar Betakaroten Tinggi. Jurnal Ilmu Pertanian Vol. 18 No.1. https://doi.org/10.22146/ipas.6177

Rifa'i H, Ashari S, Damanhuri. 2015. Keragaman 36 Aksesi Sorgum *(Sorghum bicolor* L.*)*. Jurnal Produksi Tanaman. 3(4): 330-337.

Seetharam K, Ganesamurthy K. 2013. Characterization Of Sorghum Genotypes For Yield And Other Agronomic Traits Through Genetic Variability And Diversity Analysis. Electronic Journal of Plant Breeding 4(1): 1073-1079.

Setiawan K, Kamal M, Hadi MS, Sungkono, Maulana I. 2016. Keragaan beberapa kandidat genotip sorgum sebagai penghasil biomasa. hlm 373-380. *Dalam Prosiding Seminar Nasional dan Kongres 2016 Perhimpunan Agronomi Indonesia (PERAGI)*. Departemen Agronomi dan Hortikultura, Institut Pertanian Bogor, Bogor.

Setiawan K, Restiningtias R, Utomo SD, Ardian, Hadi MS, Yuliadi E. 2019. Keragaman Genetik, Fenotip, dan Heritabilitas Beberapa Genotipe Sorghum pada Kondisi Tumpangsari dan Monokultur. Jurnal Agro 6 (2): 95-109. https://doi.org/10.15575/4568

Setiyagama MJ, Arifin AZ, Sulistyawati. 2017. Karakterisasi Beberapa Genotip Sorgum *(Sorghum bicolor* L.) Lokal Jawa Timur. Dalam jurnal Agroteknologi Merdeka Pasuruan 1 (2):18-22.

Sirappa MP, Waas ED. 2009. Kajian Varietas dan Pemupukan Terhadap Peningkatan Hasil Padi Sawah di Dataran Pasahari, Maluku Tengah. Jurnal pengkajian dan pengembangan teknologi pertanian Vol. 12 No. 1.

Sirappa MP. 2003. Prospek Pengembangan Sorghum di Indonesia sebagai Komoditas Alternatif untuk Pangan, Pakan, dan Industri. Jurnal Litbang Pertanian 22 (4).

Sulistyowati, Roeswitawati D, Ibrahim JT, Maftuchah. 2019. Agronomic Character of Several Local Genotypes of Sorghum (*Sorghum bicolor* L.) at East Java. IOP Conf. Series : Materials Science and Engineering 532. doi:10.1088/1757-899X/532/1/012023

Sulistyowati, Roeswitawati D, Ibrahim JT, Maftuchah. 2019. Genetic Diversity of Local Sorghum (*Sorghum bicolor*) Genotypes of East Java, Indonesia for Agro-Morphological and Physiological traits. Biodiversitas 20 (9) : 2503-2510. https://doi.org/10.13057/biodiv/d200911

Susilowati SH, Saliem HP. 2013. Perdagangan Sorgum di Pasar Dunia dan Asia serta Prospek Pengembangannya di Indonesia. Dalam: Sumarno, et al. (eds). Sorgum: Inovasi Teknologi dan Pengembangan. IAARD Press, Jakarta.

Morphological diversity and heritability of nine local sorghum (*Sorghum bicolor*) genotypes in East Java

MAFTUCHAH[1), 3)*], LIA FEBRIANA[1)] SULISTYAWATI[2)], HELVI ARDANA RESWARI[1)], ERFAN DANI SEPTIA[1), 3)]

[1)] Faculty of Agriculture and Animal Science, University of Muhammadiyah Malang, Jl Raya Tlogomas 246 Malang 65144 East Java, Indonesia Tel +62341-464318-319 Fax +62341-460782

[2)]Faculty of Agriculture, Universitas Merdeka Pasuruan. Jl. Ir. H. Juanda No. 68, Pasuruan City 67129, East Java, Indonesia Tel.: +62-343-413619, Fax.: +62-343-420926,

[3)] Center of Biotechnology Development, University of Muhammadiyah Malang. Jl. Jl. Tlogomas No 246, 1st floor, Malang, East Java, Indonesia. 65144 Tel./Fax. +62-341-464318 (145), *email: maftuchah@umm.ac.id

Abstract. Sorghum (*Sorghum bicolor* L. Moench) is an essential food crop after wheat, rice, maize, and barley. It has wide adaptability to various environmental conditions, including can be grown on marginal lands, so that it is potential to be developed as cheap source of carbohydrate. The present study obtain information about the morphological diversity and heritability values of local sorghum genotypes occurred in East Java Province, Indonesia. The research was conducted in Purutrejo village, Pasuruan city using nine local genotypes, namely Jombang (SG-JBG), Tuban (SG-TBN), Pasuruan (GB-PSR), Lamongan 1 (SG-LMG 1), Lamongan 2 (SG-LMG 2), Sampang 1 (SG-SPG 1), Sampang 2 (SG-SPG 2), Tulungagung 1 (SG-TLG 1) and Tulungagung 2 (SG-TLG 2). The results showed that the genotype of SG-SPG 2 produced the longest panicles, while the SG-LMG 2 had the highest seed dry weight per panicle and highest number of seeds per panicle (117.34 gram/panicle dry weight and 4581.80 seeds/panicle). The genotype of SG-TLG 2 produced the largest weight of seeds, either in fresh seed (41.43 g/1000 seeds) or dry seed (31.96 g/1000 seeds). Of the nine genotypes tested, the flowering ages ranged from 42 to 53 days after planting, and the harvest ages ranged from 70 to 91 days after planting with the fastest harvest age was achieved by SG-TLG 2 The entire value of the phenotype variety on each variable was more significant than the value of the genotype range. Heritability test results show that all experimental parameters exceed 0.5 so that it is categorized as high heritability. In general, the SG-TLG 2 genotype had the most chance to be developed, because it produced the highest seed weight, both fresh seeds (41.43 g / 1000 seeds) and dry seeds (31.96 g / 1000 seeds). Besides, the SG-TLG shows the fastest harvest age (70 days after planting).

Keywords: diversity, heritability, landrace, *Sorghum bicolor* Linn.

INTRODUCTION

Human population growth globally has increased the need for various agricultural commodities, especially cereals and pulses. Among the cereals, sorghum (*Sorghum bicolor* L) is one of the world's essential crops as the primary source of carbohydrates after wheat, rice, corn and barley. Sorghum could be developed as an alternative to substitute and/or to complement local food consumption besides rice to enhance food diversification. In addition to human food source, sorghum has also the potential as animal feed and raw materials for various industries.

Sorghum is an annual crop that is easy to cultivate, but its production is still lower than that of rice, maize, and other cereal crops. The rice production level increased by around 2.33%, while maize increased by 3.91% from 2017 to 2018. However, sorghum production data is still not available, so that sorghum production is still small and not well recorded (Kementerian Pertanian, 2020). Sorghum has wide environmental adaptability and can be developed in areas with less adaptive environmental conditions to climate change (Sirappa, 2003; Mundia *et al*., 2019). As such, sorghum has more potential to be developed as an alternative crop on marginal lands compared to rice to increase local food supplies (Sulistyowati *et al*., 2019). Besides, current research indicated that several local genotypes of sorghum, which contain high carbohydrates and protein, could be used for various food preparations (Sulistyowati *et al*., 2019). Any efforts in sorghum improvement would help government initiatives in reducing the burden of rice production and wheat import (Susilowati and Saliem, 2013).

Genetic characterization of germplasm lines aims to identify important traits that have economic value or specific characteristics to be targeted and retained. The characters could be morphological (e.g., Plant height, number of leaves, stem diameter, panicle length, leaf width, leaf length, etc.) and agronomic (e.g., days of flower, fresh weight 1000 seeds, days of maturity time, dry weight 1000 seeds, total seed dry weight per panicle, etc.). The processes of characterization and evaluation have essential meanings and roles to obtain the genetic lines that have excellence traits (Kusumawati *et al*., 2013). In the context of sorghum, the differences in genotype could be recognized more clearly in the generative phase than in the vegetative phase (Elvira *et al*., 2015).

The diversity in crop varieties and accessions will help plant breeding activities, especially in providing plant breeding materials (Rifa'i *et al*., 2015). Genetic diversity facilitates the selection process in field crops including sorghum. If the genetic variance is high, the heritability value would be high. Thus, the variable could be used as a selection criterion (Setiawan *et al.,* 2019). Heritability value could be interpreted as the proportion between genetic variance and phenotypic variance (Falconer & Mackay, 1996). The heritability value of a character do not necessarily indicate that the character inherited is affected by genetic factors or environmental conditions (Maftuchah *et al.*, 2015).

Similarly, information on morphological diversity and heritability values in sorghum would help breeders to obtain local sorghum genotypes with preferred characteristics suitable for particular purpose, for example as an alternative food source for human consumption, animal feeding, or raw material of fuel production. The present study aimed to obtain information about the morphological diversity and heritability values of local sorghum genotypes occurred in East Java Province, Indonesia. We expected the results of this study could serve as baseline information for future research and development of sorghum cultivation, especially in East Java.

MATERIALS AND METHODS

Plant materials

The research was conducted in Purutrejo village, Purworejo Sub-district, Pasuruan City, East Java Province. Plant materials used in this study were nine genotypes of local sorghum plants derived from various regions in East Java, i.e., Jombang (SG-JBG), Tuban (SG-TBN), Pasuruan (GB-PSR), Lamongan 1 (SG-LMG 1), Lamongan 2 (SG-LMG 2), Sampang 1 (SG-SPG 1), Sampang 2 (SG-SPG 2), Tulungagung 1 (SG-TLG 1), and Tulungagung 2 (SG-TLG 2).

Experimental design

The experiment was conducted as randomized block design with three replications. The design consisted of one factor (i.e. nine genotypes of local sorghum) so that there was 27 experimental units in total. The planting of sorghum was carried out by sowing sorghum seeds on a tray used a planting medium containing soil and compost. Seedlings were then planted in the field after ten days of sowing with a planting distance of 75 cm x 15 cm at plots measuring 3 x 2.5 m. Thus, each plot consisted of 21 sorghum plants. The fertilizers used were organic fertilizers and chemical fertilizers (SP 36, Urea, and KCL). Manure is an essential fertilizer given at the same time when conducted tilling. Meanwhile, chemical fertilizers were applied to the planting hole when the plants were 2 weeks after planting (WAP) and 4 WAP. The flow chart of the implementation of this research activity is as follows:

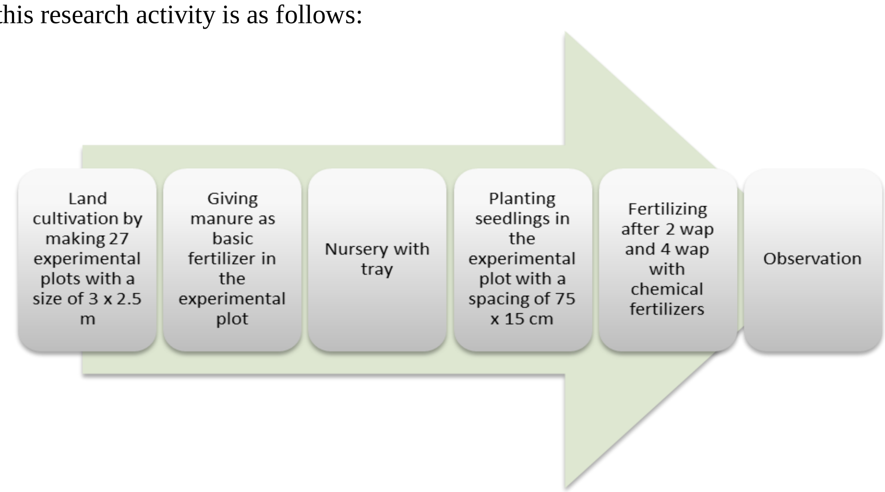

Figure 1. Flowchart of research implementation

Data collection and analysis

The variables observed were plant height, number of leaves, stem diameter, panicle length, total dry weight of grains per panicle, number of grains per panicle, fresh weight of 1000 grains, dry weight of 1000 grains, leaf length, leaf width, plant height at harvest, tillers, age, and harvest of flowering and harvest age. Data analysis was performed using variance analysis and continued with the 5% LSD test, analysis of variance and heritability testing. Analysis of genotype variety, phenotype variety and environmental variance using the formulas ($\sigma^2_e = M1$), ($\sigma^2_g = (M2-M1) / r$) and ($\sigma^2_p = \sigma^2_e + \sigma^2_g$). The M1 and M2 are based on Table 1. The diversity criteria used to follow Pinaria et al. (1995) provisions, namely broad variability if the diversity value is> twice the standard deviation of genetic variance and narrow variability if the variability is <twice the standard deviation of genetic variance. The formula used in estimating heritability is $H = \sigma^2_g / \sigma^2_p$. and classified according to Mac Whirter (1979), namely low heritability: <0.20, medium heritability: 0.20 - 0.50, high heritability: $0.50 < H \leq 1$

Table 1. Analysis of variance

Sources of Diversity (SK)	Degrees of Free (DB)	Sum of Squares (JK)	Middle Value Square (KT)
Group	r-1	JKK	
Genotype	g-1	JKG	M2
Error	(r-1)(g-1)	JKG	M1

RESULTS AND DISCUSSION

Morphological characters

Genotypic factor showed significant differences in plant height and number of leaves at 21, 28, and 35 days after planting. Table 2 shows the average plant height and number of leaves of the nine local sorghum genotypes in East Java at various observation ages. Our results indicate that the genotype of SG-TLG 2 had the highest plant height with 63.97 cm, followed by SG-JBG and SG-TLG 1 with 63.30 and 62.04 cm, respectively. On the other hand, the highest average number of leaves was shown by the genotype of SG-JBG with 8.53 strands, followed by SG-TLG 1 and SG-LMG 1 with 8.40 and 8.33 strands, respectively.

