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YIELD OF SORGHUM INTERCROPPED WITH PEANUT AT DIFFERENT PLANTING DATES AND ITS RELATIONSHIP WITH SORGHUM LEAF CHARACTERISTICS

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ABSTRACT
Leaves are photosynthetic organs that greatly affect plant growth and yield. In an intercropping system, leaves often experience shade stress, so it is necessary to adjust the planting dates between intercrops. This study aimed to determine the effect of additive intercropping of sorghum with peanut relay-planted at different dates on yield of sorghum and its relationship with leaf characteristics of the sorghum plants. The experiment, carried out in the IP2TP NTB experimental farm located East Lombok (Indonesia) from September 2020 to January 2021, was arranged according to a randomized block design with four treatments, namely W0 (sorghum monocrop), W1 (peanut relay-planted 14 days before sorghum planting), W2 (peanut relay-planted on the same day as sorghum planting), W3 (peanut relay-planted 14 days after planting (DAP) of sorghum). The experiment was made in 4 blocks (replicates). Results indicated that additive intercropping of sorghum with peanut relay-planted at different dates between rows of sorghum did no affected characteristics of sorghum leaves, but those leaf characteristics showed significant correlation with grain yield of sorghum especially the greenness levels of the leaves at 60 and 80 DAP and greenness levels of the flag leaves, which all showed significant correlation coefficients. However, those intercropping treatments had a significant effect on grain yield, dry stover weight and harvest index of sorghum, with the highest dry grain yield of 46.87 g/plant (or 3.35 ton/ha) was obtained on sorghum intercropped with peanut relay-planted on the same day as sorghum planting date.

KEY WORDS
Additive intercropping, planting dates, peanut, sorghum, leaf characteristics.

Sorghum [*Sorghum bicolor* (L.) Moench] is one of the crop species that is drought tolerant and has a wide adaptability so that it is adaptive and suitable to be developed in dry land. The drought tolerant nature of sorghum plants is related to its thick white wax coating on the peduncle, leaf axils, and the surface of sorghum leaves. This thick white wax layer in sorghum is controlled by the dominant gene “BmBm” [1], which plays a role in controlling the rate of transpiration by controlling the rate of water absorption from the soil and controlling the radiation received. In addition, sorghum is a crop species that has a high symbiotic ability with arbuscular mycorrhizal fungi (AMF) making it suitable for cultivation in dry land [2].

However, in Indonesia sorghum has a low comparative advantage which is still lower than rice and maize. Due to its excellent adaptability for cultivation in dry land and its high symbiotic ability with AMF, one alternative for cultivation of sorghum in dry land is through intercropping with legumes, such as peanuts. This cultivation technique is highly promising because in addition to its ability to establish symbiosis with Rhizobium bacteria for N_2 fixation, peanut also has a high ability to establish symbiosis with AMF so that this tripartite symbiosis can increase the rate of nitrogen fixation [3], which can increase the availability of N in the soil [4], and there is an opportunity for N transfer from peanut to cereal crops, such as rice, in an intercropping system [5].

Sorghum plants grown in dryland are also often cultivated under intercropping with legumes that are relatively drought tolerant as intercrops, such as peanut, mungbean, cowpeas, and pegeonpea. Intercropping of sorghum with cowpea was reported to reach a land equivalent ratio (LER) of 1.25 [6]. Sorghum in intercropping with soybean can increase N uptake through transfer of nitrogen from soybean to sorghum, especially at a narrower spacing between the two types of plants [7]. The rate of N transfer from legumes to cereal crops in intercropping systems also increases with the involvement of AMF hyphae infecting roots of both crops [8], [9]. Intercropping of sweet corn with peanut with the application of mycorrhiza biofertilizer was also reported to significantly increase the number of green leaves and sweet corn cob yields [10]. Waxy maize plants intercropped with soybean or mungbean also showed greener leaf color as well as higher N uptake and grain yield compared to the monocropped waxy maize plants [11].

