Compatibility of Millet and Legume under Relay Cropping Condition

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Abstract
Double-cropping millet and legumes is a popular cropping system in the Upper East region (UER) of Ghana. For improved production efficiency, suitable millet-legume combinations with short life cycles that permit extension of the growing season to facilitate double-cropping need to be explored. The objective of this study was therefore to use performance data to identify millet-legume combinations compatible for relay cropping within the UER. Three early millet cultivars (Bongo Shorthead, Arrow Millet and Bristled Millet) were factorially relayed by three legumes namely cowpea, groundnut and soybean. Bongo Shorthead followed by cowpea in a relay cropping system has the greatest prospect of accounting for superiority in grain and stover/straw yield while Bongo Shorthead followed by groundnut in a relay will provide the least suitable combination for relay cropping within the Upper East Region of Ghana.
Keywords: double cropping, millet, legumes, compatible combination, savannah zones

INTRODUCTION

Double-cropping cereal and legume is a popular cropping system in the Upper East region (UER) of Ghana. Relay cropping or inter-seeding legume into standing maize is a concept that has been explored in the Midwest as a means of extending the growing season to facilitate double-cropping (Duncan et al., 1990; Moomaw & Powell, 1990 and Reinbott et al., 1987). Conventional double-cropping, a sequential planting of legume after cereal harvest, is often fraught with poor stands, weed infestations, and delayed legume planting due to adverse weather conditions. With relay planting, the legume is inter-seeded into the millet 1 to 3 weeks before maize harvest.

Field observations have shown that, with inter-seeding herbicide inputs are less in most cases than the conventional wide-row double-cropping systems (Whitwell, 1991). Even though inter-seeded legumes often show an etiolated or spindly appearance due to shading from the cereal crop before and for some time after millet harvest, research has shown no difference in yield between an inter-seeded crop and mono-crop legumes planted the same day (Wallace et al., 1992). In addition, this concept has better utilization of soil moisture for legume stands, less herbicide use and more timely field operations for legume, including planting, spraying, and harvesting over the conventional double-cropping systems.

Cereal-legume combinations with short life cycles provide excellent opportunity for double cropping in UER where diminishing soil moisture creates terminal drought stress and thus reduces profit potential, especially for the legumes. For improved production efficiency, suitable relay compatibility between cereal and legume with short life cycles that permit extension of the growing season to facilitate double-cropping need to be explored.

Millet [*Pennisetum glaucum* (L.) R. Br.] is used in the study because is one of the most important cereal crops in the Upper East Region in northern Ghana. The importance of the crop is most pronounced in the Upper East Region where it serves as a hunger-breaker immediately after the long dry season. Most farm-families would have exhausted their scanty harvest from the previous cropping season and even have difficulties in purchasing seed for the cropping season. Pearl millet has a unique ability to tolerate and survive under adverse conditions of continuous or intermittent drought as compared to most other cereals like maize and sorghum (LCR, 1997)

Cowpea, soybean and groundnut are the most popular leguminous crops which, in mixtures with cereal crops, are predominantly cultivated by farmers within the Upper East Region of Ghana. Among the cropping systems widely used are those involving millet-grain legume cropping among small-scale farmers in the region, with the legumes generally grown as the minor crop in a system based on cereal or tuber crop (FCDP, 2005). The system is practically relevant to the development of a sustainable cropping system as the next non-leguminous crop utilizes the nitrogen fixed by the legume and thus reduces the need for added nutrients. However, there is little information regarding the compatibility of millet-legume combinations suitable for relay cropping system in the region. The objective of the current study was therefore to use performance data to identify millet-legume combinations compatible for relay cropping within the UER. Specifically, the study was to examine the grain yield and yield components of three millet cultivars and three legumes (soybean, groundnut and cowpea) under the relay cropping conditions.