Plant's appearance is influenced by one genetic factor (Panjaitan *et al*., 2015). Plant height is one of the growth parameters that is often used to determine environmental or genetic influences. Leaves are the primary organ for photosynthesis. The influence of the environment results in the genotype being able to display in its character. The existence of inappropriate environmental influences results in the appearance of genetic traits that is not optimal.

Table 2. Plant height (cm) and number of leaves (strands) of several East Java local sorghum (*Sorghum bicolor* (L.) genotypes at various observation ages

Genotype	Plant height (cm)				Number of leaves (strands)			
	14 DAP	**21 DAP**	**28 DAP**	**35 DAP**	**14 DAP**	**21 DAP**	**28 DAP**	**35 DAP**
SG-JBG	8.56 a	14.99 b	24.16 cd	63.30 e	4.80 d	6.80 d	7.93 c	8.53 e
SG-TBN	7.55 a	13.71 ab	22.10 ab	48.37 bcd	4.47 bc	6.47 cd	7.80 bc	8.13 de
SG-PSR	8.31 a	15.42 b	22.88 abc	55.55 cde	3.93 b	5.80 cd	7.07 bc	7.20 cd
SG-LMG 1	7.96 a	13.30 ab	22.65 abc	42.14 abc	4.27 bc	5.87 cd	7.87 c	8.33 e
SG-LMG 2	6.97 a	13.89 ab	20.43 ab	34.80 ab	4.07 bc	5.80 cd	7.27 bc	8.20 de
SG-SPG 1	7.13 a	11.03 a	17.27 a	29.55 a	2.53 a	2.87 a	4.67 a	5.13 a
SG-SPG 2	6.84 a	15.94 b	29.02 cd	46.60 bc	3.87 b	4.53 b	5.33 a	5.67 ab
SG-TLG 1	9.21 a	15.91 b	26.91 bc	62.04 de	4.00 bc	6.33 cd	7.47 bc	8.40 e
SG-TLG 2	8.43 a	15.77 b	33.87 d	63.97 e	4.00 bc	5.60 bc	6.73 bc	6.73 cd

Note: The numbers followed by the same letter in the same column show no significant difference in the 5% LSD test.

Figure 2. Morphology tanaman (SG-JBG), (SG-TBN), (GB-PSR), (SG-LMG 1), (SG-LMG 2), (SG-SPG 1), (SG-SPG 2), (SG-TLG 1), (SG-TLG 2).

Table 3 shows the average stem diameter at 28 DAP and 35 DAP, leaf length and width, the average plant height at harvest and the number of tillers. The biggest stem diameter was obtained by the genotypes of SG-LMG 2 and SG-TLG 1 with 1.83 cm and 1.56 cm followed by SG-TBN with 1.51 cm. The genotype of SG-LMG 1 had the longest leaf with 82.14 cm followed by SG-TLG 1 and SG-TBN with 80.11cm and 79.15 cm respectively, while the genotype with the biggest leaf width was SG-LMG 1 with 8.84 cm, followed by SG-LMG 2 and SG-TLG 1 with 8.24 cm and 7.84 cm, respectively. When harvested, SG-TLG 1 had the highest height with 274.23 cm, followed by SG-TBN and SG-JBG with 262.33 cm and 255.72cm respectively, while the genotype with the largest number of tillers was SG-TLG 2 with 4.20, followed by SG-TLG 1 and SG-PSR with 3.33 and 2.27, respectively. Nonetheless, the highest number of tillers which was produced by genotype SG-TLG did not differ significantly from SG-TLG 2.

The varying observation results indicate that each genotype has different characteristics. Siswanto (2015) states that the genetic characteristics of varieties, the environment in which they are grown, and the cultivation treatment will affect sorghum's yield potential. Genetic and environmental factors determine the number of tillers produced.

Table 3. Average stem diameter, length, the width of leaves, the value of plant height at harvest, and number of tillers of several East Java local sorghum (*Sorghum bicolor* (L.) genotypes

Genotype	Stem diameter (cm)				Leaf length (cm)		Leaf width (cm)		Plant height at harvest (cm)		Number of tillers	
	28 DAP		35 DAP									
SG-JBG	1.27	bc	1.47	bcd	77.27	d	7.70	d	255.72	d	2.07	c
SG-TBN	1.29	bc	1.51	cd	79.15	d	7.82	de	262.33	d	213	ab
SG-PSR	1.14	abc	1.19	ab	78.40	d	6.75	c	202.40	c	2,27	ab
SG-LMG 1	1.26	abc	1.46	bcd	82.14	d	8.84	e	139.47	a	1.33	a
SG-LMG 2	1.37	c	1.83	e	76.01	cd	8.24	de	167.50	b	1.87	a
SG-SPG 1	1.19	abc	1.24	abc	69.96	bc	5.69	b	191.67	c	2.07	ab
SG-SPG 2	0.93	a	1.05	a	49.29	a	4.56	a	136.15	a	1.80	a
SG-TLG 1	1.37	c	1.56	de	80.11	d	7.84	de	274.23	d	3.33	bc
SG-TLG 2	1.02	ab	1.03	a	68.33	bc	4.79	ab	214.05	c	4.20	c

Note: The numbers followed by the same letter in the same column show no significant difference in the 5% LDS test

Yield contributing traits

Observed parameters related to yield contributing traits include average panicle length, total seed dry weight per panicle, number of seeds per panicle, fresh weight, and dry weight 1000 seeds. The results of such parameters for each sorghum genotype studied here are presented in Table 4. The genotype of SG-SPG 2 had the longest panicle size with 47.75 cm, followed by SG-TLG 2 and SG-TLG 1 with 41.73 cm and 41.29 cm, respectively. The genotype of SG-LMG 2 produced the largest seed dry weight per panicle (117.34 g), followed by SG-JBG and SB-TLG 2 with, 88.87 g and 86.69 g respectively. while the genotype with the largest number of seeds per panicle was SG-LMG 2 with 4581.80, followed SG-LMG 1 and SG-TBN with 3563.90 and 3125.70 respectively. The genotype of SG-TLG 2 had the highest fresh weight 1000 seed with 41.43 g, followed by SG-TLG 1 and SG-JBG with 41.04 g and 37.86 g, respectively. While the highest dry weight 1000 seed was SG-TLG 2 with 31.96 g, followed SG-TLG 1 and SG-PSR with 31.55 g and 30.06 g, respectively.

Long panicles of plants are formed in the primordia phase. The difference in panicle length is due to different genotypes and inherited traits. Each genetic factor and the adaptability of each variety is different so that it affects the length of sorghum panicles (Sirappa and Waas, 2009). Total dry weight is one measure to study further plant growth (Ferdian et al., 2015). The total dry weight per panicle is one of the criteria for the production of sorghum. Genetic differences will result in a different panicle shape or weight of the seed unit so that each genotype has a different dry weight. Plants require sufficient nutrient content for seed formation. Genotypic differences result in different shape and weight of seeds.

Table 4. The average length of panicle, total dry weight of seeds per panicle number of seeds, fresh and dry weight of 1000 seeds per panicle of several East Java local sorghum (*Sorghum bicolor* (L.) genotypes

Genotype	Panicle length (cm)	Total seed dry weight per panicle (g/panicle)	Number of seeds per panicle	Fresh weight 1000 seeds (g)	Dry weight 1000 seeds (g)
SG-JBG	23.92 a	88.87 c	3081.80 de	37.86 cde	28.87 cd
SG-TBN	26.13 a	82.94 bc	3125.70 de	34.61 bc	26.50 bc
SG-PSR	34.69 b	68.68 b	2293.90 bc	37.25 cd	30.06 de
SG-LMG 1	25.50 a	86.68 bc	3563.90 e	34.07 bc	24.66 ab
SG-LMG 2	38.53 bc	117.34 d	4581.80 f	32.73 b	25.87 ab
SG-SPG 1	35.83 b	44.23 a	1962.10 ab	26.45 a	23.22 a
SG-SPG 2	47.75 d	48.70 a	1840.80 ab	32.65 b	26.51 bc
SG-TLG 1	41.29 c	86.69 bc	2746.60 cd	41.04 de	31.55 de
SG-TLG 2	41.73 c	45.72 a	1426.80 a	41.43 e	31.96 e

Note: The numbers followed by the same letter in the same column show no significant difference in the 5% LDS test

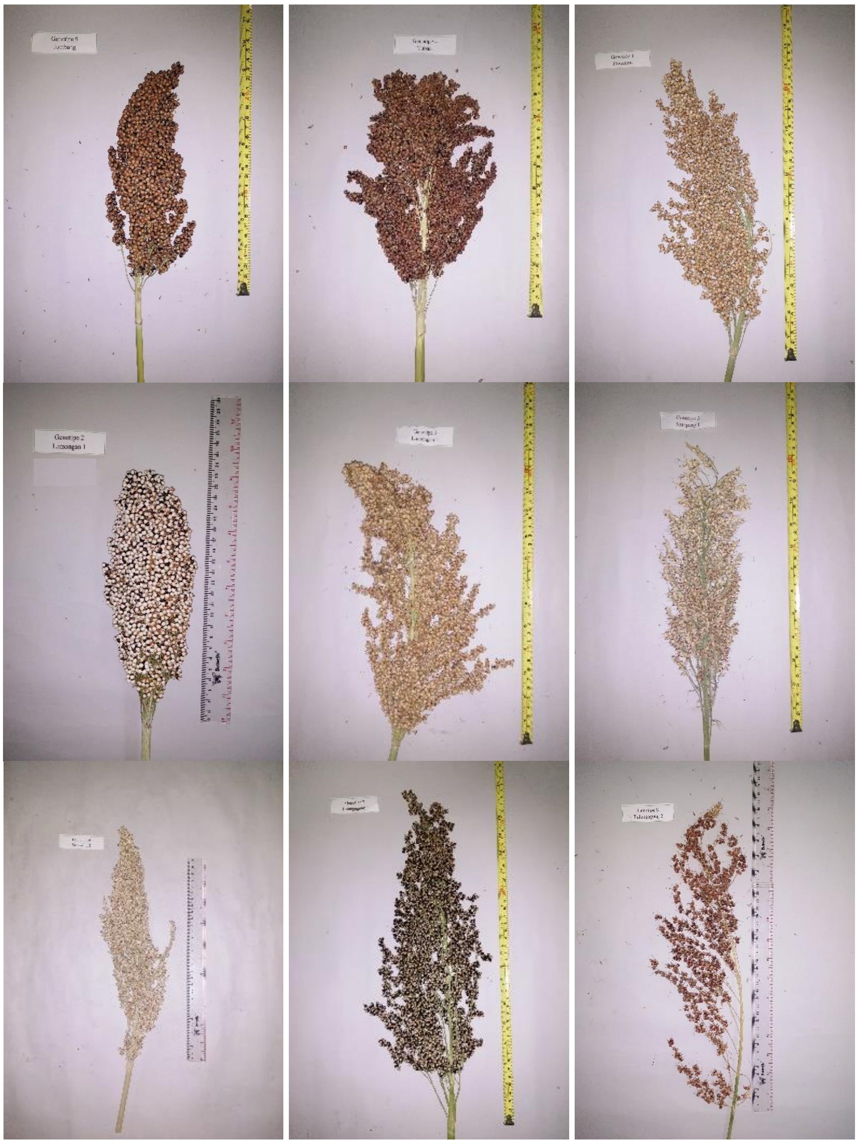

Figure 3. Seed Morphology in several genotypes SG-JBG), (SG-TBN), (GB-PSR), (SG-LMG 1), (SG-LMG 2), (SG-SPG 1),

(SG-SPG 2), (SG-TLG 1), (SG-TLG 2).

Table 5 shows that the flowering ages ranged from 42 to 53 days after planting. Meanwhile, the harvest age ranged from 70 to 91 days after planting with the fastest harvesting age was on genotype SG-TLG 2 (70 days after planting), followed by SG-PSR, SG-LMG 1 and SG-TLG 1 with 77 days after planting. The existence of the suitability of environmental conditions can stimulate the flowering and harvesting age faster. Besides, the nutrients absorbed by plants are used as a source of energy in plant growth (Setiyagama, 2017).