However, in the application of intercropping system, several arrangements are needed in order to obtain adequate profits and productivity for all types of intercrops. The arrangement is needed to minimize competition between intercropped plant species and so that each part of the plant does not shade each other which can reduce the productivity of the shaded plants. One of the arrangements that can be made to increase productivity of intercropping is setting the time of planting and/or setting the spacing for taller plants. Research by Arma et al. [12] showed that planting peanut 10 days before planting maize could increase yields of maize and peanut plants. From an intercropping between maize and peanut reported by Mas-ud et al. [13], grain yield of peanut was highest when peanut was planted on the same day as maize planting, while grain yield of maize was highest when peanut was planted two weeks after planting maize. Other research results showed that a double row spacing of 71 x 107 cm with a plant population of 123,500 plants gave the highest stem diameter and optimal yield of sweet sorghum [14].

One part of the plants that affects plant productivity is the leaf, which is the photosynthetic organ of the plant. Leaf characteristics are one of the morphological properties that greatly affect plant productivity [15]. In sorghum, panicle, flag leaf and top four leaves are the main components of the photosynthetic system that contribute about 97.5% to grain yield after anthesis [16]. In the intercropping system, the leaves often shaded so that the sunlight interception is low. The taller morphology of sorghum plants causes sorghum not to be shaded, but the presence of sorghum plants often causes the plants under it to experience shade stress. The results presented by [17] showed that shading in an intercropping system could reduce yield components of peanut, including number of pods per plant, weight of 100 pods and 100 grains. On the other hand, the presence of legumes in an intercropping system with cereals can function as nitrogen source for cereal crops because there can be a transfer of N from legumes to cereals such as in an intercropping between sorghum and soybean [7], and intercropping between maize and peanut [10], [18]. This study aimed to determine the effect of additive intercropping of sorghum with peanut relay-planted at different dates on yield of sorghum and its relationship with leaf characteristics of the sorghum plants.

MATERIALS AND METHOD OF RESEARCH

The experiment in this study was carried out in the IP2TP NTB experimental farm located in Labuhan Lombok village, East Lombok, Indonesia from September 2020 to January 2021. The plant materials used were sorghum of Gando Keta variety (local variety from Bima City) and peanut of North Lombok local variety.

The experiment was arranged according to a randomized block design with four treatments, namely W0 (sorghum monocrop), W1 (peanut relay-planted 14 days before sorghum planting), W2 (peanut relay-planted on the same day as sorghum planting), W3 (peanut relay-planted 14 days after planting (DAP) of sorghum). The experiment was made in 4 blocks (replicates). Sorghum was planted with a spacing of 70 cm x 20 cm, while peanut was planted in one row between rows of sorghum at within-row spacing of 20 cm.

Land preparation included clearing the land from weeds followed by minimum tillage. Experimental plots were the made with a size of 4.2 m x 2.8 m surrounded with a furrow of 50 cm width, which also serves as a drainage channel. Sorghum and peanuts were planted at the time and spacing according to the treatment. Planting of sorghum and peanut were done by dibbling 2 seeds of sorghum or 3-4 seeds of peanut per planting hole. The young plants were thinned at 7-10 DAP by leaving to grow one sorghum or two peanut plants per planting hole. Crop maintenance included fertilization, weeding, pest control, and irrigation only as needed by pumping well water if there was no rain for 20 days. Sorghum was fertilized with 350 kg/ha NPK fertilizer (NPK 15:15:15) dibbled at 10 DAP and 250 kg/ha Urea dibbled at 35 DAP. Peanut was fertilized once at 10 DAP with 50 kg/ha Urea. Weeding was done manually every 14 days until the peanut plants started to form gynophores. The armyworm attack to sorghum at the age of 20 and 40 DAP was controlled with insecticides of Spinoteram and Emamectin benzoate active ingredients. Sorghum was harvested at 115 DAP, followed by sun drying.

Observation variables consisted of characteristics of sorghum leaves and yield components. Leaf measurement included leaf length, width, and greenness level of the third leaf from top and the flag leaf, measured at 60 and 80 DAP. Leaf greenness level was measured using the chlorophyll meter SPAD-502 Plus. The yield component measured dry grain yield, weight of 1000 grains, dry stover weight, and harvest index. The data were analyzed correlation between variables using Microsoft Excel, and analysis of variance (ANOVA) and Tukey's HSD test at 5% significance level using CoStat for Windows ver. 6.303.