MATERIALS AND METHODS

Experimental site, design and treatments used

The experiment was conducted during the 2011 and 2012 cropping seasons (May/June to September/October) on Manga experimental station, near Bawku (11°01N, 0°16'W, 249m above sea level). The annual mean rainfall (2011-2012) of the experimental site was 924.2mm; it was erratic and as usual monomodal, starting in April and ending in October with a short dry spell in July and the peak in August.

The soils of the experimental site were mainly sandy and acidic with high levels of potassium. Soil chemical analysis of the trial site within the 0-15cm depth showed that the pH was acidic. Total N and available P content were very low while exchangeable potassium content in the soil was medium compared with the critical levels for Ghanaian soils. Details of the soil attributes of the location within the study period are presented in Table 1.

Seeds of the millet cultivars, Arrow millet (AM), Bongo Shorthead (BSH) and Bristled millet (BM) as well as the legumes (groundnut, cowpea and soybean) were obtained from the Savanna Agricultural Research Institute (SARI), Nyankpala. The millet and legume components were planted in a randomized complete block design (RCBD) with three replications. Factorial inter-seeding of the legumes in the standing millet was done one week to the harvest of each millet cultivar. The legumes were planted between the rows of the millet in the first 5 rows leaving the sixth row space as a border. The intra-row spacing of the legume lines was 20 cm with two plants per stand giving a spacing of 75 cm× 20 cm with 5 rows between the 6 rows of the millet per plot. The following treatments (millet-legume combinations) were used in the study:

- AM/ G: Arrow millet followed by groundnut
- AM/CO: Arrow millet followed by cowpea
- AM/SOY: Arrow millet followed by soybean
- BSH/G : Bongo Shorthead followed by g'nut
- BSH/CO: Bongo Shorthead followed by cowpea
- BSH/SOY:Bongo Shorthead followed by soybean
- BM/G: Bristled Millet followed by groundnut
- BM/CO: Bristled Millet followed by cowpea
- BM/SOY: Bristled Millet followed by soybean

Analyses of soil samples

Soil samples were collected at about 0-15cm soil depth, air-dried in the laboratory and sieved through a 2mm sieve. Soil pH was measured using the pH meter at 1:1 soil to water ratio. Macro-nutrients including nitrogen, phosphorus and potassium were analysed. Percentage total nitrogen was determined by the micro kjeldahl-technique (Jackson, 1962). The available phosphorus was extracted by the Bray method and determined colorimetrically (Bray and Kurtz 1945). Potassium was determined by flame emission photometry. A guide to the interpretation of soil analytical data by Prof. E. Y. Safo, of Kwame Nkrumah University of Science and Technology (KNUST), Kumasi was used to interpret the data (personal communication).

Land preparation, planting and crop management practices

The land was prepared by ploughing and harrowing using a tractor. Sowing was done manually with the aid of wooden dibber. The millet cultivars were planted at the population density recommended for sole cropping (i.e. at a spacing of 75 cm between rows and 20 cm within rows, three plants per stand in six-row plots measuring 4.5m × 5m). Fertilizer was applied to the millet in accordance with the recommended rate using 60 kg N/ha and 30 kg each of P_20_5 and K_20 at 2 weeks after sowing (WAS) and ammonium sulphate 4 weeks after sowing. Half of the N fertilizer and all the 30 kg of the P_20_5 and K_20 was applied in the form of compound fertilizer 15:15:15. Hand weeding at 2 and 4 weeks after sowing was done followed by re-shaping with bullocks at 60 days after sowing.

The legume plants were sprayed to control flower thrips (*Megalurothrips sjostedti*) and a complex of pod sucking insects using lambda cyhalothrin (Product Karate) at the rate of 20g active ingredient per hectare. Weeds were controlled by hand hoeing whenever it was necessary. Each genotype was harvested promptly when pods were dry.

Data collection and analysis

Data was collected of millet on Stand count at establishment, Stand count at mid-season, Stand count at harvest, Days to 50% flowering (DFF), spike length, spike girth, Stover weight, incidence of Downy Mildew (DM) at establishment, and at maturity, 1000 grain weight (1000GW) and Grain yield. Data collected of legumes included Days to 50% flowering (DFF), stover weight and Grain yield. Data on legumes were taken on all five rows per plot whereas data was collected on five rows of millet crop per plot (ignoring the first row to eliminate errors due to border effects).

