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AGRONOMIC CHARACTERISTICS OF SOME SORGHUM [*Sorghum bicolor* (L.) MOENCH] GENOTYPES UNDER INTERCROPPING WITH CASSAVA

MUHAMMAD SYAMSOEL HADI[1)], MUHAMMAD KAMAL[2)],
F. X. SUSILO[3)], and ERWIN YULIADI[4)]

[1)] Doctoral Program in Agricultural Science , College of Agriculture, University of Lampung - Indonesia
[2)] Division of Agronomy, College of Agriculture, University of Lampung - Indonesia
[3)] Division of Plant Protection, College of Agriculture, University of Lampung - Indonesia
[4)] Division of Agronomy, College of Agriculture, University of Lampung - Indonesia

ABSTRACT

In general, the appearance sorghum agronomic characteristics are believed to be very dynamic, highly dependent on the nature of the genetic and the environment in which plants grow. This study aims to determine the agronomic characteristics of some sorghum [*Sorghum bicolor* (L.) Moench] genotypes under intercropping with cassava. The experiment was arranged in a Split-Plot Randomized Complete Block Design with three replications, in which cropping systems (sorghum monoculture and sorghum-cassava intercropping) as the main plots and 34 sorghum genotypes as subplots. Our results showed that the growth of sorghum were generally not affected by intercropping with cassava, whereas grain yield declined with intercropping as shown by 100-grains weight, seed number and grain weight. There were significant differences among genotypes for all growth and yield components observed. Some genotypes (GH-6, GH-13, P/F 10-90A, P/F 5-193-C, Super–1, Super–2, P/I WHP, Talaga Bodas, UPCA, and Mandau) were able to act equally well as a dual-purpose sorghum to produce above-ground biomass and grain yield.

Keywords: sorghum, intercropping, cassava

INTRODUCTION

Sorghum is one of the most important crops producing cereal. In Africa, sorghum is one of the mainstay cereal crops to fulfill food needs and its cultivation acreage increases every year (Belton and Taylor, 2004). In Asia, sorghum is mainly cultivated in South Asia (Reddy and Patil. 2015). In southeastern United States, beside as forage crop sorghum has been grown traditionally as syrup and sugar crop (Teetor *et al*., 2011). Meanwhile, this crop in Indonesia is not popular due to its low economic value so far, and other factors such as farmer's knowledge and government's support. In Indonesia, sorghum plantation is still around 8,000 ha spreading in some regions (Supriyanto, 2010).

Cassava is one of the major crops that support the economy of farmers in Lampung Province in addition to palm and rubber. This plant is usually harvested from 9 – 10 months age. The first three months of the beginning of the growth of cassava, the plant canopy still gives open space between rows of cassava, which usually planted with a spacing of 80 cm x 60 cm. Thus, these conditions provide opportunities for intercropping with other plants, such as sorghum. In Lampung, cassava harvested area in 2015 is recorded 279,337 ha (Badan Pusat Statistik Provinsi Lampung, 2016), a huge potential in the use of land for the development of sorghum without having to make major changes in main crop.

Sorghum intercropping systems with cassava has so far rarely been done, at least in Lampung, or if ever has not been well documented. Land use between cassava plants in early its growth will be able to increase the productivity of land, which in turn helps improve the economy of farmers.

Research sorghum intercropped with other crops has also been conducted by researchers, with varying results. For example, other plants that were intercropped with sorghum included pigeonpea (*Cajanus cajan*) (Ito *et al*., 1993), with *Lablab purpureus* L. (Shehu *et al*., 1999), with cowpea (*Vigna unguiculata* L.) (Padi, 2007), soybeans (Ghosh *et al*., 2009), and palisade grass (Borghi *et al*., 2013). Intercropping sorghum – cassava conducted by Kamal *et al*. (2014) shows that planting sorghum 2 or 4 weeks after cassava produce grain yield and nutrient levels lower than planted simultaneously with cassava.