Table 5. Flowering age, flowering to harvest, and harvesting age of several East Java local sorghum (*Sorghum bicolor* (L.) genotypes

Genotype	Days to flower (DAP)	Flowering to harvest (days)	Days to maturity (DAP)
SG-JBG	53	38	91
SG-TBN	53	33	86
SG-PSR	49	28	77
SG-LMG 1	49	28	77
SG-LMG 2	51	35	86
SG-SPG 1	42	44	86
SG-SPG 2	42	49	91
SG-TLG 1	53	24	77
SG-TLG 2	38	32	70

Note: Days to maturity is the sum of days after planting to flower and days of flowering to harvest.

Genetic variability and heritability

The analysis of environment, genotype, and phenotype variability is shown in Table 6. These data indicate the criteria for broad genotype and phenotype variance. All values for the phenotype variety on each variable were more significant than the values for genotype variance. The indication of this is the influence of the genotype and the environment (Kotal *et al.*, 2010). Genotype diversity is a measure of genetic variation caused by the components of the genotype. In contrast, phenotype diversity is a variation of characters regulated by genotype factors and the growing environment and the two's interaction.

The wide variety of genotypes in the nine local sorghum genotypes in East Java indicates inequalities in genetic characters between genotypes. Dominant genotype variety is the main cause of the inequality of characters among plant relatives. High genetic diversity indicates a high potential for use in the improvement of plant traits. Genetic facts are inferred from phenotypic observations, which are the results of genotype interactions and the environment. The variability available in breeding material is the prime requirement for improving and selecting elite genotypes (Seetharam and Ganesamurthy, 2013).

Table 6. Analysis of environmental variety, genotype, and phenotype of several East Java local sorghum (*Sorghum bicolor* (L.) genotypes

Traits	σ^2 e	σ^2 g	2σ g	Criteria	σ^2 p	2σ p	Criteria
Plant Height (cm)	26.56	2659.65	166.76	broad	2686.22	0.14	broad
Number of Leaves	0.52	138.75	7.97	broad	139.28	0.02	broad
Stem Diameter (cm)	0.07	4.99	0.34	broad	5.06	0.01	broad
Panicle Length (cm)	12.95	9206.55	515.25	broad	9219.5	0.10	broad
Number of Seeds per Panicle	405537	125860168.2	7186137.17	broad	126265705.06	17.83	broad
Seed / Panicle Dry Weight (g)	271.79	79463.18	4547.67	broad	79735	0.46	broad
Fresh Weight 1000 seeds (g)	11.32	2847.39	164.05	broad	2858.71	0.09	broad
Dry Weight 1000 seeds (g)	6.47	1213.8	71.15	broad	1220.28	0.07	broad
Leaf Length (cm)	29.47	13576.55	765.99	broad	13606	0.15	broad
Leaf Width (cm)	0.67	320	18.04	broad	320.67	0.02	broad
Plant Height at Harvest (cm)	414.57	356701.73	19913.49	broad	357116	0.57	broad
Number of Tillers	1.32	92.32	6.2	broad	93.64	0.03	broad

Notes: σ^2 e (Variety of Environment); σ^2 g (Variety of Genotypes), 2σ g (Standard Deviation of Genotype Variety), Criteria for genotype variety: σ^2 g < 2σ g (narrow) dan σ^2 g > 2σ g (broad); σ^2 ***p*** (Variety of Phenotypes), 2σ p (Standard Deviation of Phenotype Variety), Criteria for phenotype variety: σ^2 p < 2σ p (narrow) dan σ^2 p > 2σ p (broad) .

Heritability value analysis shows that all tested parameters exceed 0.5 for each observed variable so that it is categorized as high heritability. Chaudhary (2001) stated that the high coefficient of phenotype variety compared to the coefficient of genotype variance indicates a good effect on all genotypes' environment. The wide diversity of phenotypes comes from a wide diversity of genotypes, so that the requirement for the selection process to take place in the genotype selection process is wide genetic diversity. (Rahajeng and Rahayuningtyas, 2015).

In a broad sense, the heritability prediction value is the ratio between the total genetic variance and the phenotype variety, which shows the large proportion of genetic factors in a plant character's phenotype. The estimated high heritability means that plant genetic factors that affect plant phenotypes are very large compared to environmental factors (Ardiyanti et al., 2019). The phenotype variety analysis showed that the phenotype diversity in all observed genotypes was also high (Table 7). In general, high genotype diversity will be followed by high phenotype diversity. The diversity will be inherited can be measured using the heritability parameter. It is a broad sense, a comparison between the magnitude variety of genotypes and a character's phenotypes.

The high heritability followed by wide genetic diversity in the nine East Java local sorghum genotypes indicates that genetic factors influence the characters. The high heritability of some local East Java sorghum genotypes is due to genetic factors. If genetic factors play a more important role, these characters can be inherited, and it is hoped that selection can be useful for the observed traits (Maftuchah et al., 2015). Besides, Jimmy et al. (2017) reported that high heritability was generated by all observed agronomic characters and indicated that additive genes played a more critical role in improving plant breeding more quickly. This study's results are also in line with Setiawan et al. (2016), who showed that the plant height variables of 20 sorghum genotypes showed high heritability. The selection criteria for Sorghum could be used as a biomass producer. However, this research needs to study the local sorghum further as alternative food, animal feed, or industrial raw material.

Table 7. Heritability value and criteria of heritability in several east java local sorghum (*Sorghum bicolor* (L.) Moench) genotypes

Traits	Heritability	Criteria
Plant Height (cm)	0,990	High
Number of Leaves	0,996	High
Stem Diameter (cm)	0,986	High
Panicle Length (cm)	0,999	High
Number of Seeds per Panicle	0,997	High
Seed / Panicle Dry Weight (g)	0,997	High
Fresh Weight 1000 seeds (g)	0,996	High
Dry Weight 1000 seeds (g)	0,995	High
Leaf Length (cm)	0,998	High
Leaf Width (cm)	0,998	High
Plant Height at Harvest (cm)	0,999	High
Number of Tillers	0,986	High

Description: High Heritability ($H \geq 50\%$ or $H \geq 0,5$ Medium heritability ($20\% < H < 50\%$ or $0,2 < H < 0,5$), low Heritability ($H \leq 20\%$ or $H \leq 0,2$).

In summary, the results showed that the SG-SPG 2 genotype produced the longest panicle size, while SG-LMG 2 genotype produced the highest seed dry weight per panicle and the highest number of seeds per panicle (117.34 grams of seed dry weight per panicle and 4581.80 seeds per panicle). The genotype of SG-TLG 2 produced the highest fresh weight (41.43 grams) and dry weight (31.96 grams) of 1000 seeds, but it was not different from SG-TLG 1. The highest number of tillers was produced by SG-TLG 2 (4.20 chicks) and was not significantly different from SG-TLG 1 (3.33 chicks) and SG-JBG (2.07 chicks). Of the nine genotypes tested, the flowering ages ranged from 42 to 53 days after planting, and the harvest ages ranged from 70 to 91 days after planting. The fastest harvest age was achieved by SG-TLG 2 (70 days after planting). All parameters tested showed the criteria for a wide range of genotypes and phenotypes. The entire value of the phenotype variety on each variable was more significant than the value of the genotype range. Heritability test results show that all experimental parameters exceed 0.5 so that it is categorized as high heritability. In general, the SG-TLG 2 genotype had the most chance to be developed, because it produced the highest seed weight, both fresh seeds (41.43 g / 1000 seeds) and dry seeds (31.96 g / 1000 seeds). Besides, the SG-TLG shows the fastest harvest age (70 days after planting).

ACKNOWLEDGEMENTS

Author would like to thank the Directorate of Research and the Community Service University of Muhammadiyah Malang that has funded this research through the center of study's flagship program in 2017.

REFERENCES

Ardiyanti SE, Sopandie D, Wirnas D, Trikoesoemaningtyas. 2019. Ratoon Productivity of sorghum Breeding Lines (*Sorghum bicolor* (L.) Moench). IOP Conf. Series: Earth and Environmental Science 399 012030. Doi:10.1088/1755-1315/399/1/012030.

Chaudhary R. R., 2001. Genetic Variability and Heritability in Sugarcane. Nepal Agric. Res. J., Vol. 5.

Elvira SD, Yusuf M, Maiyuslina. 2015. Karakter Agronomi Beberapa Varietas Sorgum pada Lahan Marginal di Aceh Utara. Jurnal Agrium 12(1): 1-4.

Falconer, D.S., T.F.C. Mackay. 1996. Quantitative to Genetics. The Roland Press Company. New York 356p

Ferdian B, Sunyoto, Karyanto A, Kamal M. 2015. Akumulasi Bahan Kering Beberapa Varietas Tanaman Sorgum (*Sorghum bicolor* (L.) Moench) Ratoon 1 Pada Kerapatan Tanaman Berbeda. J.Agrotek Tropika 3 (1): 41-48.

Jimmy ML, Nzuve F, Flourence O, Manyasa E, Muthomi J. 2017. Genetic variability, heritability, genetic advance and trait correlatons in selected Sorghum (*Sorghum bicolor* L. Moench) varieties. Int.J.Agron. Agri. R. 11 (5): 47-56.

Kementerian Pertanian Indonesia. 2020. Data Produksi Padi dan Jagung 2014-2018. httpswww.pertanian.go.idhomeshow=page&act=view&id=61.

Kotal BD, Das A, Choudhury BK. 2010. Genetic Variability and Association of Characters in Wheat (*Triticum aestivum* L.). Asian Journal of Crop Science 2(3):155-160. http://dx.doi.org/10.3923/ajcs.2010.155.160

Kusumawati A, Putri NK, Suliansyah I. 2013. Karakterisasi dan Evaluasi Beberapa Genotipe Sorgumn (*Sorghum bicolor* L) di Sukarami Kabupaten Solok. Jurnal Agroteknologi 4(1): 7-12. http://dx.doi.org/10.24014/ja.v4i1.57

Mac Whirter KS. 1979. Breeding of cross polinated. Brisbane : Australia.

Maftuchah, Reswari HA, Ishartati E, Zainudin A, Sudarmo H. 2015. Heretability and Correlation of Vegetative and Generative Character on Genotypes of Jatropha (*Jatropha curcas* Linn.). Energy Procedia 65 : 186-193. https://doi.org/10.1016/j.egypro.2015.01.058

Mundia CW, Secchi S, Akamani K, Wang G. 2019. A Regional Comparison of Factor Affecting Global Sorghum Production: The Case of North America, Asia and Africa's Sahel. Sustainability 11 (2135) doi:10.3390/su11072135

Panjaitan R, Zuhry E, Deviona. 2015. Karakterisasi dan Hubungan Kekerabatan 13 Genotipe Sorgum (*Sorghum bicolor* L.) Mouch Koleksi Batan. Jurnal JOM Faperta. Vol. 2 No. 1.

Pinaria, A., A. Baihaki, A. Setiamihardja, A.A. Daradjat. 1995. Penampilan fenotipik dan beberapa parameter genetik delapan kultivar kacang tanah pada lahan sawah. Zuriat 11(1):8-15.

Rahajeng W, Rahayuningtyas A. 2015. Pendugaan Komponen Ragam, Heritabilitas dan Korelasi Klon-Klon Harapan Ubijalar Berkadar Betakaroten Tinggi. Jurnal Ilmu Pertanian Vol. 18 No.1. https://doi.org/10.22146/ipas.6177

Rifa'i H, Ashari S, Damanhuri. 2015. Keragaman 36 Aksesi Sorgum *(Sorghum bicolor* L.*)*. Jurnal Produksi Tanaman. 3(4): 330-337.

Seetharam K, Ganesamurthy K. 2013. Characterization Of Sorghum Genotypes For Yield And Other Agronomic Traits Through Genetic Variability And Diversity Analysis. Electronic Journal of Plant Breeding 4(1): 1073-1079.

Setiawan K, Kamal M, Hadi MS, Sungkono, Maulana I. 2016. Keragaan beberapa kandidat genotip sorgum sebagai penghasil biomasa. hlm 373-380. *Dalam Prosiding Seminar Nasional dan Kongres 2016 Perhimpunan Agronomi Indonesia (PERAGI)*. Departemen Agronomi dan Hortikultura, Institut Pertanian Bogor, Bogor.

Setiawan K, Restiningtias R, Utomo SD, Ardian, Hadi MS, Yuliadi E. 2019. Keragaman Genetik, Fenotip, dan Heritabilitas Beberapa Genotipe Sorghum pada Kondisi Tumpangsari dan Monokultur. Jurnal Agro 6 (2): 95-109. https://doi.org/10.15575/4568

Setiyagama MJ, Arifin AZ, Sulistyawati. 2017. Karakterisasi Beberapa Genotip Sorgum *(Sorghum bicolor* L.) Lokal Jawa Timur. Dalam jurnal Agroteknologi Merdeka Pasuruan 1 (2):18-22.

Sirappa MP, Waas ED. 2009. Kajian Varietas dan Pemupukan Terhadap Peningkatan Hasil Padi Sawah di Dataran Pasahari, Maluku Tengah. Jurnal pengkajian dan pengembangan teknologi pertanian Vol. 12 No. 1.

