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Pearl millet-cowpea intercrop effect on *Striga hermonthica* and grain yield

P.A. Asodewine, S. Lamptey* and I.K. Dzomeku

Department of Agronomy, Faculty of Agriculture, University for Development Studies, P.O. Box TL 1882, Nyankpala, Tamale, Ghana

**Email: naalamp2009@yahoo.com*

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ABSTRACT

Field experiment was conducted in naturally *Striga hermonthica* (Witchweed) infested field in the Kassena-Nankana East district of the upper East region, Ghana during the 2018 cropping season. This was to investigate effects of *Striga* tolerant pearl millet varieties intercropped with cowpea on *S. hermonthica* and crop yield. The study was done in a 4 x 3 factorial experiment consisting of four pearl millet varieties (*Akad-kom*, *Kaanati*, *Naad-kohblug* and *Waapp-naara*) and three cropping patterns (sole millet, millet-cowpea (1:1) and millet-cowpea (2:1) laid out in a randomized complete block design with three replications. Results showed that *Striga* emergence and shoot biomass was highest with *Waapp-naara* variety, which led to low grain yields (1.78 t/ha). Grain yield of *Akad-kom* (1.89 t/ha) was outstanding with millet-cowpea (1:1) as the best cropping pattern. Millet-cowpea (1:1) cropping pattern had the lowest *Striga* numbers and shoot biomass. *Naad-kohblug* variety and MC (1:1) cropping pattern gave best total LER of 1.44 and 1.41, respectively. Grain yield negatively correlated with *Striga* count (r = -0.42). Millet-cowpea (1:1) cropping pattern exhibited suicidal germination of *Striga* seeds, enhanced soil fertility and promoted *Striga* seed bank depletion of 46%. Resource poor farmers in *Striga* endemic areas could plant *Akad-kom* and *Naad-kohblug* varieties as sole crops or intercropped with cowpea (1:1) to manage *Striga hermonthica* and maximize grain yields.

INTRODUCTION

Pearl millet (*Pennisetum glaucum* (L.) R. Brown) is a major cereal grown primarily in Africa and Asia in tropical semi-arid regions of the world (Vanisha *et al.* 2011). It ranks after maize, rice and sorghum as the fourth most significant tropical cereal crop in the world (FAOSTAT 2015). It is particularly crucial in marginal agricultural cultivation areas in sub-Saharan Africa where it offers food, feed and fodder to millions of individuals and animals (Angarawai *et al.* 2008, Nambiar *et al.* 2011). India and Africa are the most important producers with more than 85% of the world's production (FAOSTAT 2015). In the Sahelian and Sudan Savannah regions, where an average annual rainfall ranges from 650 to 1200 mm, pearl millet is mainly produced as a rainfed cereal crop. Although the crop is indigenous and exceptionally adapted to the region, yields are generally less than 1.0 t/ha (FAOSTAT, 2016). It is the least researched crop in terms of improvement despite its importance as a food security crop in northern Ghana (Dawud *et al.* 2017).

Factors responsible for low yield include heavy infestation by parasitic weed *Striga hermonthica* (Del.) Benth (Dawud *et al* 2017, Fadelmola *et al* 2014). *S. hermonthica* is a major biotic problem to pearl millet cultivation particularly in northern Ghana, adversely affecting the livelihood of people, especially subsistence farmers, and aggravating food insecurity and poverty (Dawud *et al* 2017, Pennisi 2010, Ayman *et al.* 2014). The weed has also forced farmers to abandon their land (Atera *et al.* 2012). Hence, the control of *Striga* is an important factor in ensuring food security in these regions (Ejeta and Gressel 2007, Rodenburg *et al.* 2006). A diverse array of control approaches such as use of trap crops, resistant/tolerant varieties as well as cultural measures aimed at improving soil fertility has been used (Teka 2014). Although these methods have helped in reducing the impact of this pernicious weed, they have not addressed the *Striga* seed problem effectively (Ransom 2000). Thus, the extensive seed bank of *Striga* in infested fields remains an impediment (Parker 2012).