All statistical analyses were conducted using the GenStat Statistical program (GenStat Discovery Edition 3, version 7.2.0.220). The dataset was analysed separately by one-way analysis of variance (ANOVA). Where the ANOVA indicated significant differences, means were separated by the least significant difference test at P =

0.05.

Table 1. Some physical and chemical properties of the surface (0-15 cm) soil at the experimental site during the 2011 cropping season.

Soil physical and chemical properties	*Experimental site*
Sand (%)	80.4
Silt (%)	16
Clay (%)	3.6
Soil texture	Loamy sand
Soil pH	4.64
Organic carbon (%)	0.35
Total nitrogen (%)	0.06
Available P (mg kg^{-1})	13.58
Exchangeable cations cmol (+) kg^{-1})	
Ca	0.07
Mg	0.05
K	65.70
CEC [cmol (+) kg^{-1}]	3.28

RESULTS AND DISCUSSION

Responses of millet grain yield and other agronomic characteristics (traits) to relay cropping conditions

Agronomic performance of millet showed that, plant count at establishment, mid-season and harvest increased from one stage of plant growth to the other for both 2011 and 2012 cropping seasons. In both seasons, there were significant (P<0.05) differences among the millet cultivars with regards to plant count at mid-season and at harvest with Bongo Shorthead producing the highest plant count in both cropping seasons while Arrow millet accounted for the least (Tabla 2).

Table 2: Plant count at establishment, mid-season and harvest of millet under relay condition during 2011 and 2012 cropping seasons

TREATMENT	2011 Plt count			2012 Plt count		
	@est	@ mid season	@harvest)	@est	@ mid season	@harvest)
AM/ G	81.0	80.0	170.0	80.7	90.0	174.0
AM/CO	83.0	95.6	175.0	87.3	96.7	178.0
AM/SOY	77.5	89.9	184.1	88.7	102.7	185.3
BSH/G	93.6	102.0	200.2	96.7	105.0	209.7
BSH/CO	96.0	105.3	210.2	97.0	106.3	209.7
BSH/SOY	87.0	96.1	208.9	88.7	97.0	202.7
BM/G	83.1	94.2	177.1	84.0	95.3	180.3
BM/CO	86.8	89.4	178.1	78.7	81.3	177.0
BM/SO	76.2	99.9	188.1	77.3	90.7	187.0
MEAN	**84.9**	**94.7**	**188.0**	**86.6**	**96.1**	**189.3**
Lsd (p<0.05)	**Ns**	**20.0**	**36.45**	**Ns**	**24.6**	**38.45**
CV (%)	**3.0**	**3.5**	**1.5**	**3.2**	**3.3**	**1.4**

There were significant (P<0.05) differences among treatments with regards to spike length and spike girth of the millets. Consistently, and in both seasons, Bristled millet produced the longest spikes while Bongo Shorthead accounted for the shortest. Spike girth however, followed a different trend. While Bongo Shorthead produced the broadest spikes, Arrow millet accounted for the narrowest. Bongo Shorthead produced significantly (P<0.05) broader spikes than the rest of the millets evaluated in both cropping seasons.

In terms of earliness to flower initiation (DFF), there were no statistical differences among the millet cultivars in 2011 as DFF ranged between 57.67 and 58.67. In 2012 however, earliness to flower initiation was significantly different among the cultivars as DFF ranged from 45.67 to 50.00 (Table 3). In 2012, Bongo Shorthead was the earliest to attain 50% flower initiation, flowering significantly earlier than the rest of the cultivars.