Sirappa MP. 2003. Prospek Pengembangan Sorghum di Indonesia sebagai Komoditas Alternatif untuk Pangan, Pakan, dan Industri. Jurnal Litbang Pertanian 22 (4).

Sulistyowati, Roeswitawati D, Ibrahim JT, Maftuchah. 2019. Agronomic Character of Several Local Genotypes of Sorghum (*Sorghum bicolor* L.) at East Java. IOP Conf. Series : Materials Science and Engineering 532. doi:10.1088/1757-899X/532/1/012023

Sulistyowati, Roeswitawati D, Ibrahim JT, Maftuchah. 2019. Genetic Diversity of Local Sorghum (*Sorghum bicolor*) Genotypes of East Java, Indonesia for Agro-Morphological and Physiological traits. Biodiversitas 20 (9) : 2503-2510. https://doi.org/10.13057/biodiv/d200911

Susilowati SH, Saliem HP. 2013. Perdagangan Sorgum di Pasar Dunia dan Asia serta Prospek Pengembangannya di Indonesia. Dalam: Sumarno, et al. (eds). Sorgum: Inovasi Teknologi dan Pengembangan. IAARD Press, Jakarta.

BIODIVERSITAS
Volume 22, Number 3, March 2021
Pages: 1310-1316

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d220330

Morphological diversity and heritability of nine local sorghum (*Sorghum bicolor*) genotypes in East Java, Indonesia

MAFTUCHAH[1,3,♥], LIA FEBRIANA[1], SULISTYAWATI[2], HELVI ARDANA RESWARI[1], ERFAN DANI SEPTIA[1,3]
[1]Faculty of Agriculture and Animal Science, Universitas Muhammadiyah Malang. Jl. Raya Tlogomas 246, Malang 65144, East Java, Indonesia
Tel./fax.: +62-341-464318 (145), ♥email: maftuchah@umm.ac.id
[2]Faculty of Agriculture, Universitas Merdeka Pasuruan. Jl. Ir. H. Juanda No. 68, Pasuruan City 67129, East Java, Indonesia
[3]Center of Biotechnology Development, Universitas Muhammadiyah Malang. Jl. Tlogomas No. 246, Malang 65144, East Java, Indonesia.

Manuscript received: 25 September 2020. Revision accepted: 16 February 2021.

Abstract. *Maftuchah, Febriana L, Sulistyawati, Reswari HA, Septia ED. 2021. Morphological diversity and heritability of nine local sorghum (*Sorghum bicolor*) genotypes in East Java, Indonesia. Biodiversitas 22: 1310-1316.* Sorghum (*Sorghum bicolor* L. Moench) is an essential food crop after wheat, rice, maize, and barley. It has wide adaptability to various environmental conditions, including can be grown on marginal lands, so that it is potential to be developed as cheap source of carbohydrates. The present study obtain information about the morphological diversity and heritability values of local sorghum genotypes that occurred in East Java Province, Indonesia. The research was conducted in Purutrejo village, Pasuruan city using nine local genotypes, namely Jombang (SG-JBG), Tuban (SG-TBN), Pasuruan (GB-PSR), Lamongan 1 (SG-LMG 1), Lamongan 2 (SG-LMG 2), Sampang 1 (SG-SPG 1), Sampang 2 (SG-SPG 2), Tulungagung 1 (SG-TLG 1) and Tulungagung 2 (SG-TLG 2). The results showed that the genotype of SG-SPG 2 produced the longest panicles, while the SG-LMG 2 had the highest seed dry weight per panicle and highest number of seeds per panicle (117.34 gram/panicle dry weight and 4581.80 seeds/panicle). The genotype of SG-TLG 2 produced the largest weight of seeds, either in fresh seed (41.43 g/1000 seeds) or dry seed (31.96 g/1000 seeds). Of the nine genotypes tested, the flowering ages ranged from 42 to 53 days after planting, and the harvest ages ranged from 70 to 91 days after planting with the fastest harvest age was achieved by SG-TLG 2 The entire value of the phenotype variety on each variable was more significant than the value of the genotype range. Heritability test results show that all experimental parameters exceed 0.5 so that it is categorized as high heritability. In general, the SG-TLG 2 genotype had the most chance to be developed, because it produced the highest seed weight, both fresh seeds (41.43 g/1000 seeds) and dry seeds (31.96 g/1000 seeds). Besides, the SG-TLG shows the fastest harvest age (70 days after planting).

Keywords: Diversity, heritability, landrace, *Sorghum bicolor*

INTRODUCTION

Human population growth globally has increased the need for various agricultural commodities, especially cereals and pulses. Among the cereals, sorghum (*Sorghum bicolor* L) is one of the world's essential crops as the primary source of carbohydrates after wheat, rice, corn, and barley. Sorghum could be developed as an alternative to substitute and/or to complement local food consumption besides rice to enhance food diversification. In addition to human food sources, sorghum has also the potential as animal feed and raw materials for various industries.

Sorghum is an annual crop that is easy to cultivate, but its production is still lower than that of rice, maize, and other cereal crops. The rice production level increased by around 2.33%, while maize increased by 3.91% from 2017 to 2018. However, sorghum production data is still not available, so that sorghum production is still small and not well recorded (MoA 2020). Sorghum has wide environmental adaptability and can be developed in areas with less adaptive environmental conditions to climate change (Mundia et al. 2019). As such, sorghum has more potential to be developed as an alternative crop on marginal lands compared to rice to increase local food supplies (Sulistyawati et al. 2019a). Besides, current research indicated that several local genotypes of sorghum, which contain high carbohydrates and protein, could be used for various food preparations (Sulistyawati et al. 2019b). Any efforts in sorghum improvement would help government initiatives in reducing the burden of rice production and wheat import (Sulistyawati and Saliem 2013).

Genetic characterization of germplasm lines aims to identify important traits that have economic value or specific characteristics to be targeted and retained. The characters could be morphological (e.g., Plant height, number of leaves, stem diameter, panicle length, leaf width, leaf length, etc.) and agronomic (e.g., days of flower, fresh weight 1000 seeds, days of maturity time, dry weight 1000 seeds, total seed dry weight per panicle, etc.). The processes of characterization and evaluation have essential meanings and roles to obtain the genetic lines that have excellent traits (Kusumawati et al. 2013). In the context of sorghum, the differences in genotype could be recognized more clearly in the generative phase than in the vegetative phase (Elvira et al. 2015).

The diversity in crop varieties and accessions will help plant breeding activities, especially in providing plant breeding materials (Rifa'i et al. 2015). Genetic diversity facilitates the selection process in field crops including sorghum. If the genetic variance is high, the heritability value would be high. Thus, the variable could be used as a selection criterion (Setiawan et al. 2019). Heritability value could be interpreted as the proportion between genetic variance and phenotypic variance (Falconer and Mackay 1996). The heritability value of a character do not necessarily indicate that the character inherited is affected by genetic factors or environmental conditions (Maftuchah et al. 2015).

Similarly, information on morphological diversity and heritability values in sorghum would help breeders to obtain local sorghum genotypes with preferred characteristics suitable for particular purposes, for example as an alternative food source for human consumption, animal feeding, or raw material of fuel production. The present study aimed to obtain information about the morphological diversity and heritability values of local sorghum genotypes that occurred in East Java Province, Indonesia. We expected the results of this study could serve as baseline information for future research and development of sorghum cultivation, especially in East Java.

MATERIALS AND METHODS

Plant materials

The research was conducted in Purutrejo Village, Purworejo Sub-district, Pasuruan City, East Java Province, Indonesia. Plant materials used in this study were nine genotypes of local sorghum plants derived from various regions in East Java, i.e., Jombang (SG-JBG), Tuban (SG-TBN), Pasuruan (GB-PSR), Lamongan 1 (SG-LMG 1), Lamongan 2 (SG-LMG 2), Sampang 1 (SG-SPG 1), Sampang 2 (SG-SPG 2), Tulungagung 1 (SG-TLG 1), and Tulungagung 2 (SG-TLG 2).

Experimental design

The experiment was conducted as randomized block design with three replications. The design consisted of one factor (i.e. nine genotypes of local sorghum) so that there was 27 experimental units in total. The planting of sorghum was carried out by sowing sorghum seeds on a tray used a planting medium containing soil and compost. Seedlings were then planted in the field after ten days of sowing with a planting distance of 75 cm x 15 cm at plots measuring 3 x 2.5 m. Thus, each plot consisted of 21 sorghum plants. The fertilizers used were organic fertilizers and chemical fertilizers (SP 36, Urea, and KCL). Manure is an essential fertilizer given at the same time when conducted tilling. Meanwhile, chemical fertilizers were applied to the planting hole when the plants were 2 weeks after planting (WAP) and 4 WAP. The flow chart of this research activity's implementation is in Figure 1.

Data collection and analysis

The variables observed were plant height, number of leaves, stem diameter, panicle length, total dry weight of grains per panicle, number of grains per panicle, fresh weight of 1000 grains, dry weight of 1000 grains, leaf length, leaf width, plant height at harvest, tillers, age, and harvest of flowering and harvest age. Data analysis was performed using variance analysis and continued with the 5% LSD test, analysis of variance and heritability testing. Analysis of genotype variety, phenotype variety and environmental variance using the formulas ($\boldsymbol{\sigma}2$ e = M1), ($\boldsymbol{\sigma}2$ g = (M2-M1)/r) and ($\boldsymbol{\sigma}2$ p = $\boldsymbol{\sigma}2$ e + $\boldsymbol{\sigma}2$ g). The M1 and M2 are based on Table 1. The diversity criteria used to follow Pinaria et al. (1995) provisions, namely broad variability if the diversity value is> twice the standard deviation of genetic variance and narrow variability if the variability is <twice the standard deviation of genetic variance. The formula used in estimating heritability is H = $\boldsymbol{\sigma}2$ g/$\boldsymbol{\sigma}2$ p. and classified according to Mac Whirter (1979), namely low heritability: <0.20, medium heritability: 0.20 - 0.50, high heritability: 0.50 <H ≤ 1.

Table 1. Analysis of variance

Sources of diversity (SK)	Degrees of free (DB)	Sum of squares (JK)	Middle-value square (KT)
Group	r-1	JKK	
Genotype	g-1	JKG	M2
Error	(r-1)(g-1)	JKG	M1

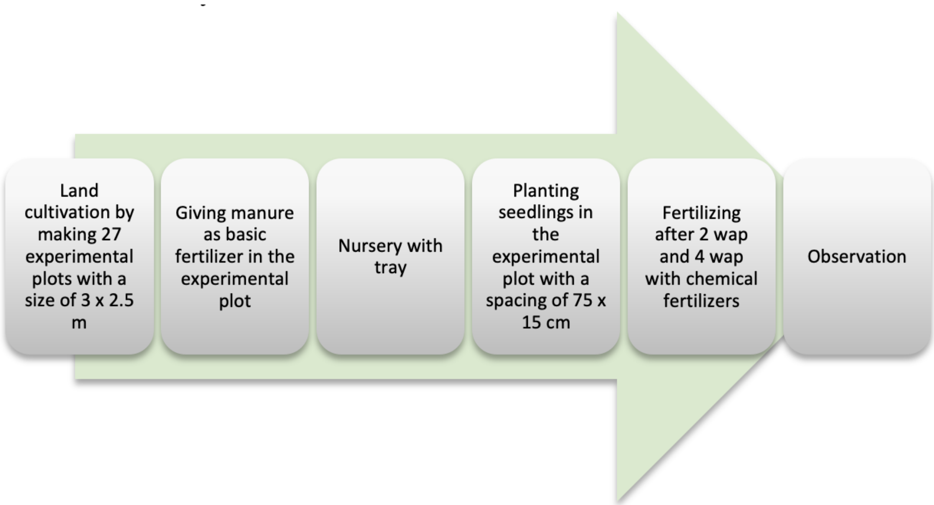

Figure 1. Flowchart of research implementation

RESULTS AND DISCUSSION

Morphological characters

Genotypic factors showed significant differences in plant height and number of leaves at 21, 28, and 35 days after planting. Table 2 shows the average plant height and number of leaves of the nine local sorghum genotypes in East Java at various observation ages. Our results indicate that the genotype of SG-TLG 2 had the highest plant height with 63.97 cm, followed by SG-JBG and SG-TLG 1 with 63.30 and 62.04 cm, respectively. On the other hand, the highest average number of leaves was shown by the genotype of SG-JBG with 8.53 strands, followed by SG-TLG 1 and SG-LMG 1 with 8.40 and 8.33 strands, respectively.

Plant's appearance is influenced by one genetic factor (Panjaitan et al. 2015). Plant height is one of the growth parameters that is often used to determine environmental or genetic influences. Leaves are the primary organ for photosynthesis. The influence of the environment results in the genotype being able to display its character. The existence of inappropriate environmental influences results in the appearance of genetic traits that is not optimal.

