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GRAIN YIELD AND, NUTRIENT AND STARCH CONTENT OF SORGHUM (*Sorghum bicolor* (L.) Moench) GENOTYPES AS AFFECTED BY DATE OF INTERCROPPING WITH CASSAVA IN LAMPUNG, INDONESIA

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ABSTRACT

Sorghum (*Sorghum bicolor* (L.) Moench) is one of the cereal crops utilized as source of food, feed and bioethanol production. Intercropping with cassava is a promising means of developing sorghum plants in Lampung province of Indonesia. However, little information on sorghum intercropped with cassava has been documented. The study sought to evaluate the effect of planting dates on grain yield and content N, P, K and seed starch of several sorghum genotypes intercropped with cassava. A field experiment was conducted in Waway Karya of East Lampung, Lampung Province-Indonesia in 2009-2010. The treatments were arranged factorially with split-plot in randomized block design with three replications. The main plot was planting dates consisting of three levels, that was, 0, 2 and 4 weeks after planting cassava. Sub-plot was sorghum genotypes including Kawali, Mandau, B-76 and B-92. Fertilizers used were urea, SP-36 and KCl. Sorghum plants were intercropped with cassava and planted in interrows of cassava, while cassava was planted with row spacing of 80 cm x 60 cm. Sorghum plants intercropped with cassava and planted at 2 and 4 weeks after planting cassava resulted in lower grain yield and content of nutrient and seed starch compared to that planted at the same date of cassava planting. The highest reduction occured at the planting date of 4 weeks after planting cassava, that was, 72.9% for sorghum grain yield. The reduction in N, P and K content of sorghum plants caused by 4-weeks delayed planting was 14.5, 26.7 and 41.9%, respectively, while the reduction of seed starch content was only 6.0%.

Key words: cassava canopy, competition, nutrient content, panicle, planting date, shade, starch

INTRODUCTION

The demand for food in Indonesia, especially rice is continously increasing in paralell with the increase of Indonesian population. It is predicted that Indonesian population in 2030 will be 425 million, so the need for rice is 59 millions ton (Suswono, 2012). Thus, increasing rice production still becomes a major concern in Indonesian agricultural development . Most of Indonesian rice production is dominated by lowland rice. In fact, the area of paddy field in Indonesia is decreasing due to land conversion for nonagricultural purposes. This leads to weaken the food security in Indonesia. Therefore, many efforts have been done to increase the food security such as developing other food-producing plants besides rice plants. Recently, sorghum has started to be developed intensively in Indonesia, since it is potentially utilized as sources of food, feed and fuels (Rooney and Waniska, 2000).

Lampung is one of provinces in Indonesia located in Sumatra Island. Agricultural land in Lampung is dominated by upland agriculture, so lack of water frequently limit crop productivity. Food crops such as rice, corn and cassava are major food crops in Lampung-Indonesia and are cultivated mostly in monoculture systems. Actually, intercropping cassava with other food crops is still possible since growth and development of cassava canopy at early growth stages are very slow (Kamal, 2009). On the other hand, slow growth of cassava canopy at early stage potentially creates the problem of soil erosion and weed control. Coolman and Hoyt (1993) reported that intercropping could be more eficient than monoculture in utilizing limited resources. Moreover, intercropping systems are frequently effective to reduce damage associated with insect and pathogen attacks besides weed control. Lithourgidis et al. (2011) indicated that intercropping is an alternative way for sustainable agriculture.

Ecologically, sorghum plants could grow in wide ranges of environmental conditions. Sunyoto and Kamal (2009) reported that sorghum could grow well under agroclimate conditions of Lampung-Indonesia although their yield was affected by planting dates and sorghum genotypes. In general, sorghum that is cultivated in the dry season produces higher yield compared to that cultivated in wet (rainy) season. The study reported by Netondo et al. (2004) indicated that sorghum plants are relatively highly tolerant to drought. Thus, it could be used for optimizing biomass production in upland agriculture frequently subjected to water shortage.