Intercropping millet and cowpea can suppress the germination of *S. hermonthica*, improve soil fertility, reduce the level of inorganic fertilizer requirement and reduce *Striga* seed bank (Sunda 2014). Farmers have attempted to intercrop *Striga* tolerant millet varieties with cowpea in the Sudan Savanna, but there is little information on its efficacy in reducing *Striga* infestation, as well as increasing productivity. Resistance is often regional and performance depends on environmental conditions. Also, information on performance of tolerant varieties screened under *S. hermonthica* susceptible areas in the Sudan Savannah region of Ghana is lacking. The study seeks to evaluate the effects of intercropping locally developed *Striga* tolerant pearl millet and cowpea on *S. hermonthica* management and pearl millet yield.

MATERIALS AND METHODS

Field study was conducted at Saabisi-Natugnia in the Kassena-Nankana East District (latitude 100 45' N and Longitude 010 06' W) in the Upper East Region of Ghana during the 2018 cropping season. The vegetation of the site is grassland regrowth with short trees, shrubs and thumps. The climate is warm, Semi-arid with average total annual monomial rainfall of 950 mm. Day temperatures are high recording 42° Celsius (especially between February and March) and night temperatures could be as low as 18° Celsius. The soil in the study area has been described as Savannah ochrosols with Aeolian Sandy loam (IUSS World Reference Base 2006). Cumulative precipitation during the crop growing season at the experimental site was 980.4 mm.

The study was done in a 4 × 3 factorial laid in a randomized complete block design (RCBD) and replicated thrice. A factorial treatment combination consisting of four pearl millet varieties (*Akad-kom*, *Kaanati*, *Naad-kohblug* and *Waapp-naara*) and three cropping patterns (Sole millet, one row of millet: one row of cowpea (1:1) and two rows of millet: one row of cowpea (2:1) were used. Additional plot was created under each replication to enable calculation of land equivalent ratio (LER). There were thirteen (13) plots in each replication measuring 5 x 5 m (25 m^2) with total plot size of 1,587 m^2. An alley of 1.5 m between blocks and 1.0 m between plots was used for easy movement of materials and agronomic operations.

The local photoperiod sensitive medium maturing spreading cowpea type "*Padituya*" from farmers was used. Each of the millet variety was planted at a planting distance of 0.75 × 0.3 m (0.225 m^2) and row length of 5 m (approximately 7 stands per row). A maximum of five seeds per hole and seedlings thinned to two per hole two weeks after emergence. Cowpea was planted three seeds per hole and thinned to two at a spacing of 0.75 × 0.2 m (0.15 $m^{2)}$ and row length of 5 m (approximately 7 stands per row). In sole and intercrop, millet and cowpea were sown at a depth of 3 cm on the same day. Empty hills were refilled. The plots were hoe-weeded at 2 and 5 weeks after planting. Number of emerged *Striga* plants per plot was counted at 8, 10, 12 and 14 weeks after the appearance of the first *Striga* plant in the field. The *Striga* were uprooted at each *Striga* count and weight was taken. The parasites were then packed in envelopes and dried for 48 hours at 80 ^oC and dry weight recorded using electronic scale.

For determination of *Striga* seed bank, soil samples were taken randomly from each plot and thoroughly mixed to achieve a composite sample. *Striga* count determination was done using potassium carbonate separation method as described by Berner *et al.* (1997). Average *Striga* counts were also determined for each plots after harvest.

Grain and biomass yield: The grain yield per plot for each treatment was determined from two middle rows with an area of 7.1 m^2. Grain yield was estimated using a measurement scale to weigh the grain yield per plot after drying the panicles in the sun to about 10% moisture content, threshing, winnowing, and cleaning. Using the formula (10000 x yield per plot)/ (plot size x 1000), the grain yield per plot was converted to kg/ha. Pearl millet stalks were cut near the soil surface and their total fresh weight taken. A sub-sample was thereafter taken from the total stalks in each plot, weighed and recorded. The sub-sample was thereafter dried and weighed. The weights for both were used to calculate the pearl millet biomass.