Table 2. Plant height (cm) and number of leaves (strands) of several East Java local sorghum (*Sorghum bicolor*) genotypes at various observation ages

Genotype	Plant height (cm)								Number of leaves (strands)							
	14 DAP		21 DAP		28 DAP		35 DAP		14 DAP		21 DAP		28 DAP		35 DAP	
SG-JBG	8.56	a	14.99	b	24.16	cd	63.30	e	4.80	d	6.80	d	7.93	c	8.53	e
SG-TBN	7.55	a	13.71	ab	22.10	ab	48.37	bcd	4.47	bc	6.47	cd	7.80	bc	8.13	de
SG-PSR	8.31	a	15.42	b	22.88	abc	55.55	cde	3.93	b	5.80	cd	7.07	bc	7.20	cd
SG-LMG 1	7.96	a	13.30	ab	22.65	abc	42.14	abc	4.27	bc	5.87	cd	7.87	c	8.33	e
SG-LMG 2	6.97	a	13.89	ab	20.43	ab	34.80	ab	4.07	bc	5.80	cd	7.27	bc	8.20	de
SG-SPG 1	7.13	a	11.03	a	17.27	a	29.55	a	2.53	a	2.87	a	4.67	a	5.13	a
SG-SPG 2	6.84	a	15.94	b	29.02	cd	46.60	bc	3.87	b	4.53	b	5.33	a	5.67	ab
SG-TLG 1	9.21	a	15.91	b	26.91	bc	62.04	de	4.00	bc	6.33	cd	7.47	bc	8.40	e
SG-TLG 2	8.43	a	15.77	b	33.87	d	63.97	e	4.00	bc	5.60	bc	6.73	bc	6.73	cd

Note: The numbers followed by the same letter in the same column show no significant difference in the 5% LSD test.

Figure 2. Plant morphology in the experimental fields: A. SG-JBG, B. SG-TBN, C. GB-PSR, D. SG-LMG 1, E. SG-LMG 2, F. SG-SPG 1, G. SG-SPG 2, H. SG-TLG 1, I. SG-TLG 2

Table 3 shows the average stem diameter at 28 DAP and 35 DAP, leaf length and width, the average plant height at harvest and the number of tillers. The biggest stem diameter was obtained by the genotypes of SG-LMG 2 and SG-TLG 1 with 1.83 cm and 1.56 cm followed by SG-TBN with 1.51 cm. The genotype of SG-LMG 1 had the longest leaf with 82.14 cm followed by SG-TLG 1 and SG-TBN with 80.11cm and 79.15 cm respectively, while the genotype with the biggest leaf width was SG-LMG 1 with 8.84 cm, followed by SG-LMG 2 and SG-TLG 1 with 8.24 cm and 7.84 cm, respectively. When harvested, SG-TLG 1 had the highest height with 274.23 cm, followed by SG-TBN and SG-JBG with 262.33 cm and 255.72 cm respectively, while the genotype with the largest number of tillers was SG-TLG 2 with 4.20, followed by SG-TLG 1 and SG-PSR with 3.33 and 2.27, respectively. Nonetheless, the highest number of tillers which was produced by genotype SG-TLG did not differ significantly from SG-TLG 2.

The varying observation results indicate that each genotype has different characteristics. Siswanto (2015) states that the genetic characteristics of varieties, the environment in which they are grown, and the cultivation treatment will affect sorghum's yield potential. Genetic and environmental factors determine the number of tillers produced.

Yield contributing traits

Observed parameters related to yield contributing traits include average panicle length, total seed dry weight per panicle, number of seeds per panicle, fresh weight, and dry weight 1000 seeds. The results of such parameters for each sorghum genotype studied here are presented in Table 4. The genotype of SG-SPG 2 had the longest panicle size with 47.75 cm, followed by SG-TLG 2 and SG-TLG 1 with 41.73 cm and 41.29 cm, respectively. The genotype of SG-LMG 2 produced the largest seed dry weight per panicle (117.34 g), followed by SG-JBG and SB-TLG 2 with, 88.87 g and 86.69 g respectively. while the genotype with the largest number of seeds per panicle was SG-LMG 2 with 4581.80, followed SG-LMG 1 and SG-TBN with 3563.90 and 3125.70 respectively. The genotype of SG-TLG 2 had the highest fresh weight 1000 seed with 41.43 g, followed by SG-TLG 1 and SG-JBG with 41.04 g and 37.86 g, respectively. While the highest dry weight 1000 seed was SG-TLG 2 with 31.96 g, followed SG-TLG 1 and SG-PSR with 31.55 g and 30.06 g, respectively.

Long panicles of plants are formed in the primordia phase. The difference in panicle length is due to different genotypes and inherited traits. Each genetic factor and the adaptability of each variety is different so that it affects the length of sorghum panicles (Sirappa and Waas 2009). Total dry weight is one measure to study further plant growth (Ferdian et al. 2015). The total dry weight per panicle is one of the criteria for the production of sorghum. Genetic differences will result in a different panicle shape or weight of the seed unit so that each genotype has a different dry weight. Plants require sufficient nutrient content for seed formation. Genotypic differences result in different shapes and weights of seeds.

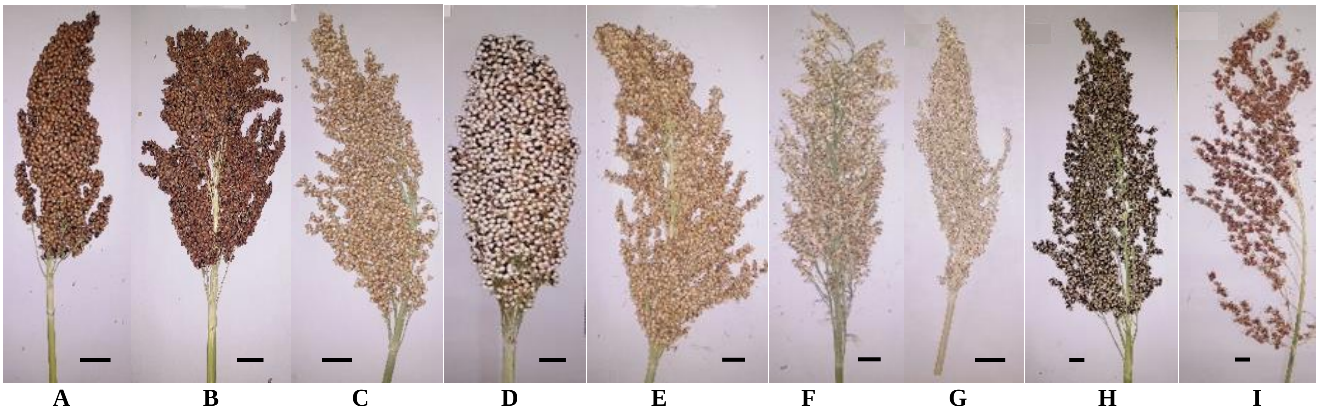

Figure 3. Seed morphology of several genotypes: A. SG-JBG, B. SG-TBN, C. SG-PSR, D. SG-LMG 1, E. SG-LMG 2, F. SG-SPG 1, G. SG-SPG 2, H. SG-TLG 1, I. SG-TLG 2. Bar = 2 cm

Table 3. Average stem diameter, length, the width of leaves, the value of plant height at harvest, and number of tillers of several East Java local sorghum (*Sorghum bicolor* (L.) genotypes

Genotype	Stem diameter (cm) 28 DAP		Stem diameter (cm) 35 DAP		Leaf length (cm)		Leaf width (cm)		Plant height at harvest (cm)		Number of tillers	
SG-JBG	1.27	bc	1.47	bcd	77.27	d	7.70	d	255.72	d	2.07	c
SG-TBN	1.29	bc	1.51	cd	79.15	d	7.82	de	262.33	d	213	ab
SG-PSR	1.14	abc	1.19	ab	78.40	d	6.75	c	202.40	c	2,27	ab
SG-LMG 1	1.26	abc	1.46	bcd	82.14	d	8.84	e	139.47	a	1.33	a
SG-LMG 2	1.37	c	1.83	e	76.01	cd	8.24	de	167.50	b	1.87	a
SG-SPG 1	1.19	abc	1.24	abc	69.96	bc	5.69	b	191.67	c	2.07	ab
SG-SPG 2	0.93	a	1.05	a	49.29	a	4.56	a	136.15	a	1.80	a
SG-TLG 1	1.37	c	1.56	de	80.11	d	7.84	de	274.23	d	3.33	bc
SG-TLG 2	1.02	ab	1.03	a	68.33	bc	4.79	ab	214.05	c	4.20	c

Note: The numbers followed by the same letter in the same column show no significant difference in the 5% LDS test

Table 4. The average length of panicle, total dry weight of seeds per panicle number of seeds, fresh and dry weight of 1000 seeds per panicle of several East Java local sorghum (*Sorghum bicolor*) genotypes

Genotype	Panicle length (cm)		Total seed dry weight per panicle (g/panicle)		Number of seeds per panicle		Fresh weight 1000 seeds (g)		Dry weight 1000 seeds (g)	
SG-JBG	23.92	a	88.87	c	3081.80	de	37.86	cde	28.87	cd
SG-TBN	26.13	a	82.94	bc	3125.70	de	34.61	bc	26.50	bc
SG-PSR	34.69	b	68.68	b	2293.90	bc	37.25	cd	30.06	de
SG-LMG 1	25.50	a	86.68	bc	3563.90	e	34.07	bc	24.66	ab
SG-LMG 2	38.53	bc	117.34	d	4581.80	f	32.73	b	25.87	ab
SG-SPG 1	35.83	b	44.23	a	1962.10	ab	26.45	a	23.22	a
SG-SPG 2	47.75	d	48.70	a	1840.80	ab	32.65	b	26.51	bc
SG-TLG 1	41.29	c	86.69	bc	2746.60	cd	41.04	de	31.55	de
SG-TLG 2	41.73	c	45.72	a	1426.80	a	41.43	e	31.96	e

Note: The numbers followed by the same letter in the same column show no significant difference in the 5% LDS test

Table 5 shows that the flowering ages ranged from 42 to 53 days after planting. Meanwhile, the harvest age ranged from 70 to 91 days after planting with the fastest harvesting age was on genotype SG-TLG 2 (70 days after planting), followed by SG-PSR, SG-LMG 1, and SG-TLG 1 with 77 days after planting. The existence of the suitability of environmental conditions can stimulate the flowering and harvesting age faster. Besides, the nutrients absorbed by plants are used as a source of energy in plant growth (Setiyagama 2017).

Genetic variability and heritability

The analysis of environment, genotype, and phenotype variability is shown in Table 6. These data indicate the criteria for broad genotype and phenotype variance. All values for the phenotype variety on each variable were more significant than the values for genotype variance. The indication of this is the influence of the genotype and the environment (Kotal et al. 2010). Genotype diversity is a measure of genetic variation caused by the components of the genotype. In contrast, phenotype diversity is a variation of characters regulated by genotype factors and the growing environment, and the two's interaction.

The wide variety of genotypes in the nine local sorghum genotypes in East Java indicates inequalities in genetic characters between genotypes. Dominant genotype variety is the main cause of the inequality of characters among plant relatives. High genetic diversity indicates a high potential for use in the improvement of plant traits. Genetic facts are inferred from phenotypic observations, which are the results of genotype interactions and the environment. The variability available in breeding material is the prime requirement for improving and selecting elite genotypes (Seetharam and Ganesamurthy 2013).

Heritability value analysis shows that all tested parameters exceed 0.5 for each observed variable so that it is categorized as high heritability. Chaudhary (2001) stated that the high coefficient of phenotype variety compared to the coefficient of genotype variance indicates a good effect on all genotypes' environment. The wide diversity of phenotypes comes from a wide diversity of genotypes, so that the requirement for the selection process to take place in the genotype selection process is wide genetic diversity. (Rahajeng and Rahayuningtyas 2015).

In a broad sense, the heritability prediction value is the ratio between the total genetic variance and the phenotype variety, which shows the large proportion of genetic factors in a plant character's phenotype. The estimated high heritability means that plant genetic factors that affect plant phenotypes are very large compared to environmental factors (Ardiyanti et al. 2019). The phenotype variety analysis showed that the phenotype diversity in all observed genotypes was also high (Table 7). In general, high genotype diversity will be followed by high phenotype diversity. The diversity that will be inherited can be measured using the heritability parameter. It is a broad sense, a comparison between the magnitude variety of genotypes and a character's phenotypes.