Sorghum plants basically could be cultivated on monoculture and intercropping systems. However, the development of sorghum in Lampung- Indonesia by monoculture system will face the problem of land use competition with other food crops such as rice, corn and cassava. Thus, intercropping is a promising means of developing sorghum plants in Lampung-Indonesia, especially intercropped with cassava. Lampung is the biggest cassava producer in Indonesia, accounting for more than 30 % of Indonesian cassava production (BPS, 2012). Many reports show that sorghum plants could be intercropped with corn, soybean, cowpea and peanut (Langat et al., 2006; Mohammed et al. 2006; Egbe, 2010; Musa et al. 2011). However, little information about intercropping sorghum plants with cassava was documented. Hamim et al. (2012) reported that planting time of sorghum on intercropping with cassava determines sorghum grain yield.

This study sought to evaluate the effect of planting dates on grain yield and content of N, P, K and seed starch of several sorghum genotypes intercropped with cassava.. Better understanding of morphophysiology of sorghum plants intercropped with cassava would be useful in developing sorghum plants through intercropping.

MATERIALS AND METHODS

Experimental Site

The field experiment was conducted in the district of Waway Karya, East Lampung, Lampung Province, Indonesia in 2009-2010. The experimental site was located 70 m above sea level with a rainfall of 120 mm month^{-1}, and it was considered as rain-fed agricultural land with the soil pH of 5.8.

Experimental Design

Four sorghum genotypes used were Kawali, Mandau, B-76 and B-92, and cassava cuttings of UJ5 cv. were used in this experiment. These four sorghum genotypes have different yield potential. Fertilizers used included urea, SP-36 and KCl. Herbicide, glyphosate, was used to control weeds, while carbosulfan (25.5%) was used to control insect pests.

The treatments consisting of planting dates and sorghum genotypes were arranged in factorial with split plot in Randomized Complete Block Design with three replications. The main plot was sorghum planting dates, while the sub-plot was sorghum genotypes. Planting dates consisted of three levels, that was, 0, 2 and 4 weeks after planting cassava. Sorghum genotypes consisted of Kawali, Mandau, B-76 and B-92.

Cultural Practice

Before planting, soil was sprayed by herbicide (glyphosate) with the dosage of 2 L ha^{-1}. One week later, soil was plowed and plotted. Each plot was 5 by 4 m in size, and interplot had the distance of 60 cm. Cassava was planted with row spacing of 80 cm x 60 cm, so each plot had 6 rows of cassava. The dosage of urea, SP-36 and KCl was 300, 100 and 100 kg ha^{-1}, respectively. Urea and KCl were split; ½ dosage was applied at 3 weeks after planting, and another half-dosage was applied at 14 weeks after planting. SP-36 was applied once at 3 weeks after planting. During the experiment, pesticide was not used to controll pest and disease in cassava.

Sorghum seeds were planted in each plot manually after planting cassava. Sorghum were planted as an intercrop between cassava rows with the distance of 20 cm in rows , and the distance of cassava and sorghum rows was 40 cm. The number of sorghum rows in each plot was 5 rows and each of which had 24 hills.

Sorghum plants intercropped with cassava were planted in different planting dates, that was, the same time of planting cassava (0 week), 2 weeks after planting cassava (2 WAP) and four weeks after plating cassava (4 WAP). The dosage of urea, SP-36 and KCl was 200, 100 and 100 kg ha^{-1}, respectively. SP-36 and KCl were applied once at 2 weeks after planting, while Urea was splitted, that is, ½ dosage was applied at 2 weeks after planting and another half-dosage was applied at 5 weeks after planting. During the experiment sorghum plants sometimes were irrigated to prevent them from water stress. Pest and diseases were controlled by pesticide application. Aphids and leaf blight were observed although their attack was relatively light.