At physiological maturity, millet plants were manually harvested from an area of 7.1 m2 (4 ´ 3.3 m) per plot. Grains were threshed, winnowed and cleaned. They were weighed, converted to grain yield, and reported in ton per hectare. The above ground biomass and grain yield were determined on a dry-weight basis by oven drying the crop samples at 105°C for 45 min and subsequently to constant weight at 85°C.

Land equivalent ratio

The competition function was calculated to analyze the impacts of competition between plants and to assess intercrop efficiency and land equivalent ratio (LER). The LER is a precise evaluation of the intercropping situation's biological effectiveness was calculated as outlined by Alhassan and Egbe (2014):

LER = LERim+LERsm …...1

LER= Yim/Ysm ……….......................……………………..2

LER = Yic/Ysc …………....…………………………………..3

Where the subscript letters, m and c stand for pearl millet and cowpea, respectively; Yim and Ysm are yields of pearl millet intercrop and sole crop while Yic and Ysc represent yields of cowpea intercrop and sole crop. LER value above one indicates an advantage of intercropping over sole cropping while LER value below one shows that there is no advantage by intercropping.

Statistical analysis

Data collected were subjected to Analysis of Variance (ANOVA) using GENSTAT statistical software version 12. Significant differences among treatments were determined using Least Significance Difference (LSD) at 5% level of probability. All count data (*i.e., Striga* count) were transformed logarithmically (Kihara *et al*. 2011) before being subjected to ANOVA to reduce variation in the results. Linear correlation coefficients were also calculated to determine the degree of association among the pearl millet agronomic parameters and *Striga* counts.

RESULTS AND DISCUSSION

Effect on *Striga*

Composite soil samples taken at separate depths from the site before the beginning of the experiment varied with 0-10 cm recording the highest number of *Striga* counts compared to 10-20 cm (**Table 1**). *Striga* seeds were least (195) in the 10-20 cm soil depth compared to 359 in 0-10 cm depth. The high *Striga* seed count in the 0-10 cm depth could be due to method of dissemination (Woomer and Savala 2008) which usually happens on top soil resulting to an increase in *Striga* seed bank. Weber *et al.* (1995) reported several thousand *Striga* seeds close to the surface of the soil, but less as soil depth increases.

Striga attack incidence and severity depends on *Striga* susceptibility of the host (Esilaba 2008). Increased *Striga* emergence in *Waapp-naara* variety may be due to its susceptibility to the parasitic weed (Fasil and Verkleij 2007). Rodenburg *et al.* (2006) also reported fewer *Striga* emergence in resistant crops compared to non-resistant crops. The low *Striga* emergence in *Kaanati, Akad-kom,* and *Naad-kohblug* intercropped with cowpea in the MC (1:1) cropping pattern may be attributed to reduced *Striga* germination or reduced attachment of germinated *Striga* to host plant roots as a result of interactive effect between variety and intercropping. These observations corroborate earlier reports by Kureh *et al.* (2006), who reported that *S. hermonthica* density is significantly suppressed when cereals are intercropped with legumes. Cowpea inclusion might have suppressed both emergence and development of *S. hermonthica,* which improved the productivity of the pearl millet component in the system. The presence of cowpea also might have suppressed *Striga* plant growth and development, which reduced *Striga* biomass compared to sole pearl millet.

Table 1. Initial average *Striga* counts at Saabisi

Soil depth (cm)	*STRIGA* COUNT Seeds/100g soil				
	1st SET	2nd SET	3rd SET	4th SET	Average count
0-10	367	354	357	358	359
10-20	195	190	196	199	195

The best sustainable control of *Striga* should be the depletion of *Striga's* vast, long-lived seed bank (Zwanenburg *et al*. 2016). Reduced percentage *Striga* seed bank by variety (31.4 to 42.7%) and cropping pattern (37.6 to 46.2%) may be attributed to induced germination of *S. hermonthica* by host-plant resistance varieties and trap crop (cowpea), respectively. Dugje and Ngala (2012) reported that the level of *Striga hermonthica* infestation of sole millet was significantly higher than millet intercropped with cowpea. De Groote *et al.* (2010) recorded *Striga* suicidal germination and decreased seed bank of *Striga* in intercrop of maize and soybean. Dawud *et al.* (2017) also recorded parasite seed bank depletion with trap crop, thereby reducing harm to cereal crops. Interaction between *Kaanati* and *Akad-kom* varieties and the MC (1:1) cropping pattern reduced percentage *Striga* seed bank by 42% - 46%. The decreased number of *Striga* seed banks can be attributed to germination stimulant by the cowpea (Padituya) roots resulting to suicidal germination. This agrees with De Groote *et al.* (2010) and who observed that the use of trap crop such as soybean triggers suicidal germination of *Striga* and therefore reduces the *Striga* seed bank in the soil when intercropped with maize. Result from the present study indicates that *Striga* tolerant pearl millet varieties can help reduce *Striga* soil seed bank in *Striga* endemic areas as more will germinate but its growth and development will not be supported.