Table 5. Flowering age, flowering to harvest, and harvesting age of several East Java local sorghum (*Sorghum bicolor*) genotypes

Genotype	Days to flower (DAP)	Flowering to harvest (days)	Days to maturity (DAP)
SG-JBG	53	38	91
SG-TBN	53	33	86
SG-PSR	49	28	77
SG-LMG 1	49	28	77
SG-LMG 2	51	35	86
SG-SPG 1	42	44	86
SG-SPG 2	42	49	91
SG-TLG 1	53	24	77
SG-TLG 2	38	32	70

Note: Days to maturity is the sum of days after planting to flower and days of flowering to harvest

Table 6. Analysis of environmental variety, genotype, and phenotype of several East Java local sorghum (*Sorghum bicolor*) genotypes

Traits	σ^2 e	σ^2 g	2σ g	Criteria	σ^2 p	2σ p	Criteria
Plant Height (cm)	26.56	2659.65	166.76	Broad	2686.22	0.14	Broad
Number of Leaves	0.52	138.75	7.97	Broad	139.28	0.02	Broad
Stem Diameter (cm)	0.07	4.99	0.34	Broad	5.06	0.01	Broad
Panicle Length (cm)	12.95	9206.55	515.25	Broad	9219.5	0.10	Broad
Number of Seeds per Panicle	405537	125860168.2	7186137.17	Broad	126265705.06	17.83	Broad
Seed/Panicle Dry Weight (g)	271.79	79463.18	4547.67	Broad	79735	0.46	Broad
Fresh Weight 1000 seeds (g)	11.32	2847.39	164.05	Broad	2858.71	0.09	Broad
Dry Weight 1000 seeds (g)	6.47	1213.8	71.15	Broad	1220.28	0.07	Broad
Leaf Length (cm)	29.47	13576.55	765.99	Broad	13606	0.15	Broad
Leaf Width (cm)	0.67	320	18.04	Broad	320.67	0.02	Broad
Plant Height at Harvest (cm)	414.57	356701.73	19913.49	Broad	357116	0.57	Broad
Number of Tillers	1.32	92.32	6.2	Broad	93.64	0.03	Broad

Notes: σ^2 e (Variety of Environment); σ^2 g (Variety of Genotypes), 2σ g (Standard Deviation of Genotype Variety), Criteria for genotype variety: σ^2 g < 2σ g (narrow) dan σ^2 g > 2σ g (broad); σ^2 ***p*** (Variety of Phenotypes), 2σ p (Standard Deviation of Phenotype Variety), Criteria for phenotype variety: σ^2 p < 2σ p (narrow) dan σ^2 p > 2σ p (broad).

Table 7. Heritability value and criteria of heritability in several east java local sorghum (*Sorghum bicolor*) genotypes

Traits	Heritability	Criteria
Plant height (cm)	0.990	High
Number of leaves	0.996	High
Stem diameter (cm)	0.986	High
Panicle length (cm)	0.999	High
Number of seeds per panicle	0.997	High
Seed/panicle dry weight (g)	0.997	High
Fresh weight 1000 seeds (g)	0.996	High
Dry weight 1000 seeds (g)	0.995	High
Leaf length (cm)	0.998	High
Leaf width (cm)	0.998	High
Plant height at harvest (cm)	0.999	High
Number of tillers	0.986	High

Description: High Heritability (H ≥ 50% or H ≥ 0.5 Medium heritability (20% < H < 50% or 0.2 < H < 0.5), low Heritability (H ≤ 20% or H ≤ 0.2).

The high heritability followed by wide genetic diversity in the nine East Java local sorghum genotypes indicates that genetic factors influence the characters. The high heritability of some local East Java sorghum genotypes is due to genetic factors. If genetic factors play a more important role, these characters can be inherited, and it is hoped that selection can be useful for the observed traits (Maftuchah et al. 2015). Besides, Jimmy et al. (2017) reported that high heritability was generated by all observed agronomic characters and indicated that additive genes played a more critical role in improving plant breeding more quickly. This study's results are also in line with Setiawan et al. (2016), who showed that the plant height variables of 20 sorghum genotypes showed high heritability. The selection criteria for Sorghum could be used as a biomass producer. However, this research needs to study the local sorghum further as alternative food, animal feed, or industrial raw material.

In summary, the results showed that the SG-SPG 2 genotype produced the longest panicle size, while SG-LMG 2 genotype produced the highest seed dry weight per panicle and the highest number of seeds per panicle (117.34 grams of seed dry weight per panicle and 4581.80 seeds per panicle). The genotype of SG-TLG 2 produced the highest fresh weight (41.43 grams) and dry weight (31.96 grams) of 1000 seeds, but it was not different from SG-TLG 1. The highest number of tillers was produced by SG-TLG 2 (4.20 chicks) and was not significantly different from SG-TLG 1 (3.33 chicks) and SG-JBG (2.07 chicks). Of the nine genotypes tested, the flowering ages ranged from 42 to 53 days after planting, and the harvest ages ranged from 70 to 91 days after planting. The fastest harvest age was achieved by SG-TLG 2 (70 days after planting). All parameters tested showed the criteria for a wide range of genotypes and phenotypes. The entire value of the phenotype variety on each variable was more significant than the value of the genotype range. Heritability test results show that all experimental parameters exceed 0.5 so that it is categorized as high heritability. In general, the SG-TLG 2 genotype had the most chance to be developed, because it produced the highest seed weight, both fresh seeds (41.43 g/1000 seeds) and dry seeds (31.96 g/1000 seeds). Besides, the SG-TLG shows the fastest harvest age (70 days after planting).

ACKNOWLEDGEMENTS

The authors would like to thank the Directorate of Research and the Community Service University of Muhammadiyah Malang, Indonesia that has funded this research through the center of study's flagship program in 2017.

REFERENCES

Ardiyanti SE, Sopandie D, Wirnas D, Trikoesoemaningtyas. 2019. Ratoon productivity of sorghum breeding lines (*Sorghum bicolor* (L.) Moench). IOP Conf Ser Earth Environ Sci 399: 012030. DOI: 10.1088/1755-1315/399/1/012030.

Chaudhary RR. 2001. Genetic variability and heritability in sugarcane. Nepal Agric Res J 5. DOI: 10.3126/narj.v4i0.4870

Elvira SD, Yusuf M, Maiyuslina. 2015. Karakter agronomi beberapa varietas sorgum pada lahan marginal di Aceh Utara. Jurnal Agrium 12 (1): 1-4. [Indonesian]

Falconer DS, Mackay TFC. 1996. Quantitative to Genetics. The Roland Press Company, New York.

Ferdian B, Sunyoto, Karyanto A, Kamal M. 2015. Akumulasi bahan kering beberapa varietas tanaman sorgum (*Sorghum bicolor* (L.) Moench) ratoon 1 pada kerapatan tanaman berbeda. Jurnal Agrotek Tropika 3 (1): 41-48. [Indonesian]

Jimmy ML, Nzuve F, Flourence O, Manyasa E, Muthomi J. 2017. Genetic variability, heritability, genetic advance and trait correlations in selected sorghum (*Sorghum bicolor* L. Moench) varieties. Intl J Agron Agric Res 11 (5): 47-56.

MoA. 2020. Data Produksi Padi dan Jagung 2014-2018. Kementerian Pertanian Indonesia, Jakarta httpswww.pertanian.go.idhomeshow=page&act=view&id=61. [Indonesian]

Kotal BD, Das A, Choudhury BK. 2010. Genetic variability and association of characters in wheat (*Triticum aestivum* L.). Asian J Crop Sci 2 (3): 155-160. DOI: 10.3923/ajcs.2010.155.160.

Kusumawati A, Putri NK, Suliansyah I. 2013. Karakterisasi dan evaluasi beberapa genotipe sorgum (*Sorghum bicolor* L) di Sukarami Kabupaten Solok. Jurnal Agroteknologi 4 (1): 7-12. DOI: 10.24014/ja.v4i1.57. [Indonesian]

Mac Whirter KS. 1979. Breeding of cross pollinated crops. In: Knight R (ed.) Plant Breeding. Australian Vice-Chancellors' Committee, Brisbane, Australia.

Maftuchah, Reswari HA, Ishartati E, Zainudin A, Sudarmo H. 2015. Heritability and correlation of vegetative and generative character on genotypes of jatropha (*Jatropha curcas* Linn.). Energy Procedia 65: 186-193. DOI: 10.1016/j.egypro.2015.01.058.

Mundia CW, Secchi S, Akamani K, Wang G. 2019. A Regional comparison of factor affecting global sorghum production: The case of North America, Asia and Africa's sahel. Sustainability 11: 2135. DOI: 10.3390/su11072135.

Panjaitan R, Zuhry E, Deviona. 2015. Karakterisasi dan hubungan kekerabatan 13 genotipe sorgum (*Sorghum bicolor* L.) Mouch koleksi Batan. Jurnal JOM Faperta 2 (1). [Indonesian]

Pinaria A, Baihaki A, Setiamihardja A, Daradjat AA. 1995. Penampilan fenotipik dan beberapa parameter genetik delapan kultivar kacang tanah pada lahan sawah. Zuriat 11 (1): 8-15. [Indonesian]

Rahajeng W, Rahayuningtyas A. 2015. Pendugaan komponen ragam, heritabilitas dan korelasi klon-klon harapan ubijalar berkadar betakaroten tinggi. Jurnal Ilmu Pertanian 18 (1). DOI: 10.22146/ipas.6177. [Indonesian]

Rifa'i H, Ashari S, Damanhuri. 2015. Keragaman 36 aksesi sorgum (*Sorghum bicolor* L.). Jurnal Produksi Tanaman 3 (4): 330-337. [Indonesian]

Seetharam K, Ganesamurthy K. 2013. Characterization of sorghum genotypes for yield and other agronomic traits through genetic variability and diversity analysis. Electr J Plant Breed 4 (1): 1073-1079.

Setiawan K, Kamal M, Hadi MS, Sungkono, Maulana I. 2016. Keragaan beberapa kandidat genotip sorgum sebagai penghasil biomasa. Prosiding Seminar Nasional dan Kongres 2016 Perhimpunan Agronomi Indonesia (PERAGI). Departemen Agronomi dan Hortikultura, Institut Pertanian Bogor, Bogor. [Indonesian]

Setiawan K, Restiningtias R, Utomo SD, Ardian, Hadi MS, Yuliadi E. 2019. Keragaman genetik, fenotip, dan heritabilitas beberapa genotipe sorghum pada kondisi tumpangsari dan monokultur. Jurnal Agro 6 (2): 95-109. DOI: 10.15575/4568. [Indonesian]

Setiyagama MJ, Arifin AZ, Sulistyawati. 2017. Karakterisasi beberapa genotip sorgum *(Sorghum bicolor* L.) lokal Jawa Timur. Jurnal Agroteknologi Merdeka Pasuruan 1 (2): 18-22. [Indonesian]

Sirappa MP, Waas ED. 2009. Kajian varietas dan pemupukan terhadap peningkatan hasil padi sawah di Dataran Pasahari, Maluku Tengah. Jurnal Pengkajian dan Pengembangan Teknologi Pertanian 12 (1). [Indonesian]

Sulistyawati, Roeswitawati D, Ibrahim JT, Maftuchah. 2019a. Agronomic character of several local genotypes of sorghum (*Sorghum bicolor* L.) at East Java. IOP Conf Series: Materials Science and Engineering 532. DOI: 10.1088/1757-899X/532/1/012023

Sulistyawati, Roeswitawati D, Ibrahim JT, Maftuchah. 2019b. Genetic diversity of local sorghum (*Sorghum bicolor*) genotypes of East Java, Indonesia for agro-morphological and physiological traits. Biodiversitas 20 (9): 2503-2510. DOI: 10.13057/biodiv/d200911

Susilowati SH, Saliem HP. 2013. Perdagangan Sorgum di Pasar Dunia dan Asia serta Prospek Pengembangannya di Indonesia. Dalam: Sumarno, Damardjati DS, Syam D, Hermanto (eds). Sorgum: Inovasi Teknologi dan Pengembangan. IAARD Press, Jakarta. [Indonesian]

Morphological diversity and heritability of local sorghum (*Sorghum bicolor* L. Moench) in East Java

MAFTUCHAH[1), 3)*], LIA FEBRIANA[1)] SULISTYAWATI[2)], HELVI ARDANA RESWARI[1)], ERFAN DANI SEPTIA[1), 3)]

[1)] Faculty of Agriculture and Animal Science, University of Muhammadiyah Malang, Jl Raya Tlogomas 246 Malang 65144 East Java, Indonesia Tel +62341-464318-319 Fax +62341-460782

[2)]Faculty of Agriculture, Universitas Merdeka Pasuruan. Jl. Ir. H. Juanda No. 68, Pasuruan City 67129, East Java, Indonesia Tel.: +62-343-413619, Fax.: +62-343-420926,

[3)] Center of Biotechnology Development, University of Muhammadiyah Malang. Jl. Jl. Tlogomas No 246, 1st floor, Malang, East Java, Indonesia. 65144 Tel./Fax. +62-341-464318 (145), *email: maftuchah@umm.ac.id

Manuscript received: DD MM 2020 (Date of abstract/manuscript submission). Revision accepted: ....