Data Collection and Analysis

The variables observed were plant height, leaf number, stem diameter, biomass production, panicle length, seed number, seed size, grain yield, of N, P and K content in sorghum leaves, and seeed starch content. For nutrient analysis, sorghum leaves were sampled at maturity (harvesting time). The content of N was determined by Kjeldahl method, while P content was determined by spectrophotometry (Spectronic 20- Milton Boy Co.) and the reading was taken at 693 nm. K content was determined by flame photometry (Model PFP7-Jenway). Nutrient analysis was according to the method described by Agus et al. (2005).

Starch content was analyzed by a modified Somogy method as explained before (JICA, 1983). Ten grams of sorghum seed powder was placed in a 300 mL Erlenmeyer flask where 20 mL of HCl (25%) and 200 mL distilled water were added. The Erlenmeyer flask was closed and allowed to hydrolyze for 2-3 minutes. The solution was neutralized by adding NaOH (20%) until the pH of 6.8-7.0 was reached. The solution was diluted 500—1000x and 10 mL of sample was placed into a 100-mL Erlenmeyer flask where 10 mL of Reagent A and 10 mL of distilled water were added. The solution was allowed to boil for 3 minutes and left to cool. Thereafter, 10 mL of reagent B and 10 mL of Reagent C and some drops of amylum indicator (1%) were added. Finally, the sample was titrated by using Na_2SO_3 0.1 N solution. Based on the amount of Na_2SO_3 0.1 N used, starch content was calculated (JICA, 1983).

All data were subjected to Analysis of Variance (ANOVA). The difference of treatment means was determined by Fisher's LSD test at the significant level of 5% (P=0.05).

RESULTS AND DISCUSSIONS

Sorghum growth

The results of the experiment revealed that planting dates significantly influenced growth of sorghum plants intercropped with cassava although its effect depended on sorghum genotypes. Planting dates of 2 and 4 weeks after planting cassava resulted in lower plant height (Table 1), leaf number (Table 2), stem diameter (Table 3) and biomass production (Table 4) compared to that in the planting date of 0 week (the same date of planting cassava).

In general, the delay of sorghum planting dates up to 2 and 4 weeks after planting cassava reduced plant height, leaf number, stem diameter and biomass production although the magnitude of reduction depends on sorghum genotypes, especially at 2 WAP. However, at 4 WAP all sorghum genotypes showed great inhibition and no significant growth difference. The reduction of sorghum growth in intercropping with cassava was most likely due to interspecific competition. At the planting dates of 2 and 4 weeks after planting cassava, the development of cassava canopy exceeded sorghum plants. Thus, sorghum plants suffered from low light intensity caused by shade of cassava canopy, which in turn reduced sorghum growth.

Similar results were reported by Hamim et al. (2012) indicating the reduction of sorghum growth in intercropping with cassava, while Suwarto et al. (2005) reported the reduction of maize growth in intercropping with cassava. Mouneke et al. (2007) also reported that the difference in canopy development frequently creates interspesific competition for sunlight in intercropping systems, resulting in growth inhibition.

In terms of sorghum genotypes, Kawali consistently showed the superiority of plant height, leaf number, stem diameter and biomass production compared to other sorghum genotypes.

Table 1. Effect of planting dates and genotypes on plant height and weight of 1000 seeds of sorghum plants intercropped with cassava

Treatments	Plant height (cm)	Weight of 1000 seeds (g)
Planting dates (weeks after cassava planting)		
0	134.17a	25.72a
2	114.57ab	22.38a
4	111.08bc	24.25a
Sorghum genotypes		
Kawali	122.22a	24.73a
Mandau	114.57a	22.52a
B-76	124.49a	24.07a
B-92	120.87a	22.34a

* The numbers followed by the same letters in the same columns and treatments are not significantly different with LSD test at P=0.05.