Appearance sorghum agronomic characteristics in general are often regarded as a dynamic, highly dependent on the nature of the genetic (Santos *et al*., 2013) and the environment in which the plants grow. El Naim *et al*. (2012) showed that the sorghum grain yield was positively correlated with the number of grains per panicle and panicle number per unit area. Tolk *et al*. (2013) found that under drought conditions, the stay green hybrid maintained yield by retaining greater seed numbers.

Genotype differences determine the agronomic performance on flowering, dough and physiological maturity phases, while the difference of season gives a slight influence (Munirathinam *et al*., 2013). The big difference in the appearance of agronomic among genotypes can also be caused by physiological differences among genotypes.

Djanaguiramana *et al*. (2014), for example, shows the differences in the physiological appearance among genotypes, in which the plants are tolerant to high temperatures experienced less oxidative damage in leaf and seed pollen than plants that are sensitive. Leaf is part of most plants responsible for photosynthesis. This will have an impact on agronomic performance of sorghum. Research conducted by Sihono (2009), Sihono et al. (2010) and Sihono (2013) also showed variation in agronomic performance of various genotypes tested. In addition there have been improvements in agronomic characteristics of two promising mutant strains that have higher production than the parent, showing that the mutation technique could be one option to improve the agronomic appearance. Elangovan *et al*. (2014) show that genetic diversity among genotypes of sweet sorghum produces the different phenotype that can be viewed from various aspects, both agronomically and biochemistry. Cluster analysis results obtained in this study illustrates the existence of some similarity in traits and yield among the genotypes.

This study aims to determine the agronomic characteristics of some sorghum [*Sorghum bicolor* (L.) Moench] genotypes under intercropping with cassava.

MATERIALS AND METHODS

Time and Experimental Site

Field experiment was started at the end of rainy season of 2015 (rainfall of 186 mm in April) and harvested at dry season (rainfall of 14 mm in September). The experimental site was situated 70 m above sea level on dry land located in Village of Sri Margorahayu, Sub-district of Anak Tuha, Regency of Central Lampung.

Experimental Design

The experiment was arranged in a Split-Plot Randomized Complete Block Design with three replications, in which cropping systems (sorghum monoculture and sorghum-cassava intercropping) as the main plots and 34 sorghum genotypes as subplots. Sorghum genotypes included Mandau, Samurai-1, Samurai-2, Kawali, P/F 5-193-C, P/I WHP, P/I 10-90A, P/I 150-21-A CYMIT, Talaga Bodas, UPCA, Super-1, Super-2, Numbu, Pahat, and 20 mutant sorghum genotypes, namely GH-1, GH-2, GH-3, GH-4, GH-5, GH-6, GH-7, GH-8,

GH-9, GH-10, GH-11, GH-12, GH-13, GH-14, GHP-1, GHP-3, GHP-5, GHP-11, GHP-29, and GHP-33. The cassava grown was Variety of Kasetsart.

For sorghum monoculture, each plot consisted of 50 plants grown in a 10 meter-long row, considered as an experimental unit. In sorghum-cassava intercropping, sorghum is planted (at the same time with cassava) between rows of cassava plants. The distance between rows both for sorghum and cassava was 80 cm, while the distance between plants in the row was 20 cm and 60 cm for sorghum and cassava, respectively.

Cultural Practice

Before planting, the soil plowed two times and leveled then plotted. The time span between the first to the second plowing is one week, and leveling the ground was implemented a day after the second plowing.

Application urea on sorghum plants (totally 150 kg / ha) and KCl (100 kg/ha) was done two times that is at 7 days and 30 days after planting (DAP), while SP-36 (75 kg/ha) was applied once at 7 DAP, along with urea and KCl. Fertilization of urea on cassava (totally 150 kg/ha) and KCl (200 kg/ha) was done two times that is at 30 DAP and 90 DAP, while SP-36 (75 kg/ha) was applied once at 30 DAP, along with urea and KCl. Fertilizer is placed in the hole between plants in a row and then covered with soil.

Sorghum was harvested at around 120 DAP, when the seed has reached physiological maturity (varies depending on the genotype).

Data Collection and Analysis

Observations of agronomic characteristics were performed on three samples of plants per experiment unit at harvest. Observations were made on root dry weight, shoot dry weight (leaf + stem), plant height, 100-grains weight, number of grain per plant, and grain weight per plant. The data analysis subjected to Analysis of Variance and LSD, Pearson's Correlation as well by using Minitab Ver.17.