Table 3: Spike length, spike girth and DFF of millet under relay condition during 2011 and 2012 cropping seasons

TREATMENT	2011			2012		
	Spike length (cm)	spike girth (mm)	DFF	Spike length (cm)	spike girth (mm)	DFF
AM/ G	21.3	73.5	58.67	27.3	70.5	50.00
AM/CO	22.5	70.3	58.33	22.8	78.3	48.33
AM/SOY	25.5	74.5	58.00	25.0	78.5	50.00
BSH/G	13.6	114.5	58.00	17.9	104.5	45.67
BSH/CO	15.0	125.2	57.67	15.8	129.2	46.33
BSH/SOY	12.5	117.5	58.33	11.7	118.0	45.33
BM/G	30.5	77.5	59.00	32.6	79.5	47.67
BM/CO	31.8	78.3	58.00	30.5	79.3	50.00
BM/SO	29.0	72.9	58.67	30.0	79.0	50.00
MEAN	**20.0**	**89.4**	**58.30**	**23.7**	**90.8**	**48.15**
Lsd (p<0.05)	**1.06**	**1.85**	**Ns**	**1.41**	**1.02**	**1.683**
CV (%)	**12.5**	**5.81**	**0.5**	**13.0**	**5.31**	**2.000**

The 1000-grain weight of pearl millet was generally low with Bristle millet recording the heaviest 1000-grain weight followed by Bongo Shorthead with Arrow millet producing the least. In terms of straw yield, Bongo Shorthead produced the highest straw yield in both cropping seasons followed by Bristled millet, whilst Arrow millet produced the lowest (Table 4). Grain yield values were statistically different in both seasons with BSH maintaining consistently higher values above the mean yields of 2.333t/ha and 2.58 t/ha in 2011 and 2012 respectively. Grain yields of Arrow Millet were below these mean figures in both cropping seasons.

Table 4: 1000GW, Straw yield and Grain yield of millet under relay condition during 2011 and 2012 cropping seasons

TREATMENT	2011			2012		
	1000GW (g)	Straw Yield (t/ha)	Grain Yield(t/ha)	100GW (g)	Straw Yield (t/ha)	Grain Yield(t/ha)
AM/ G	9.0	15.8	1.797	8.8	14.3	2.64
AM/CO	8.5	25.3	2.130	8.5	24.5	1.36
AM/SOY	9.5	24.5	2.080	8.0	25.8	2.12
BSH/G	9.5	28.9	2.567	9.5	29.1	4.27
BSH/CO	8.8	25.2	2.447	9.5	31.5	3.82
BSH/SOY	9.2	27.5	2.660	9.5	30.8	4.18
BM/G	11.5	21.7	2.373	10.0	22.1	1.49
BM/CO	10.0	25.3	2.590	11.5	26.1	1.51
BM/SO	12.5	21.9	2.350	11.9	23.5	1.81
MEAN	**9.8**	**24.0**	**2.333**	**9.7**	**25.3**	**2.58**
Lsd (p<0.05)	**0.46**	**0.85**	**0.5172**	**0.71**	**1.02**	**1.267**
CV (%)	**14.2**	**11.1**	**8.0**	**13**	**15.3**	**28.5**

Downy mildew incidence was generally higher at the maturity stage than at the establishment (30 days after sowing) stage in both cropping seasons. Bongo Shorthead was most affected whilst Bristled millet was the least affected at both stages for each of the cropping seasons. Thus, Bongo Shorthead was more significantly (P<0.05) affected by the Downy mildew incidence than the rest of the millets. There were significant (P<0.05) differences among the millets with regards to the number of chaffy heads recorded at harvest with the Bongo Shorthead recording significantly (P<0.05) the highest chaffy heads whilst Bristled millet recorded the least number of chaffy heads (Table 5).