Table 2. Leaf number of different sorghum genotypes as affected by date of intercropping with cassava

Sorghum planting date	Leaf number (number per plant)			
	Kawali	**Mandau**	**B-76**	**B-92**
0 WAP	14.00c C	12.27b B	11.47b AB	11.07b A
2 WAP	12.53b C	11.53b B	11.13b AB	10.60b A
4 WAP	9.73a A	9.67a A	9.33a A	9.13a A

* WAP = weeks after planting cassava
** The numbers followed by the same-small letters in the same column and the same capital letter in the same rows are not significantly different with LSD test at P=0.05.

Table 3. Stem diameter of different sorghum genotypes as affected by date of intercropping with cassava

Sorghum planting date	Stem diameter (cm)			
	Kawali	**Mandau**	**B-76**	**B-92**
0 WAP	2.52c C	1.92c AB	1.78c A	1.68c A
2 WAP	1.64b B	1.35b A	1.24b A	1.21b A
4 WAP	1.09a A	1.07a A	0.99a A	0.93a A

* WAP = weeks after planting cassava
** The numbers followed by the same-small letters in the same column and the same capital letter in the same rows are not significantly different with LSD test at P=0.05.

Table 4. Biomass production of different sorghum genotypes as affected by date of intercropping with cassava

Sorghum planting date	Biomass production (g/plant)			
	Kawali	**Mandau**	**B-76**	**B-92**
0 WAP	288.29b C	196.26b AB	253.13b BC	187.60b A
2 WAP	257.59b B	140.31ab A	143.75a A	154.92ab A
4 WAP	97.21a A	105.57a A	123.10a A	88.19a A

* WAP = weeks after planting cassava
**The numbers followed by the same-small letters in the same column and the same capital letter in the same rows are not significantly different with LSD test at P=0.05.

Sorghum yield component and grain yield

The interaction effect of planting dates and genotypes on yield components of sorghum plants intercropped with cassava was also found (Table 5, 6 and 7). The performance of sorghum yield components planted at 2 and 4 weeks after planting cassava were lower than that planted at 0 WAP although the magnitude of the reduction depends on sorghum genotypes, especially at 2 WAP. On the average, the reduction of panicle length, panicle weight and seed number caused by the delay of sorghum planting dates of 2-4 WAP was 3.5-19.1%, 26.2-69.3% and 25.1-71.3%, respectively. It seems that seed number was the most sensitive sorghum yield component to shading caused by cassava canopy. In contrast, weight of 1000 seeds was not significantly affected by planting dates of sorghum plants intercropped with cassava (Table 1). This is in agreement with the previous study reported by Hamim *et al.* (2012). The result of the study reported by Kamal (2007) indicated that the treatment of 50% shade suppressed growth and development of rice yield components. The reduction of sorghum yield components caused by 2- and 4-week delayed planting was related to the inhibition of sorghum growth. As mentioned earlier, the canopy of cassava created shading on sorghum plants, which in turn, reduced photosynthetic rate and resulted in lower assimilate supply for sorghum yield component development.

Table 5. Panicle length of different sorghum genotypes as affected by date of intercropping with cassava

Sorghum planting date	Panicle length (cm)			
	Kawali	Mandau	B-76	B-92
0 WAP	23.27b C	21.73b BC	19.37b AB	17.60a A
2 WAP	22.80b B	21.20b B	18.07ab A	17.00a A
4 WAP	17.11a A	16.57a A	16.50a A	16.13a A

* WAP = weeks after planting cassava
** The numbers followed by the same-small letters in the same column and the same capital letter in the same rows are not significantly different with LSD test at P=0.05.

Table 6. Panicle weight of different sorghum genotypes as affected by date of intercropping with cassava

Sorghum planting date	Panicle weight (g)			
	Kawali	Mandau	B-76	B-92
0 WAP	73.61b C	42.75b AB	55.57b BC	36.03b A
2 WAP	60.90b B	24.89ab A	33.73a A	33.87b A
4 WAP	15.23a A	16.12a A	19.53a A	12.87a A

* WAP = weeks after planting cassava
** The numbers followed by the same-small letters in the same column and the same capital letter in the same rows are not significantly different with LSD test at P=0.05.