RESULTS AND DISCUSSIONS

Results of analysis of variance for all growth and yield components of 34 sorghum genotypes are presented in Table 1.

The results of our observations showed that there were, except for leaf number at 50 DAP, no significant difference between monoculture and sorghum – cassava intercropping on growth components of sorghum plants. It indicates that sorghum is fairly suitable intercropped with cassava plant for the forage purpose (Table 1). It is supported by Borghi *et al*. (2013) proved cropping system is very beneficial for both plants intercropped. In this experiment, all genotypes showed significant differences in agronomic performance for all growth and yield components observed. This indicated adequate amount of variability among genotypes that may be helpful for trait improvement by selection as suggested by Khandelwal *et al*. (2015).

Sorghum growth components

The results of our observations suggest that the monoculture system generates the number of leaves (8.3) more than intercropped system (7.6). However, this is not followed by the difference between the two systems for other growth components, such as the dry weights of stem, leaf and canopy. This is an indication that the intercropped system is reliable to produce sorghum forage-based livestock in order to utilize the open space at the beginning of the cassava plant growth.

Some genotypes showed greater growth potential than other genotypes. This is evident from observations at harvest (Table 2) shows that the Super-1, Super-2, and P/I WHP GH-1, GH-2, GH 4, GH-6, GH-13, and P/F 5-193-C tend to be appropriate as forage sorghum. Those genotypes grew taller and had high shoot dry weight. This is in accordance with Wight *et al*. (2012) mentioned that the plant height can be used as a useful indicator of dry mass production in sorghum hybrids sensitive to photoperiod.

Mutant sorghum genotypes of GH-3, GH-5, GH-7, GH-8, GH-9, GH-10, GH-11, GH-12, GH-14, GHP-1, GHP-3, GHP-5, GHP-11, GHP-29, and GHP-33 in this experiment did not show high above-ground biomass.

Sorghum yield components and grain yield

The results showed that the yield components in monoculture system was generally better than intercropped system. This is apparent from the 100-grains weight, grain number, and grain weight per plant of 34 genotypes tested.

Some genotypes like Talaga Bodas, UPCA, GH3, Numbu, Super - 2, GH-6, Mandau, P/I WHP, GH-14, P/F 5-193-C, Super–1, Kawali, P/F 10-90A, and GH-7 produced grain weight higher than the other genotypes (Table 4). This is also supported by the high grain number and 100-grain weight of the genotypes mentioned above.

The differences in the growth and yield among genotypes in this study was similar to the results of Sihono (2009), Sihono et al. (2010) and Sihono (2013) which showed variations in agronomic performance of various genotypes tested. Munirathnam et al. (2013) showed that genotype differences determine the agronomic performance on flowering stage, dough stage, and physiological maturity, while the difference of the season has a little impact. The difference in agronomic appearance among genotypes can also be caused by physiological differences among genotypes.

Grain weight of promising lines of GH-9 and GH-10, and GHP-3 in this study was less than observed by Hadi *et al*. (2016). This difference is probably caused by the location, indicating that those promising lines of sorghum are environmentally dependent.

Based on above ground biomass (revealed by shoot dry weight) and yield (seen from the grain weight per plant) in general there are 15 potential sorghum genotypes as shown in Table 5 below. Ten sorghum genotypes (GH-6, GH-13, P/F 10-90A, P/F 5-193-C, Super–1, Super–2, P/I WHP, Talaga Bodas, UPCA, and Mandau) indicate to be potential as dual-purpose and can be grown for forage or grain production. Forage sorghums are generally taller, leafier and, at least historically, produce less grain than those classified as grain sorghum (Bean *et al*, 2013). Based on Khandelwal et al. (2015) tall plants with high fresh biomass might be poor in translocation of photosynthate, one of the reasons why forage sorghum produces less grain. In contrary, our research showed some promising line (GH-3, GH-6, GH-7, GH-13, and GH-14) were still able to produced fairly high grain although they are tall genotypes. According to Perazzo *et al*. (2014) the negative correlation between plant height and panicle showed that the plant size determines the repartition of the sorghum plant components. Higher plants usually have a higher biomass production and lower participation on the panicles, which becomes a character as forage sorghum. For plants that are shorter, there is a higher percentage of panicles, which becomes a character of grain sorghum. Plants with a medium size has a balanced distribution among the components, as a character dual-purpose sorghum.