RESULTS AND DISCUSSION

The results of ANOVA summarized in Table 1 show that additive intercropping between sorghum and peanut relay-planted at different dates relative to planting date of the sorghum plants did not affect the size and other characteristics of sorghum leaves as well as weight of 1000 dry grains. However, those intercropping treatments significantly affected dry grain yield per plant, dry stover weight per plant, and harvest index of the sorghum plants. The highest average of grain yield per plant was obtained on sorghum plants intercropped with peanut relay-planted on the same date of the sorghum planting date (W2) and the lowest grain yield of sorghum was on the sorghum plants intercropped with peanut planted 14 days before planting sorghum. Since in this treatment peanut was planted prior to planting sorghum, and this treatment resulted in lower grain yield of sorghum, it seems that there was a higher degree of competition for below-ground resources imposed by the peanut plants to sorghum plants. This opinion was also based on the amount of grain yield produced by sorghum plants in the monocrop treatment, in which there was a tendency that sorghum grain yield under additive intercropping with peanut planted 14 days of sorghum planting (W1) was lower that sorghum plants in the monocrop (W0). Thus the lower yield of sorghum in the W1 than in the W0 treatment must have been due to the presence of competing peanut plants between rows of sorghum. Similar results of intercropping experiment between maize and peanut reported by Mas-ud et al. [13] in which grain yield of maize was higher when maize was planted two weeks before planting peanut compared with planting both crop on the same day, while peanut grain yield was higher when peanut was planted two weeks before planting maize compared with planting both crops on the same day.

Although the characteristics of the sorghum leaves, including the greenness levels of the leaves, were not significantly different between the intercropping treatments, grain yield of sorghum showed significant correlation with the characteristics of the sorghum leaves, especially the greenness levels of the leaves (Table 2). Leaf greenness measured using the Chlorophyll SPAD represent number or density of the chlorophyll in the leaves, which are higher in greener or higher greenness level leaves than in the less green leaves. It therefore means that leaves with higher greenness levels would be potentially more productive in producing assimilates both for crop growth and for grain weight during the grain filling stage.

Table 1 – Summary of ANOVA results of each sorghum variable and its mean comparison using Tukey's HSD at 5% level of significance

Observation variables of sorghum plants	W0 (mono-cropped sorghum)		W1 (sorghum-peanut) – 14 DAP		W2 (sorghum-peanut) – 0 DAP		W3 (sorghum-peanut) + 14 DAP		HSD 5%
LL 60 DAP (cm)	92.60		90.98		90.53		90.28		ns[1)]
LW 60 DAP (cm)	7.32		7.79		8.00		7.70		ns
LG 60 DAP	46.18		47.68		52.79		47.22		ns
LL 80 DAP (cm)	83.15		83.70		81.90		81.90		ns
LW 80 DAP (cm)	7.65		8.02		8.12		7.66		ns
LG 80 DAP	48.25		51.16		56.73		54.63		ns
FLL 80 DAP (cm)	55.15		55.95		53.65		55.80		ns
FLW 80 DAP (cm)	6.68		6.74		7.11		7.01		ns
FLG 80 DAP	48.65		50.55		53.97		53.32		ns
Dry grain yield (g/plant)	40.12	ab	36.94	b	46.87	a	39.61	ab	7.88
Weight of 1000 grains (g)	28.23		27.49		30.39		29.53		ns
Dry stover weight (g)	293.39	a	252.81	ab	228.20	ab	201.39	b	77.17
Harvest index (%)	12.03	c	12.85	bc	17.29	a	16.57	ab	4.00

[1)] ns = non-significant ANOVA; mean values in each row sharing the same letter indicate non-significant difference between treatments.