Table 7. Seed number of different sorghum genotypes as affected by date of intercropping with cassava

Sorghum planting date	Seed number (no. panicle^{-1})			
	Kawali	Mandau	B-76	B-92
0 WAP	2146.47c B	1474.73c A	1485.33c A	1248.80b A
2 WAP	1689.20b B	901.00b A	1073.60b A	1098.73b A
4 WAP	506.60a A	414.93a A	489.73a A	414.67a A

* WAP = weeks after planting
** The numbers followed by the same-small letters in the same column and the same capital letter in the same rows are not significantly different with LSD test at P=0.05.

Since adequate supply of assimilate was highly required for sorghum grain filling (Huang and Ma 1995), the reduction of assimilate supply caused by shading decreased sorghum grain yield. Thus, it is not surprising that sorghum grain yield at 2 and 4 weeks after planting cassava was lower than that at the planting date of 0 week (Fig. 1).

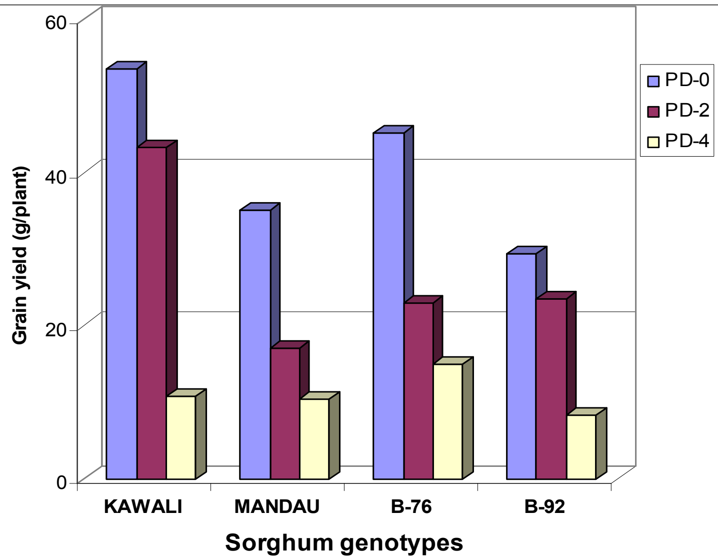

Figure 1. Grain yield of some sorghum genotypes intercropped with cassava at different planting dates
(PD-0= 0 week after cassava planting; PD-2= 2 weeks after cassava planting; PD-4= 4 weeks after cassava planting)

Sorghum genotype of Kawali indicated the highest grain yield compared to other genotypes (Fig. 1). This was substantiated with the data of sorghum growth and yield components in which Kawali consistently showed better growth and greater yield components than other genotypes.

Interestingly, Kawali also showed less reduction of grain yield at the planting date of 2 weeks after planting cassava compared to other shorgum genotypes.

However, at the planting date of 4 weeks after planting cassava all sorghum genotypes indicated similar reduction of grain yield. This means that depressive effects of cassava on sorghum grain yield at 4 WAP was much more pronounced than that at 2 weeks after planting cassava. Thus the delay of sorghum planting dates up to 4 weeks after planting cassava was not recommended in intercropping systems of sorghum and cassava.

Nutrient and starch content

The planting dates of sorghum intercropped with cassava significantly influenced N, P and K nutrient levels (Table 8), while the interaction effect of planting date and sorghum genotype on nutrient content was not significant. The planting dates of 2 and 4 WAP consistently resulted in lower content of N, P and K compared to that at the planting date of 0 WAP. This reduction of nutrient content was most likely attributed to the inhibition of sorghum growth caused by the delay of sorghum planting dates in intercropping with cassava. Epstein and Bloom (2005) reported that the inhibition of plant growth can lead to the inhibition of nutrient uptake since nutrient uptake is related to plant metabolism (Mengel and Kirby, 1987). The differences in sorghum genotypes also resulted in nutrient content differences (Table 8). Many studies showed that nutrient uptake is affected by genetic factors (Mengel and Kirby, 1987; Kamoshita *et al*., 1995; Hirei *et al*., 2001; Setiawan and Kamal, 2008). Sorghum genotype of Kawali also demonstrated superiority of N and P content compared to other sorghum genotypes (Table 8).