The correlation analysis (Table 6) indicates that the root has an important role to above-ground biomass (shown by shoot dry weight) and grain yield.

The results of this study indicate the importance of roots to support stem, shoot, and grain weight. This is evident from the existence of fairly high correlations between root dry weight to stem dry weight, shoot dry weight, and the grain weight. Based on Magalhães *et al*. (2016), the characteristics of the root has an important role not only in drought avoidance, but also conservative of the water absorbed from the soil.

We can conclude that the growth of sorghum were generally not affected by intercropping with cassava, whereas grain yield declined with intercropping as shown by 100-grains weight, seed number and grain weight. There were significant differences among genotypes for all growth and yield components observed. Some genotypes (GH-6, GH-13, P/F 10-90A, P/F 5-193-C, Super–1, Super–2, P/I WHP, Talaga Bodas, UPCA, and Mandau) were able to act equally well as a dual-purpose sorghum to produce above-ground biomass and grain yield.

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Table 1. Summary of the P values of some growth and yield components of sorghum genotypes intercropped with cassava.

No	Variable	System	Genotype	System*Genotype
1	Leaf number at 50 DAP	0.048	0.000	0.742
2	Plant height	0.162	0.000	0.584
3	Root Dry Weight	0.159	0.000	0.407
4	Stem Dry Weight	0.075	0.000	0.567
5	Leaf Dry Weight	0.106	0.000	0.644
6	Shoot Dry Weight	0.075	0.000	0.563
7	100-grain Weight	0.052	0.000	0.018
8	Grain Number	0.021	0.000	0.613
9	Grain Weight	0.041	0.000	0.298