Abstract. Sorghum (*Sorghum bicolor* L. Moench) is an essential food crop after wheat, rice, maize, and barley. it has wide adaptability. grown on marginal lands as cheap sorce of carbohydrate. The present study aims at stdying the morphological diversity and heritability values of major sorghum landraces in East Java. The research was conducted in Purutrejo village of Pasuruan city. The local genotypes were derived from Jombang (SG-JBG), Tuban (SG-TBN), Pasuruan (GB-PSR), Lamongan 1 (SG-LMG 1), Lamongan 2 (SG-LMG 2), Sampang 1 (SG-SPG 1), Sampang 2 (SG-SPG 2), Tulungagung 1 (SG-TLG 1), Tulungagung 2 (SG-TLG 2). The results showed that the Sampang 2 genotype produced the longest panicles, while the Lamongan 2 had the highest seed dry weight per panicle and highest number of seeds per panicle (117.34 gram/panicle dry weight and 4581.80 seeds/panicle). The genotype of Tulungagung 2 produced the highest fresh (41.43 g/1000 seeds) and dry seed weight (31.96 g/1000 seeds). In addition, , the results also showed that it was genetically different from Tulungagung 1 genotype. Similarly, the highest number of tillers was produced by Tulungagung 2 (4.20 tiller) and was not significantly different from Tulungagung 1 (3.33 tiller) and Jombang (2.07 tiller). Based on the result of nine local genotypes tested, the flowering ranged from 42 to 53 days after planting and days to harvest ranged from 70 to 91 days after planting. The early maturity was observed in Tulungagung 2 (70 days after planting) as against others. The phenotype variety's entire value on each variable was significant than the amount of the genotype range. The highest heritability value in all the observed exceeded 0.5.

Keywords: diversity, heritability, landrace, *Sorghum bicolor* Linn.

INTRODUCTION

The increasing population has increased the need for various agricultural commodities, especially cereals and pulses.. Among the cereals, sSorghum (Sorghum bicolor L) is one of the world's essential crops as the primary source of carbohydrates after wheat, rice, corn, and barley. Sorghum could be developed as an alternative to local food besides rice to increase food needs. Besides, Sorghum also has the potential as animal feed and industrial material. Sorghum is an annual crop that was easy to cultivate, but its production is still lower than that of rice, maize, and other cereal crops. Sorghum has wide environmental adaptability and can be developed in areas with less adaptive environmental conditions to climate change (Sirappa, 2003; Mundia *et al*., 2019). These showed that Sorghum has more potential to be developed as an alternative to increasing local food on marginal lands compared to rice (Sulistyowati *et al*., 2019a). Besides, current research indicated several local genotypes of Sorghum, which contain high carbohydrates and protein could be used for various food preparations (Sulistyowati *et al*., 2019b). Sorghum improvement would upplement government initiatives in reducing the burden of rice and wheat import (Susilowati and Saliem, 2013).

Genetic characterization of germplasm lines aims to identify important traits that have economic value or which possess specific characteristics of the variety concerned. The characters could be morphological (qualitative and quantitative), agronomic (Flowering and maturity time,), physiological,. Characterization and evaluation prcesses have essential meanings and roles determining these materials' good value (Kusumawati *et al.*, 2013). The differences in Sorghum's genotype could be recognized more clearly in the generative phase than in the vegetative phase (Elvira *et al.*, 2015). The diversity among these accessions will help plant breeding activities, especially in providing plant breeding materials (Rifa'i *et al*., 2015).

Genetic diversity facilitates the selection process in field crops including sorghum. If the genetic variance were high, the heritability value would be high. Thus, the variable could be used as a selection criterion (Setiawan *et al.,* 2019). Heritability value could be interpreted as the proportion between genetic variance and phenotypic variance (Falconer &

Mackay, 1996). The heritability value of a character did not indicate that the character is genetic or environmental (Maftuchah *et al.*, 2015).

Information on morphological diversity and heritability values help to breed for local sorghum genotypes suitable as an alternative to food, feed, or fuel. In this context, The present study aimed to obtain information about the morphological diversity and heritability values of local sorghum genotypes of East Java.

MATERIALS AND METHODS

The research was conducted in Purutrejo village, Purworejo district, Pasuruan city. The planting material used in this study were consisted of nine genotypes of local sorghum plants derived from various regions in East Java, i.e., Jombang (SG-JBG), Tuban (SG-TBN), Pasuruan (GB-PSR), Lamongan 1 (SG-LMG 1), Lamongan 2 (SG-LMG 2), Sampang 1 (SG-SPG 1), Sampang 2 (SG-SPG 2), Tulungagung 1 (SG-TLG 1), Tulungagung 2 (SG-TLG 2).

The experiment was conducted as randomized block design with three replications. The design consisted of one factor (9 genotypes of local Sorghum) so that there was 27 experimental unit. The sorghum planting was carried out by seeding on a tray used a planting medium, i.e., soil and compost. Seedlings were planted in the field after ten days of planting with a planted distance of 75 cm x 15 cm at plots measuring 3 x 2.5 m. Thus, each plot consists of 21 sorghum plants. The fertilizers used organic fertilizers and inorganic fertilizers (SP 36, Urea, and KCL). Manure is an essential fertilizer given at the same time as tillage. Meanwhile, inorganic fertilizers are applied to the planting hole when the plants are 2 WAP and 4 WAP.

The variables observed were plant height, number of leaves, stem diameter, panicle length, total dry weight of grains per panicle, number of grains per panicle, fresh weight of 1000 grains, dry weight of 1000 grains, leaf length, leaf width, plant height at harvest, tillers, age, and harvest of flowering and harvest age. Data analysis was performed using variance analysis and continued with the 5% LSD test, analysis of variance and heritability testing.

RESULTS AND DISCUSSION

Morphological characters:

Genotypic treatments showed significant differences in plant height at 21, 28, and 35 days after planting. Table 1 shows the average plant height and number of leaves several local sorghum genotypes in East Java at various observation ages Plant height is one of the growth parameters that is often used to determine environmental or genetic influences. The influence of the environment results in the genotype being able to display its character. The existence of inappropriate environmental influences results in the appearance of genetic traits that it was not optimal. Leaves are the primary organ for photosynthesis. The highest average number of leaves was shown by the genotypes of Jombang, Lamongan-1, and Tulungagung 1 (Table 2). In comparison, the largest average stem diameter is shown by Genotype Lamongan 2 (Table 3). The diversity of a plant's appearance is influenced by one genetic factor (Panjaitan *et al*., 2015).

Table 1. Plant height (cm) and number of leaves (strands) of several East Java local sorghum genotypes at various observation ages

Genotype	Plant Height (cm)								Number of Leaves (strands)							
	14 DAP		21 DAP		28 DAP		35 DAP		14 DAP		21 DAP		28 DAP		35 DAP	
SG-JBG	8,56	a	14,99	b	24,16	cd	63,30	e	4,80	d	6,80	d	7,93	c	8,53	e
SG-TBN	7,55	a	13,71	ab	22,10	ab	48,37	bcd	4,47	bc	6,47	cd	7,80	bc	8,13	de
SG-PSR	8,31	a	15,42	b	22,88	abc	55,55	cde	3,93	b	5,80	cd	7,07	bc	7,20	cd
SG-LMG 1	7,96	a	13,30	ab	22,65	abc	42,14	abc	4,27	bc	5,87	cd	7,87	c	8,33	e
SG-LMG 2	6,97	a	13,89	ab	20,43	ab	34,80	ab	4,07	bc	5,80	cd	7,27	bc	8,20	de
SG-SPG 1	7,13	a	11,03	a	17,27	a	29,55	a	2,53	a	2,87	a	4,67	a	5,13	a
SG-SPG 2	6,84	a	15,94	b	29,02	cd	46,60	bc	3,87	b	4,53	b	5,33	a	5,67	ab
SG-TLG 1	9,21	a	15,91	b	26,91	bc	62,04	de	4,00	bc	6,33	cd	7,47	bc	8,40	e
SG-TLG 2	8,43	a	15,77	b	33,87	d	63,97	e	4,00	bc	5,60	bc	6,73	bc	6,73	cd

Note: The numbers followed by the same letter in the same column show no significant difference in the 5% LSD test.

Table 2 shows the average leaf length and width of several genotypes of local Sorghum in East Java. In comparison, the average plant height at harvest and the number of tillers were shown in Table 3. The highest number of tillers was produced by genotype Tulungagung 2 (4.20 tillers) and did not differ significantly from genotype Tulungagung 1 (3.33 tillers) and genotype Jombang. The diversity of observations indicates that each genotype has different characteristics. Siswanto (2015) states that the genetic characteristics of varieties, the environment in which they are grown, and the cultivation treatment will affect Sorghum's yield potential. Genetic and environmental factors determine the number of chicks produced.

Table 2. Average stem diameter, length, the width of leaves, the value of plant height at harvest, and number of tillers of several East Java local sorghum genotypes

Genotype	Stem Diameter (cm)				Leaf length (cm)		Leaf Width (cm)		Plant Height at Harvest (cm)		Number of Tillers	
	28 DAP		35 DAP									
SG-JBG	1,27	Bc	1,47	bcd	77,27	d	7,70	d	255,72	d	2,07	c
SG-TBN	1,29	Bc	1,51	cd	79,15	d	7,82	de	262,33	d	2,13	ab
SG-PSR	1,14	Abc	1,19	ab	78,40	d	6,75	c	202,40	c	2,27	ab
SG-LMG 1	1,26	Abc	1,46	bcd	82,14	d	8,84	e	139,47	a	1,33	a
SG-LMG 2	1,37	C	1,83	e	76,01	cd	8,24	de	167,50	b	1,87	a
SG-SPG 1	1,19	Abc	1,24	abc	69,96	bc	5,69	b	191,67	c	2,07	ab
SG-SPG 2	0,93	A	1,05	a	49,29	a	4,56	a	136,15	a	1,80	a
SG-TLG 1	1,37	C	1,56	de	80,11	d	7,84	de	274,23	d	3,33	bc
SG-TLG 2	1,02	Ab	1,03	a	68,33	bc	4,79	ab	214,05	c	4,20	c

Note: The numbers followed by the same letter in the same column show no significant difference in the 5% LDS test

Yield contributing traits:

The average panicle length, total seed dry weight per panicle, number of seeds per panicle, fresh weight, and dry weight 1000 seeds of several East Java local sorghum genotypes are shown in Table 3. The Sampang 2 genotype shows the longest panicle size, while Lamongan 2 produces the longest seed dry weight per panicle (117.34 grams). dry seeds/panicle) and the highest number of seeds per panicle (4581.80 seeds/panicle) (Table 3). Long panicles of plants are formed in the primordia phase. The difference in panicle length is due to different genotypes and inherited traits. Each genetic factor and the adaptability of each variety is different so that it affects the length of sorghum panicles (Sirappa and Waas, 2009).

Total dry weight is one measure to study further plant growth (Ferdian et al., 2015). The total dry weight per panicle is one of the criteria for the production of Sorghum. Genetic differences will result in a different panicle shape or weight of the seed unit so that each genotype has a different dry weight. Plants require sufficient nutrient content for seed formation. The highest total dry weight and the number of seeds per panicle were produced by the genotype Lamongan 2. The genotype of Tulungagung 2 produced the highest fresh weight and dry weight of 1000 seeds and was not significantly different from Tulungagung 1. The fresh weight of seeds in Tulungagung 2 was 41.43 grams / 1000 seeds, and the dry weight was 31.96 grams / 1000 seeds. Genotypic differences result in different shape and weight of seeds.

Table 3. The average length of panicle, total dry weight of seeds per panicle number of seeds, fresh and dry weight of 1000 seeds per panicle of several East Java local sorghum genotypes

Genotype	Panicle Length (cm)		Total Seed Dry Weight Per Panicle (g / panicle)		Number of Seeds per Panicle		Fresh Weight 1000 Seeds (g)		Dry Weight 1000 Seeds (g)	
SG-JBG	23,92	a	88,87	c	3081,80	de	37,86	cde	28,87	cd
SG-TBN	26,13	a	82,94	bc	3125,70	de	34,61	bc	26,50	bc
SG-PSR	34,69	b	68,68	b	2293,90	bc	37,25	cd	30,06	de
SG-LMG 1	25,50	a	86,68	bc	3563,90	e	34,07	bc	24,66	ab
SG-LMG 2	38,53	bc	117,34	d	4581,80	f	32,73	b	25,87	ab
SG-SPG 1	35,83	b	44,23	a	1962,10	ab	26,45	a	23,22	a
SG-SPG 2	47,75	d	48,70	a	1840,80	ab	32,65	b	26,51	bc
SG-TLG 1	41,29	c	86,69	bc	2746,60	cd	41,04	de	31,55	de
SG-TLG 2	41,73	c	45,72	a	1426,80	a	41,43	e	31,96	e

Note: The numbers followed by the same letter in the same column show no significant difference in the 5% LDS test

Table 4 shows that the flowering ages ranged from 42 to 53 days after planting. Meanwhile, the harvest age ranges from 70 to 91 days after planting. The fastest harvesting age was on genotype Tulungagung 2 (70 days after planting). The existence of the suitability of environmental conditions can stimulate the flowering and harvesting age faster. Besides, the nutrients absorbed by plants are used as a source of energy in plant growth (Setiyagama, 2017).