Table 8. Effect of planting dates and genotypes on nutrient content of sorghum plants intercropped with cassava

Treatments	Nitrogen (N) content (%)	Phosphorus (P) content (%)	Potassium (K) content (%)
Planting dates (weeks after cassava planting)			
0	1.79a	0.15a	0.31a
2	1.70a	0.13b	0.23b
4	1.53b	0.11b	0.18b
Sorghum genotypes			
Kawali	1.81a	0.16a	0.29a
Mandau	1.69ab	0.14ab	0.23a
B-76	1.62b	0.12bc	0.20a
B-92	1.58b	0.10c	0.23a

* The numbers followed by the same letters in the same columns and treatments are not significantly different with LSD test P=0.05.

The content of starch in sorghum seeds was also affected by planting dates of sorghum plants intercropped with cassava. Planting dates of 2 and 4 weeks after planting cassava (PD-2 and PD-4) resulted in lower starch content of sorghum seeds compared to that of planting date of 0 week (PD-0) after planting cassava (Fig. 2). As mentioned earlier that planting dates of sorghum intercropped with casava at 2 and 4 weeks after planting cassava suffered from shading caused by cassava canopy development, which in turn reduce assimilate supply during grain filling period. As a result, starch accumulation in the seeds of sorghum planted at 2 and 4 weeks after planting cassava was lower than that at planting date of 0 week (PD-0) after planting cassava. The result of the experiment dealing with shading in rice plants indicates that rice plants grown under shade condition produces less starch compared to rice plants grown under full-sun condition (Laut et al., 2000), while Huber and Israel (1982) reported that changes in starch and sucrose content under shade are related to the activity of SPS enzyme which catalyzes the synthesis of sucrose-P from UDP Glucose. Among sorghum genotypes, Kawali showed the highest seed starch content compared to other genotypes (Fig. 2), suggesting that Kawali consistently indicates the superiority of growth, nutrient uptake, yield components, grain yield and starch content.

Compared to grain yield reduction caused by the delay of planting dates (Fig. 1), the reduction of starch content in sorghum seeds at the planting dats of 2 and 4 weeks after planting cassava was lower (Fig. 2). This is related to grain-developing process which involves yield component formation and development. Thus, the reduction of sorghum yield components such as panicle weight and length, and seed number result in lower grain yield. In terms of seed starch content, the amount of assimilate produced during grain filling is critical since the number of sorghum seeds is already set earlier. Huang and Ma (1995) stated that the dry matter accumulation in shorghum seeds was mostly supplied by the assimilate produced during reproductive stage. Thus, the difference of starch content in shorghum seeds was not as big as the difference in grain yield.

From the stand point of nutrient uptake, the reduction of sorghum grain yield caused by the delay of sorghum planting dates of 2 and 4 weeks after planting cassava (Fig. 1) was in parallel with the reduction of N, P and K content caused by 2- and 4-week delayed planting (Table 8). The result of correlation analyses revealed that sorghum grain yield was highly correlated with N(r=0.855**), P(r=0.745**) and K(r=0.832**) uptake.