Interaction between pearl millet varieties and intercropping significantly influenced ($p<0.05$) *Striga* count at 8, 10 and 12 WAP (**Table 2**). *Waapp-naara* significantly increased *Striga* emergence count with a mean of 4.40, 4.85 and 7.47 at 8, 10 and 12 WAP, respectively compared to other treatment. At week 10 and 12, *Naad-kohblug* gave the least mean *Striga* seedling emergence/plot of 1.74 and 1.79, respectively. Among the cropping pattern, sole crop recorded the highest *Striga* count of 4.00 and 6.73 at 10 and 12 WAP, respectively with MC (1:1) treatment recording the lower of 1.71 and 2.63 at 10 and 12 WAP, respectively. For *Striga* biomass production, MC (2:1) gave the highest (2.00 kg/ha), followed by sole crop (1.99 kg/ha) and MC (1:1) 1.19 kg/ha at 8 WAP.

Percentage reduction in *Striga* soil seed bank were significantly affected by variety cropping pattern interaction. Percentage *Striga* soil seed bank reduction ranged from 31.40% (*Waapp-naara*) to 42.70% (*Akad-kom*) for varieties compared to cropping pattern 37.56% (sole crop) to 46.20% (MC (1:1) (**Figure 1**).

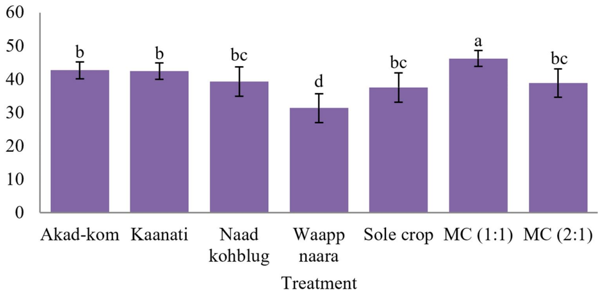

Figure 1. Per cent reduction in *Striga* soil seed bank after harvest

Effect on pearl millet

The interaction between pearl millet varieties and cropping patterns did not significantly (P>0.05) affect the panicle length and girth of pearl millet. However, variety significantly (P<0.05) influenced panicle length and girth. *Naad-kohblug* produced the highest (31.07 cm, 11.12cm) panicle length and girth, respectively while *Akad-kom* produced the lowest (12.38 cm, 7.11 cm) as shown in **Table 3**.

Table 2. Effects of pearl millet varieties and cropping patterns on *Striga* count and biomass production

Treatment	*Striga* count ($\sqrt{x} + 0.5$)				*Striga* biomass (kg/ha)			
	8 WAP	10 WAP	12 WAP	14 WAP	8 WAP	10 WAP	12 WAP	14 WAP
Variety								
Akad-kom	2.27	2.57	4.00	1.75	1.46	1.71	2.39	1.18
Kaanati	2.25	3.06	4.52	1.15	1.40	2.02	2.61	0.91
Naad-kohblug	2.68	1.74	1.79	1.07	1.65	1.30	1.26	1.30
Waapp-naara	4.40	4.85	7.47	2.59	2.40	3.13	4.56	1.80
LSD (p=0.05)	1.48	1.66	1.96	1.57	0.70	0.95	1.12	0.84
Cropping pattern								
Sole crop	3.49	4.00	6.73	1.87	1.99	2.65	4.06	1.32
MC (1:1)	1.72	1.71	2.63	1.86	1.19	1.22	1.76	1.27
MC (2:1)	3.50	3.45	3.97	1.69	2.00	2.25	2.28	1.32
V * CP	2.56	2.87	3.39	NS	NS	1.64	1.94	NS
LSD (p=0.05)	1.28	1.44	1.69	1.35	0.60	0.82	0.97	0.73