Table 4. Flowering age, flowering to harvest, and harvesting age of several East Java local sorghum genotypes

Genotype	Days to flower (DAP)	Flowering to Harvest (Days)	Days to maturity (DAP)
SG-JBG	53	38	91
SG-TBN	53	33	86
SG-PSR	49	28	77
SG-LMG 1	49	28	77
SG-LMG 2	51	35	86
SG-SPG 1	42	44	86
SG-SPG 2	42	49	91
SG-TLG 1	53	24	77
SG-TLG 2	38	32	70

The analysis of environmental diversity, genotype, and phenotype variability is shown in Table 9. These data indicate the criteria for broad genotype and phenotype variance. All values for the phenotype variety on each variable were more significant than the values for genotype variance. The indication of this is the influence of the genotype and the environment (Kotal *et al.*, 2010). Genotype diversity is a measure of genetic variation caused by the components of the genotype. In contrast, phenotype diversity is a variation of characters regulated by genotype factors and the growing environment and the two's interaction.

The wide variety of genotypes in the nine local sorghum genotypes in East Java indicates inequalities in genetic characters between genotypes. Dominant genotype variety is the main cause of the inequality of characters among plant relatives. High genetic diversity indicates a high potential for use in the improvement of plant traits. Genetic facts are inferred from phenotypic observations, which are the results of genotype interactions and the environment. The variability available in breeding material is the prime requirement for improving and selecting elite genotypes (Seetharam and Ganesamurthy, 2013).

Genetic variability and heritability

Table 5. Analysis of Environmental Variety, Genotype, and Phenotype

Traits	σ^2 e	σ^2 g	2σ g	Criteria	σ^2 p	2σ p	Criteria
Plant Height (cm)	26,56	2659,65	166.76	broad	2686,22	0,14	broad
Number of Leaves	0,52	138,75	7.97	broad	139,28	0,02	broad
Stem Diameter (cm)	0,07	4,99	0.34	broad	5,06	0,01	broad
Panicle Length (cm)	12,95	9206,55	515.25	broad	9219,5	0,10	broad
Number of Seeds per Panicle	405537	125860168,2	7186137.17	broad	126265705,06	17,83	broad
Seed / Panicle Dry Weight (g)	271,79	79463,18	4547.67	broad	79735	0,46	broad
Fresh Weight 1000 seeds (g)	11,32	2847,39	164.05	broad	2858,71	0,09	broad
Dry Weight 1000 seeds (g)	6,47	1213,8	71.15	broad	1220,28	0,07	broad
Leaf Length (cm)	29,47	13576,55	765.99	broad	13606	0,15	broad
Leaf Width (cm)	0,67	320	18.04	broad	320,67	0,02	broad
Plant Height at Harvest (cm)	414,57	356701,73	19913.49	broad	357116	0,57	broad
Number of Tillers	1,32	92,32	6.2	broad	93,64	0,03	broad

note: σ^2 e (Variety of Environment), σ^2 g (Variety of Genotypes), 2σ g(Standard Deviation of Genotype Variety), σ^2 ***p***(Variety of Phenotypes), 2σ p(Standard Deviation of Phenotype Variety). σ^2 g < 2σ g (Narrow) dan σ^2 g > 2σ g (broad). σ^2 p < 2σ p (Narrow) dan σ^2 p > 2σ p (broad) .

Heritability value analysis shows that all tested parameters exceed 0.5 for each observed variable so that it is categorized as high heritability. Chaudhary (2001) concluded that the high coefficient of phenotype variety compared to the coefficient of genotype variance indicates a good effect on all genotypes' environment. The wide diversity of phenotypes comes from a wide diversity of genotypes, so that the requirement for the selection process to take place in the genotype selection process is wide genetic diversity. (Rahajeng and Rahayuningtyas, 2015).

In a broad sense, the heritability prediction value is the ratio between the total genetic variance and the phenotype variety, which shows the large proportion of genetic factors in a plant character's phenotype. The estimated high heritability means that plant genetic factors that affect plant phenotypes are very large compared to environmental factors

(Ardiyanti et al., 2019). The phenotype variety analysis showed that the phenotype diversity in all observed genotypes was also high (Table 6). In general, high genotype diversity will be followed by high phenotype diversity. The diversity will be inherited can be measured using the heritability parameter. It was a broad sense, a comparison between the magnitude variety of genotypes and a character's phenotypes. The high heritability followed by wide genetic diversity in the nine East Java local sorghum genotypes indicates that genetic factors influence the characters. The high heritability of some local East Java sorghum genotypes is due to genetic factors. If genetic factors play a more important role, these characters can be inherited, and it is hoped that selection can be useful for the observed traits (Maftuchah et al., 2015). Besides, Jimmy et al. (2017) reported that high heritability was generated by all observed agronomic characters and indicated that additive genes played a more critical role in improving plant breeding more quickly. This study's results are also in line with Setiawan et al. (2016), who showed that the plant height variables of 20 sorghum genotypes showed high heritability. The selection criteria for Sorghum could be used as a biomass producer. However, this research needs to study the local Sorghum more deeply as an alternative food, animal feed, or industrial raw material.

Table 6. Heritability

Traits	Heritability	Criteria
Plant Height (cm)	0,990	High
Number of Leaves	0,996	High
Stem Diameter (cm)	0,986	High
Panicle Length (cm)	0,999	High
Number of Seeds per Panicle	0,997	High
Seed / Panicle Dry Weight (g)	0,997	High
Fresh Weight 1000 seeds (g)	0,996	High
Dry Weight 1000 seeds (g)	0,995	High
Leaf Length (cm)	0,998	High
Leaf Width (cm)	0,998	High
Plant Height at Harvest (cm)	0,999	High
Number of Tillers	0,986	High

Description: High Heritability ($H \geq 50\%$ or $H \geq 0,5$ Medium heritability ($20\% < H < 50\%$ or $0,2 < H < 0,5$), low Heritability($H \leq 20\%$ or $H \leq 0,2$).

The results showed that the Sampang 2 genotype produced the most extended panicle size. The Lamongan 2 genotype produced the highest seed dry weight per panicle and the highest number of seeds per panicle (117.34 grams of seed dry weight per panicle and 4581.80 seeds per panicle). The genotype of Tulungagung 2 produced the highest fresh weight and dry weight of 1000 seeds and was not different from Tulungagung 1. The fresh weight of 1000 seeds in Tulungagung 2 was 41.43 grams, and the dry weight of 1000 seeds was 31.96 grams. The highest number of tillers was produced by Tulungagung 2 (4.20 chicks) and was not significantly different from Tulungagung 1 (3.33 chicks) and Jombang (2.07 chicks). Of the nine genotypes tested, the flowering ages ranged from 42 to 53 days after planting, and the harvest ages ranged from 70 to 91 days after planting. The fastest harvest age is in Tulungagung 2 (70 days after planting). All parameters tested showed the criteria for a wide range of genotypes and phenotypes. The entire value of the phenotype variety on each variable was more significant than the value of the genotype range. Heritability test results show that all experimental parameters exceed 0.5 so that it is categorized as high heritability.

ACKNOWLEDGEMENTS

Author would like to thank the Directorate of Research and the Community Service University of Muhammadiyah Malang that has funded this research through the center of study's flagship program in 2017.

REFERENCES

Ardiyanti SE, Sopandie D, Wirnas D, Trikoesoemaningtyas. 2019. Ratoon Productivity of sorghum Breeding Lines (*Sorghum bicolor* (L.) Moench). IOP Conf. Series: Earth and Environmental Science 399 012030. Doi:10.1088/1755-1315/399/1/012030.

Chaudhary R. R., 2001. Genetic Variability and Heritability in Sugarcane. Nepal Agric. Res. J., Vol. 5.

Elvira SD, Yusuf M, Maiyuslina. 2015. Karakter Agronomi Beberapa Varietas Sorgum pada Lahan Marginal di Aceh Utara. Jurnal Agrium 12(1): 1-4.

Falconer, D.S., T.F.C. Mackay. 1996. Quantitative to Genetics. The Roland Press Company. New York 356p

Ferdian B, Sunyoto, Karyanto A, Kamal M. 2015. Akumulasi Bahan Kering Beberapa Varietas Tanaman Sorgum (Sorghum bicolor (L.) Moench) Ratoon 1 Pada Kerapatan Tanaman Berbeda. J.Agrotek Tropika 3 (1): 41-48.

Jimmy ML, Nzuve F, Flourence O, Manyasa E, Muthomi J. 2017. Genetic variability, heritability, genetic advance and trait correlatons in selected Sorghum (*Sorghum bicolor* L. Moench) varieties. Int.J.Agron. Agri. R. 11 (5): 47-56.

Kotal BD, Das A, Choudhury BK. 2010. Genetic Variability and Association of Characters in Wheat (*Triticum aestivum* L.). Asian Journal of Crop Science 2(3):155-160. http://dx.doi.org/10.3923/ajcs.2010.155.160

Kusumawati A, Putri NK, Suliansyah I. 2013. Karakterisasi dan Evaluasi Beberapa Genotipe Sorgumn (*Sorghum bicolor* L) di Sukarami Kabupaten Solok. Jurnal Agroteknologi 4(1): 7-12. http://dx.doi.org/10.24014/ja.v4i1.57

Maftuchah, Reswari HA, Ishartati E, Zainudin A, Sudarmo H. 2015. Heretability and Correlation of Vegetative and Generative Character on Genotypes of Jatropha (*Jatropha curcas* Linn.). Energy Procedia 65 : 186-193. https://doi.org/10.1016/j.egypro.2015.01.058

Mundia CW, Secchi S, Akamani K, Wang G. 2019. A Regional Comparison of Factor Affecting Global Sorghum Production: The Case of North America, Asia and Africa's Sahel. Sustainability 11 (2135) doi:10.3390/su11072135

Panjaitan R, Zuhry E, Deviona. 2015. Karakterisasi dan Hubungan Kekerabatan 13 Genotipe Sorgum (Sorghum Bicolor (L.) Mouch Koleksi Batan. Jurnal JOM Faperta. Vol. 2 No. 1.

Rahajeng W, Rahayuningtyas A. 2015. Pendugaan Komponen Ragam, Heritabilitas dan Korelasi Klon-Klon Harapan Ubijalar Berkadar Betakaroten Tinggi. Jurnal Ilmu Pertanian Vol. 18 No.1. https://doi.org/10.22146/ipas.6177

Rifa'i H, Ashari S, Damanhuri. 2015. Keragaman 36 Aksesi Sorgum *(Sorghum bicolor* L*.)*. Jurnal Produksi Tanaman. 3(4): 330-337.

Seetharam K, Ganesamurthy K. 2013. Characterization Of Sorghum Genotypes For Yield And Other Agronomic Traits Through Genetic Variability And Diversity Analysis. Electronic Journal of Plant Breeding 4(1): 1073-1079.

Setiawan K, Kamal M, Hadi MS, Sungkono, Maulana I. 2016. Keragaan beberapa kandidat genotip sorgum sebagai penghasil biomasa. hlm 373-380. *Dalam Prosiding Seminar Nasional dan Kongres 2016 Perhimpunan Agronomi Indonesia (PERAGI)*. Departemen Agronomi dan Hortikultura, Institut Pertanian Bogor, Bogor.

Setiawan K, Restiningtias R, Utomo SD, Ardian, Hadi MS, Yuliadi E. 2019. Keragaman Genetik, Fenotip, dan Heritabilitas Beberapa Genotipe Sorghum pada Kondisi Tumpangsari dan Monokultur. Jurnal Agro 6 (2): 95-109. https://doi.org/10.15575/4568

Setiyagama MJ, Arifin AZ, Sulistyawati. 2017. Karakterisasi Beberapa Genotip Sorgum *(Sorghum bicolor* L.) Lokal Jawa Timur. Dalam jurnal Agroteknologi Merdeka Pasuruan 1 (2):18-22.

Sirappa MP, Waas ED. 2009. Kajian Varietas dan Pemupukan Terhadap Peningkatan Hasil Padi Sawah di Dataran Pasahari, Maluku Tengah. Jurnal pengkajian dan pengembangan teknologi pertanian Vol. 12 No. 1.

Sirappa MP. 2003. Prospek Pengembangan Sorghum di Indonesia sebagai Komoditas Alternatif untuk Pangan, Pakan, dan Industri. Jurnal Litbang Pertanian 22 (4).

Sulistyowati, Roeswitawati D, Ibrahim JT, Maftuchah. 2019. Agronomic Character of Several Local Genotypes of Sorghum (*Sorghum bicolor* L.) at East Java. IOP Conf. Series : Materials Science and Engineering 532. doi:10.1088/1757-899X/532/1/012023

Sulistyowati, Roeswitawati D, Ibrahim JT, Maftuchah. 2019. Genetic Diversity of Local Sorghum (*Sorghum bicolor*) Genotypes of East Java, Indonesia for Agro-Morphological and Physiological traits. Biodiversitas 20 (9) : 2503-2510. https://doi.org/10.13057/biodiv/d200911

Susilowati SH, Saliem HP. 2013. Perdagangan Sorgum di Pasar Dunia dan Asia serta Prospek Pengembangannya di Indonesia. Dalam: Sumarno, et al. (eds). Sorgum: Inovasi Teknologi dan Pengembangan. IAARD Press, Jakarta.