In principle, leaves are the most important plant organs associated with the process of photosynthesis. The results of the correlation analysis (Table 2) show that the leaf characteristics of sorghum plants that have the greatest contribution to grain yield are the greenness of the leaves at 60 to 80 DAP and the greenness of the flag leaves at 80 DAP, with a positive and significant (p-value < 0.05) correlation coefficient value, with the determinant coefficient (R^2) of R^2 = 58.68%, R^2 = 47.47%, and R^2 = 31.70%, respectively. The significant contribution of leaf characteristics to yield was because at the age of 80 DAP the sorghum plant had entered the panicle formation stage so that the plant's requirement for nutrients and assimilate from photosynthesis was very high. In the vegetative stage, maximum assimilation was obtained from the productive leaves in the center of the plant. The productive leaves (3-6th leaf from top) are in the middle because the chlorophyll has been fully formed and is not shaded so that the light can be intercepted by the leaves perfectly. Shade either by the leaves of other plants or by the upper leaves of the plant itself can reduce the rate of photosynthesis due to the reduced amount of light intercepted by the leaves. Therefore, leaf characteristics greatly affect crop yields, as stated by Peng et al. [19] that the long, erect, narrow and thick upper leaf characters are indicators used in breeding for high yielding varieties.

Table 2 – Correlation coefficients and their p-values between variables of sorghum plants

Variables	LL60	LW60	LG60	LL80	LW80	LG80	FLL80	FLW80	FLG80	GY	W1000	DSW
LW 60 DAP	-0.247											
p-value	0.357											
LG 60 DAP	-0.109	0.366										
p-value	0.687	0.163										
LL 80 DAP	-0.279	0.178	0.305									
p-value	0.295	0.510	0.250									
LW 80 DAP	-0.492	0.278	0.286	0.422								
p-value	0.053	0.297	0.283	0.104								
LG 80 DAP	-0.369	0.267	0.833	0.210	0.285							
p-value	0.159	0.318	0.000	0.435	0.285							
FLL 80 DAP	-0.407	0.126	0.490	0.755	0.390	0.532						
p-value	0.118	0.643	0.054	0.001	0.135	0.034						
FLW 80 DAP	-0.535	0.192	0.458	0.486	0.565	0.622	0.775					
p-value	0.033	0.476	0.074	0.056	0.023	0.010	0.000					
FLG 80 DAP	-0.281	0.023	0.660	0.186	0.335	0.879	0.407	0.531				
p-value	0.292	0.933	0.005	0.490	0.205	0.000	0.118	0.034				
Grain yield	-0.025	0.323	0.766	0.182	0.133	0.689	0.246	0.423	0.563			
p-value	0.926	0.222	0.001	0.499	0.624	0.003	0.359	0.103	0.023			
1000 grain wt	0.350	0.134	0.542	0.151	-0.209	0.502	0.192	0.159	0.415	0.724		
p-value	0.184	0.621	0.030	0.577	0.437	0.048	0.476	0.556	0.110	0.002		
Dry stover wt	0.120	-0.345	0.061	0.315	-0.104	-0.154	0.271	0.000	-0.117	0.063	-0.168	
p-value	0.658	0.190	0.821	0.234	0.701	0.568	0.310	1.000	0.666	0.816	0.533	
Harvest index	-0.097	0.463	0.377	-0.133	0.215	0.496	-0.091	0.222	0.415	0.483	0.538	-0.834
p-value	0.722	0.071	0.150	0.623	0.424	0.051	0.739	0.408	0.110	0.058	0.031	0.000

The flag leaf is the last leaf to form, and the emergence of the flag leaf marks the end of the vegetative stage. The flag leaf functions to wrap around the panicle and is the largest source of assimilate for the panicle [20]. The position of the flag leaf which is directly at the bottom of the panicle causes the presence of the flag leaf as a source of assimilate which greatly affects the quality of the panicle and sorghum grains. The role of flag leaf as a producer of assimilate during the seed filling process is supported by Limbongan et al. [21] on Mandoti local rice, in which the local rice with long flag leaf characteristics had a positive correlation with grain yield. From the results of the correlation analysis (Table 2), it is clear that the level of greenness of the flag leaves has a very positive effect on grain yields.