Table 2. Growth components of some sorghum genotypes at harvest^{z}

No	Genotype	Root Dry Weight (g)	Stem Dry Weight (g)	Leaf Dry Weight (g)	Shoot Dry Weight (g)	Plant height (cm)
1	H-1	1.17 ɔc	55.44 ɔcd	17.15 cdefg	72.59 ɔc	198.75 def
2	H-2	8.93 cdefg	52.67 ɔcde	13.56 ghijk	66.23 ɔcde	202.17 def
3	H-3	9.29 cdef	43.82 defgh	14.32 efghij	58.14 defgh	184.50 fgh
4	H-4	1.19 ɔc	51.98 ɔcde	16.89 cdefg	68.88 ɔcd	197.25 def
5	H-5	9.03 cdefg	45.32 cdefgh	15.34 defghi	60.66 cdef	175.00 ghi
6	H-6	9.55 cde	57.07 ɔc	16.31 cdefgh	73.38 ɔc	218.17 cd
7	H-7	8.88 cdefg	44.35 cdefgh	13.55 ghijk	57.90 defghi	186.33 efg
8	H-8	5.65 ghi	30.61 hijkl	10.13 :l	40.74 hijkl	215.58 cde
9	H-9	0.24 cd	34.14 ghijk	11.22 kl	45.36 ghijkl	177.33 ghi
10	H-10	7.97 defgh	44.50 cdefgh	12.27 ijkl	56.77 defghij	192.25 efg
11	H-11	8.81 cdefg	15.00 nn	24.28	39.28 kl	115.83 mno
12	H-12	7.48 defghi	40.94 efghi	9.26 l	50.20 efghijk	159.58 hij
13	H-13	1.21 ɔc	47.74 cdef	17.84 cdef	65.58 ɔcde	152.83 ijk
14	H-14	8.22 defgh	29.41 ijklmn	16.39 cdefgh	45.80 ghijkl	121.92 lmn
15	HP-1	6.18 fghi	14.68 nn	15.43 defghi	30.11	71.11 q
16	HP-3	4.19	13.44	16.17 cdefgh	29.61	86.42 pq
17	HP-5	9.00 cdefg	18.98 lmn	20.56 ɔ	39.54 ijkl	60.00
18	HP-11	4.74 i	17.84 nn	15.83 defgh	33.67 l	71.92 q
19	HP-29	8.56 cdefg	24.88 :lmn	18.74 cd	43.62 ghijkl	84.08 pq
20	HP-33	5.41 hi	14.09 n	18.22 cde	32.31 l	113.00 nno
21	awali	9.58 cde	30.08 ijklm	18.19 cde	48.28 fghijkl	145.00 klm
22	Iandau	0.03 cd	42.71 defgh	15.48 defghi	58.19 defgh	141.17 klm
23	umbu	7.96 defgh	38.46 fghij	14.09 fghij	52.54 efghij	187.58 efg
24	/F 10-90A	0.78 c	51.08 ɔcde	11.28 kl	62.36 cdef	237.00 b
25	/F 5-193-C	0.84 c	56.17 ɔcd	15.58 defghi	71.75 ɔc	240.25 b
26	/I 150-21-A YMMIT	5.46 hi	25.02 klmn	8.19	33.22 l	194.08 ef
27	/I WHP	0.39 cd	60.37 ɔ	18.83 c	79.21 ɔ	188.08 efg
28	ahat	3.84	15.17 nn	17.47 cdef	32.64 l	99.50 op
29	amurai - 1	7.02 efghi	42.90 defgh	15.54 defghi	58.43 defg	174.67 ghi
30	amurai - 2	5.68 ghi	25.92 klmn	12.87 hijk	38.79 :l	147.75 kl
31	uper - 1	1.99 ɔ	58.48 ɔc	15.30 defghi	73.78 ɔc	229.08 bc
32	uper - 2	4.82	65.86	17.81 cdef	83.66	261.00
33	alaga Bodas	0.73 cd	46.52 cdefg	15.41 defghi	61.92 cdef	190.23 efg
34	PCA	8.79 cdefg	42.79 defgh	17.34 cdefg	60.13 def	173.42 ghij

^{z} Means within columns followed by the same letter(s) are not significantly different ($P \leq 0.05$).

Table 3. Performance of vegetative and yield components of sorghum genotypes intercropped with cassava[z]

Components	System	
	Monoculture	Intercropping
Leaf number at 50 DAP	8.25 a	7.55 b
100-grains weight	2.24 a	2.15 b
Grain number	1309.88 a	1063.22 b
Grain weight	30.84 a	24.72 b

[z] Means within rows followed by the same letter are not significantly different ($P \leq 0.05$).

Table 4. Yield components of some sorghum genotypes at harvest[z]

No	Genotype	100-grain Weight (g)		Grain Number		Grain Weight (g)	
1	GH-1	2.37	defg	1108.11	cdefghijkl	24.16	ghijklmn
2	GH-2	2.54	bcde	715.11	kl	18.88	klmn
3	GH-3	2.81	abc	1452.50	bcdef	40.78	abc
4	GH-4	2.37	defg	1033.89	defghijkl	25.72	efghijklm
5	GH-5	2.44	cdef	1120.11	cdefghijkl	27.66	defghijkl
6	GH-6	2.35	defgh	1501.00	abcde	37.78	abcde
7	GH-7	2.54	bcde	1238.89	bcdefghijk	31.80	abcdefghijk
8	GH-8	2.28	defghi	791.39	jkl	18.91	klmn
9	GH-9	2.17	efghij	944.89	fghijkl	21.63	hijklmn
10	GH-10	2.21	efghij	934.83	fghijkl	20.13	jklmn
11	GH-11	1.67	mno	1346.39	bcdefghi	25.74	efghijklm
12	GH-12	2.03	ghijklm	1226.72	bcdefghijk	24.59	fghijklmn
13	GH-13	2.08	fghijk	1234.28	bcdefghijk	29.14	bcdefghijkl
14	GH-14	1.72	klmno	2017.39	a	37.02	abcdefg
15	GHP-1	1.63	no	930.33	fghijkl	16.40	lmn
16	GHP-3	1.94	ijklmn	664.72	l	12.94	mn
17	GHP-5	1.88	jklmn	1011.17	efghijkl	20.46	ijklmn
18	GHP-11	1.78	klmno	892.39	hijkl	17.73	lmn
19	GHP-29	1.21	p	655.89	l	12.43	n
20	GHP-33	1.49	op	835.50	ijkl	16.27	lmn
21	Kawali	2.06	fghijkl	1545.50	abcd	33.51	abcdefghi
22	Mandau	2.36	defgh	1361.06	bcdefghi	37.30	abcdef
23	Numbu	2.87	ab	1363.22	bcdefghi	39.29	abcd
24	P/F 10-90A	2.22	defghij	1431.06	bcdefg	32.79	abcdefghij
25	P/F 5-193-C	2.37	defg	1372.06	bcdefgh	34.20	abcdefgh
26	P/I 150-21-A CYMMIT	1.99	hijklmn	918.39	ghijkl	19.84	jklmn