Table 5: Incidence of downy mildew (DM) at establishment, at maturity and number of chaffy heads of millet under relay condition during 2011 and 2012 cropping seasons

TREATMENT	2011			2012		
	DM @est	DM @maturity)	No. of Chaffy Heads	DM @est	DM @maturity)	No. of Chaffy Heads
AM/ G	6.75	23.3	102	6.80	24.3	105
AM/CO	6.50	25.3	99	6.55	26.5	100
AM/SOY	6.25	24.5	100	6.00	25.8	107
BSH/G	7.25	29.3	107	7.00	29.1	117
BSH/CO	7.65	30.5	110	7.55	31.5	110
BSH/SOY	7.50	29.8	105	7.75	30.8	111
BM/G	5.75	21.3	90	5.65	23.1	90
BM/CO	5.50	22.0	92	5.55	23.1	88
BM/SO	5.60	21.5	89	5.75	24.5	87
MEAN	**6.53**	**25.3**	**99.3**	**6.51**	**26.5**	**101.7**
Lsd (p<0.05)	**1.05**	**1.9**	**10.**9	**1.07**	**2..6**	12.8
CV (%)	**34.8**	**13.9**	**31.90**	**3.2**	**3.3**	**28.9**

Responses of legume grain yield and other agronomic traits to relay cropping systems

There were significant differences among the various legumes for days to flower initiation under the cropping systems. Consistently, and in both cropping seasons, cowpea flowered earlier than the mean DFF of 51.89 and 60.00 in 2011 and 2012 respectively. Soybean flowered significantly ($P<0.05$) later than the means in both seasons. Quantitative data such as grain yield and straw yield values of the legumes could not be compared statistically since they were not of the same genus (Table 6). However, in terms of stover and grain yields, cowpea clearly maintained consistent yield superiority over the other legumes with cowpea stover yield values ranging from 14.5t/ha (in 2012 under AM/CO) to 17.2t/ha (in 2011 under BSH/CO), followed by soybean with stover yield ranging from 8.5t/ha (in 2012 under BM/SOY) to 12.9t/ha (in 2011 under BM/SOY). Groundnut produced the least stover ranging from 7.7t/ha (in 2012 under BSH/G) to 9.7t/ha (in 2011under BM/G). Legume grain yield trend was similar to that of stover yield. Cowpea out-yielded the other legumes with a range from 3.13t/ha (in 2011 under AM/CO) to 4.82t/ha (in 2012 under BSH/CO) followed by soybean whose grain yield ranged from 1.80t/ha (in 2011 under AM/SOY) to 3.12t/ha (in 2012 under AM/SOY). Groundnut produced the least grain yield, ranging from 1.27t/ha (in 2012 under BSH/G) to 2.64t/ha (in the same year under AM/ G).

Table 6: DFF, Stover weight and Grain yield of legumes under relay condition during 2011 and 2012 cropping seasons

TREATMENT	2011			2012		
	DFF	Stover Wt (t/ha)	Grain Yield(t/ha)	DFF	Stover Wt (t/ha)	Grain Yield(t/ha)
AM/ G	48 .00	8.0	1.79	55.37	7.9	2.64
AM/CO	47.67	15.3	3.13	39.67	14.5	4.36
AM/SOY	53.67	10.5	1.80	55.33	9.9	3.12
BSH/G	47.33	8.9	1.56	54.67	7.7	1.27
BSH/CO	46.67	17.2	4.47	40.33	15.5	4.82
BSH/SOY	55.33	11.5	2.66	54.02	8.7	2.18
BM/G	46.67	9.7	2.37	54.31	8.1	1.49
BM/CO	46.00	15.8	3.95	40.00	16.1	4.51
BM/SOY	54.67	12.9	2.350	54.11	8.5	1.81
MEAN**	**49.56**			**49.76**		
Lsd (p<0.05) **	**3.180**			**1.778**		
CV (%)**	**0.4**			**1.7**		

**** Mean, Lsd and CV could not be computed for quantitative data such as stover weight and Grain yield since the legumes are not of the same genus**

Responses of grain yield and other agronomic characteristics to cropping systems

The erratic nature of rainfall as well as the various soil attributes observed within the period under study were characteristic of the Guinea and Sudan savannah zones (Padi, 2007).