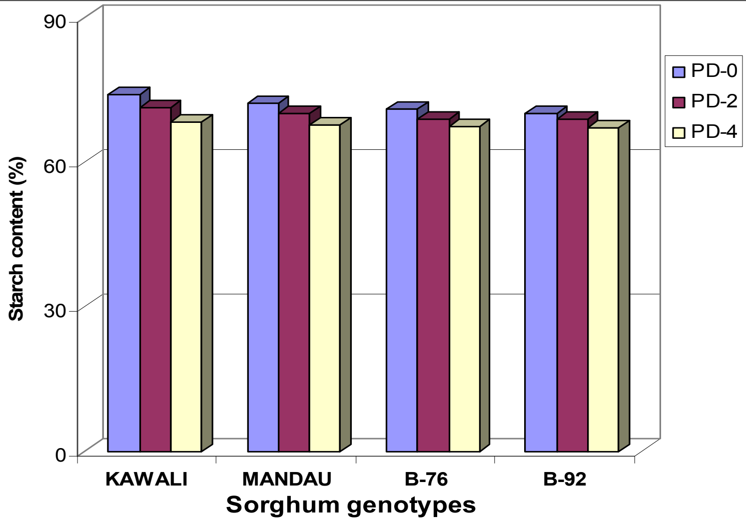

Figure 2. Starch content in sorghum seeds intercropped with cassava at different planting dates

(PD-0= 0 week after cassava planting; PD-2= 2 weeks after cassava planting; PD-4= 4 weeks after cassava planting)

Since the involment of N, P and K in plant growth and development is highly significant (Epstein and Bloom, 2005; Taiz and Zeiger, 2010), the reduction of N, P and K uptake could reduce the production of sorghum yield components and grain yield. In other words, data of correlation coefficient (Table 9) substantiated the results of the experiment presented earlier (Table 1, 2 ,3, 4, 5,6,7, 8 and Fig. 1 and 2).

Table 9. Correlation coefficient of growth variabel with yield components, nutrient uptake and starch content of sorghum plants intercropped with cassava

Variables	Plant height	Leaf number	Stem diameter	Biomass production	Panicle Length	Panicle weight	Seed Number	Weight of 1000 seeds	Grain yield	N uptake	P uptake	K uptake	Starch content
Plant Height	1.000	0.616*	0.813**	0.783**	0.496	0.752*	0.751*	0.406	0.808**	0.706*	0.608*	0.720*	0.692*
Leaf Number		1.000	0.919**	0.891**	0.933**	0.916**	0.957**	0.286	0.897**	0.850**	0.761**	0.772**	0.976**
Stem Dianeter			1.000	0.808**	0.791**	0.887**	0.925**	0.241	0.909**	0.852**	0.780**	0.850**	0.973**
Biomass Production				1.000	0.799**	0.988**	0.962**	0.592	0.992**	0.836**	0.692*	0.807**	0.902**
Panicle Length					1.000	0.808**	0.835**	0.317	0.787**	0.685**	0.570	0.607*	0.909**
Panicle Weight						1.000	0.977**	0.538	0.989**	0.818**	0.701*	0.775**	0.907**
Seed Number							1.000	0.387	0.974**	0.897**	0.798**	0.834**	0.951**
Weight of 1000 seeds								1.000	0.545	0.231	0.053	0.316	0.306
Grain yield									1.000	0.855**	0.745*	0.832**	0.914**
N uptake										1.000	0.915**	0.957**	0.876**
P uptake											1.000	0.884**	0.788**
K uptake												1.000	0.841**
Starch content													1.000

* indicates significant correlation; ** indicates highly significant correlation

CONCLUSION

Sorghum plants intercropped with cassava and planted at 2 and 4 WAP resulted in lower grain yield and content of nutrient and seed starch compared to that planted at the same date of cassava planting (0 WAP). Intercropping at 2 and 4 WAP reduced sorghum grain yield, sorghum seed starch content and N, P and K content. But the reduction of sorghum yield component planted at 2 WAP depended on sorghum genotypes. Sorghum plants could be intercropped with cassava as long as they were planted at the same date of cassava planting. The sorghum genotype of Kawali showed the highest grain yield and content of nutrient and seed starch content. It seems that the reduction of sorghum grain yield, nutrient uptake and seed starch content caused by 2- and 4 week-delayed planting in intercropping with cassava was related to shading caused by cassava canopy development.

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