Other desirable leaf characters are erect, thick, small and short leaves. Leaves, which are erect and wide, will increase the penetration of sunlight and absorption of CO_2 thereby increasing the activity of the photosynthesis process [20], [22]. The presence of peanuts as an interplant may also be very significant in supporting sorghum plant nutrition, especially for N content, which has been proven that there is a transfer of N from legumes to sorghum plants [7]. Table 1 also shows that sorghum plants grown in additive intercropping with peanuts, which were planted at the same time as peanut planting date (W2), 14 days after planting peanuts (W1), or 14 days before planting peanuts (W3) had greater leaf width and leaf greenness, although not statistically significant. Nevertheless, leaf greenness levels had a significant contribution to the grain yield, with significant determinant coefficients (R^2).

There are indications of the influence of the presence of peanuts relay-planted between rows of sorghum as a nitrogen sources that supports the growth and development of the leaves of the sorghum plants. Table 1 also shows that the greenness of sorghum leaves was higher in sorghum plants intercropped with peanuts than without peanut intercropping. Wangiyana et al. [23] also reported that red rice plants intercropped with peanut had significantly higher levels of green leaf color than the monocropped rice plants. Slightly different from rice, sorghum plants have aggressive growth especially at the age of 25-30 DAP. The presence of peanut plants of the same age or younger will not affect the vegetative growth of sorghum plants. Sorghum plants require the same N as maize plants. In an intercropping system with peanuts, the N needs of sorghum can be met through N fertilization and N transfer from legumes such as soybean [7] and peanuts [5], [18].

Peanut plants are sources of nitrogen because they can have a symbiotic relationship with *Rhizobium* bacteria to run biological nitrogen fixation and deposite fixed-N to the rhizosphere [4]. The formation of root nodules starts at the age of 21-28 DAP and nitrogen fixation begins to occur at the age of 25-30 DAP [24], [25]. The nitrogen is used by peanut plants as a host plant to stimulate growth. In the intercropping system using legumes, nitrogen exudation often occurs around the root zone. This nitrogen is then absorbed by surrounding plants such as sorghum. Nutrient availability levels were also reported to be higher in the rhizosphere of maize and peanut in intercropping systems than in the rhizosphere of each monocrop [18].

The results of data analysis of the yield components of sorghum (Table 1) showed that additive intercropping with peanuts relay-planted at different dates relative to the sorghum planting date had a significant effect on yield components of sorghum, especially grain yield, dry stover weight and harvest index of sorghum. Among the different planting dates tested, relay-planting of peanut plants on the same planting day with sorghum showed the highest grain yield and harvest index, while the dry stover weight of sorghum was highest in monocropped sorghum (Table 1). This is also supported by a significant correlation between leaf greenness and grain yield of sorghum, with a correlation coefficient of $r=+0.766$ ($p=0.001$) with the leaf greenness level at 60 DAP, $r=+0.689$ ($p= 0.003$) with the leaf greenness level of 80 DAP, and $r=+0.563$ ($p=0.023$) with the greenness level of the flag leaf at 80 DAP (Table 2). The level of leaf greenness also tended to be higher in sorghum intercropped with peanuts, especially in the treatment W2, where peanut and sorghum were planted on the same date (Table 1). The highest dry grain yield was also obtained in the W2 treatment, with an average value of 46.87 g/plant or equivalent to 3.35 tons/ha which is significantly higher than those in the monocropped sorghum (W0).

CONCLUSION

It can be concluded that additive intercropping of sorghum with peanut relay-planted at different dates did no affected characteristics of sorghum leaves, but those leaf characteristics showed significant correlation with grain yield of sorghum especially the greenness levels of the leaves at 60 and 80 DAP and greenness levels of the flag leaves that all showed significant correlation coefficients. Unlike leaf characteristics, those intercropping treatments had a significant effect on grain yield, dry stover weight and harvest index of sorghum, with the highest dry grain yield of 46.87 g/plant (or 3.35 ton/ha) was obtained on sorghum intercropped with peanut relay-planted on the same day as sorghum planting date.

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