The significant (P<0.05) differences among the millet cultivars with regards to plant count at mid-season and at harvest as well as spike length and spike girth of the millets indicates that there was influence of the relay cropping system on millet plant population, spike length and spike girth. Bongo Shorthead which accounted for the highest stand count at mid-season and at harvest and also produced the broadest spikes in both cropping seasons is likely to generate better yield components and thus is a promising candidate for the relay combination with the legumes.

The fact that Bongo Shorthead was more significantly (P<0.05) affected by the downy mildew incidence than the others and also recorded the highest number of chaffy heads and still accounted for the greatest straw and grain yields suggests that with adequate control measures against the incidence of downy mildew and chaffy heads, Bongo Shorthead could be a preferred cultivar for the relay cropping system. The higher grain and straw yields could be attributed to their relatively higher plant count (population) and better resource utilization. The low incidence of downy mildew and number of Chaffy heads in Bristled millet could be attributed to its inherent ability to resist the disease. Thus plant breeding efforts geared towards conferring resistance in Bongo Shorthead from Bristled millet could further enhance the suitability of the former cultivar in the cropping system.

In 2012, Bongo Shorthead was the earliest to attain 50% flower initiation, flowering significantly earlier than the rest of the cultivars and was also among the earliest to flower in both cropping seasons. The cultivar thus has desirable agronomic attributes in terms of maturity period as the short maturity enables it to fit into the short cropping season (Yirzagla *et al*., 2013) and erratic rainfall patterns typical of the Guinea and Sudan savanna zones of Ghana. The early maturing cultivar could complete its life cycle before the severity of the terminal drought which otherwise would have suppressed grain and straw yield considerably.

The observation that cowpea maintained consistent yield superiority under all the relay cropping conditions suggests that this legume could be a reliable relay-adaptive cultivar for purposes of relay cropping within the Upper East Region of Ghana.

The fact that cowpea flowered significantly (P<0.05) earlier and also maintained consistent yield superiority over the other legumes suggests that in terms of maturity period as well as food and fodder production attributes, it is suitable for the relay cropping system as the short maturity enables it to fit into the short cropping season typical of the area. Cowpea attained maximum yield of 17.2t/ha stover and 4.82t/ha grain values both under BSH/CO relay cropping condition while groundnut produced the least stover of 7.7t/ha and accounted for the least grain yield of 1.27t/ha all under BSH/G relay cropping condition. These observations point to the fact that under normal rainfall pattern, Bongo Shorthead followed by cowpea in a relay cropping system has the greatest prospect of accounting for superiority in grain and stover/straw yield while Bongo Shorthead followed by groundnut in a relay will provide the least suitable combination for relay cropping within the Upper East Region of Ghana.

References

Bray, R.H. and Kurtz L.T., (1945). Determination of total organic and available forms P in soils. *Soil science* 39:39-45

Duncan,S.R,W. T.Schapaugh,Jr., andJ. P. Shroyer (1990). Relay intercropping soybeans into wheat in Kansas. J. Prod. Agric. 3:576-581.

Food Crops Development Project- Cowpea Production Guide (2005)

Jackson, M. L. (1962). Soil chemical analysis. Practice, Hall, Inc. New York.

Moomaw, R. S. and T. A. Powell (1990). Multiple cropping systems in small grains in northeast Nebraska. J. Prod. Agric. 35:69476.

Padi, F.K. (2007). Genotype x environment interaction and Yield Stability in cowpea- based cropping system *Euphytica* 158:24

Reinbott, T. M., Z. R Helsel, D. G. Helsel, M. R Gebhardt, and H. C. Minor. (1987). lntercroppiug soybean into standing green wheat. Agron. J. 79:88

Yirzagla J, F. K. Padi, R. Akromah, M. M. Dawuda (2013). Evaluation of Cowpea Genotypes for Maize-based Additive Series Intercropping in the Guinea and Sudan Savanna Zones of Ghana. *Journal of Advances in Agricultural Science and Technology. Vol1(1) pp 001- 008*