27	P/I WHP	2.76	abc	1266.06	bcdefghij	37.11	abcdefg
28	Pahat	1.69	lmno	1006.78	efghijkl	17.77	lmn
29	Samurai - 1	2.07	fghijk	1333.83	bcdefghi	28.88	cdefghijkl
30	Samurai - 2	2.21	efghij	1051.94	defghijkl	24.66	fghijklmn
31	Super - 1	2.59	abcd	1231.89	bcdefghijk	34.11	abcdefgh
32	Super - 2	2.50	bcde	1620.56	abc	38.30	abcde
33	Talaga Bodas	2.94	a	1462.39	bcdef	44.33	a
34	UPCA	2.47	cde	1722.39	ab	42.24	ab

[z] Means within columns followed by the same letter(s) are not significantly different ($P \leq 0.05$).

Table 5. Fifteen genotypes of sorghum potential as a producer of livestock and seeds.

No.	Potential as forage sorghums		Potential as a grain sorghum	
	Genotype	Shoot Dry Weight (g)	Genotype	Grain Weight (g)
1.	Super–2	83,6611	Talaga Bodas	44,3278
2.	P/I WHP	79,2056	UPCA	42,2389
3.	Super–1	73,7833	GH-3	40,7833
4.	GH-6	73,3778	Numbu	39,2889
5.	GH-1	72,5944	Super-2	38,3000
6.	P/F 5-193-C	71,7500	GH-6	37,7778
7.	GH-4	68,8778	Mandau	37,3000
8.	GH-2	66,2278	P/I WHP	37,1056
9.	GH-13	65,5833	GH-14	37,0222
10.	P/F 10-90A	62,3556	P/F 5-193-C	34,2000
11.	Talaga Bodas	61,9217	Super-1	34,1111
12.	GH-5	60,6611	Kawali	33,5111
13.	UPCA	60,1333	P/F 10-90A	32,7889
14.	Samurai–1	58,4344	GH-7	31,8000
15.	Mandau	58,1889	GH-13	29,1444

Table 6. Pearson's correlation coefficients between growth and yield components of 34 sorghum genotypes under intercropping with cassava[z]

	Plant Height	Root Dry Weight	Stem Dry Weight	Leaf Dry Weight	Shoot Dry Weight	100-grain Weight	Grain Number
Root Dry Weight	0.373						
	0.000						
Stem Dry Weight	0.602	0.732					
	0.000	0.000					
Leaf Dry Weight	-0.268	0.453	0.188				
	0.000	0.000	0.007				
Shoot Dry Weight	0.499	0.785	0.974	0.404			
	0.000	0.000	0.000	0.000			
100-grain Weight	0.548	0.403	0.568	-0.037	0.520		
	0.000	0.000	0.000	0.595	0.000		
Grain Number	0.198	0.563	0.457	0.375	0.511	0.286	
	0.005	0.000	0.000	0.000	0.000	0.000	
Grain Weight	0.329	0.646	0.616	0.317	0.647	0.545	0.901
	0.000	0.000	0.000	0.000	0.000	0.000	0.000

[z]Number below Pearson correlation coefficient is P-Value