NS = No significant difference; WAP- Weeks after planting

Table 3. Effects of pearl millet varieties and cropping patterns on yield components and grain yield of millet

Treatment	Panicle		Productive tiller count		Yield	
	Length (cm)	Girth (cm)	7 WAP	9 WAP	Grain yield (t/ha)	Stover yield (t/ha)
Variety						
Akad-kom	12.38	11.12	1.49	1.68	1.89	2.60
Kaanati	27.44	7.11	1.33	1.36	1.82	2.00
Naad-kohblug	31.07	8.08	1.15	1.68	1.89	3.30
Waapp-naara	22.91	9.08	0.74	1.70	1.78	2.33
LSD (p=0.05)	0.83	0.16	0.35	0.31	0.06	0.24
Cropping pattern						
Sole crop	23.55	8.82	1.22	1.73	1.83	2.26
MC (1:1)	23.44	8.87	1.09	1.40	1.89	2.66
MC (2:1)	23.36	8.86	1.22	1.68	1.79	2.76
V * CP	NS	NS	NS	NS	NS	NS
LSD (p=0.05)	0.71	0.14	0.30	0.27	0.06	0.21

NS = No significant difference; WAP- Weeks after planting

The main effect of pearl millet variety significantly affected number of productive tiller counts at 7 WAP. *Akad-kom* treatment recorded the highest (1.49 per/plant) number of productive tiller counts than *Kaanati*, *Naad-kohblug* and *Waapp-naara* treatments at 7 WAP.

The interaction between pearl millet varieties and cropping patterns did not significantly (P>0.05) influence grain yield. However, variety was significantly (p<0.05) different with *Akad-kom* recording the greatest (1892.00 kg/ha) while *Waapp-naara* the least (1778.00 kg/ha).

The MC (1:1) cropping pattern significantly increased grain yield by 5% compared to MC (2:1). Stover yield significantly differed (p<0.05) among pearl millet varieties with *Naad-kohblug* producing the highest Stover yield (3300 kg/ha) and *Kaanati* least (2000 kg/ha). The interaction between pearl millet varieties and cropping patterns did not significantly (P>0.05) affect stover yield.

Kaanati, Akad-kom and *Naad-kohblug* with MC (1:1) cropping pattern were identified with low *Striga* emergence and with good agronomic performance in this study. This indicates that these genotypes based on phenotypic data were more resistant/tolerant to *Striga* infestation. *Waapp-naara* variety on the other hand supported *Striga* emergence and biomass production resulting to a significantly lower grain yield.

There were significant negative correlations between *Striga* parameters (*Striga* counts and biomass) measured and yield (stover and grain yield). For example, grain yield negatively correlated with *Striga* emergence (r = -0.42). This is an indication that yield was significantly reduced by *Striga* infestation. Mesfin (2016), Ezeaku *et al.* (2015), and Kanampiu *et al* (2018) found similar results in pearl millet. This result is in line with the findings of Kim (1997), who reported significant and negative correlation between maize grain yield and *Striga* emergence. *Akad-kom and Naad-kohblug* varieties respectively recorded greater productive tiller numbers in the present study. These could be the contributing characters for high grain yield. Pearl millet varieties that showed greater tiller numbers and low *Striga* counts might be indicative of genotypes that are less prone to *Striga* infestation. Between *Striga* count and productive tiller count there was a significant negative correlation (r = -0.01).

Land equivalent ratio

Land equivalent ratio was significantly (p<0.05) affected by intercropping (**Table 4**). The highest land equivalent ratio value of 1.44 was recorded on *Naad-kohblug* variety and the lowest land equivalent ratio value of 1.24 was recorded on *Waapp-naara* variety. All other treatment means were statistically similar. The MC (1:1) gave the highest (1.41) land equivalent ratio and this was significantly (p<0.05) greater than the MC (2:1) cropping pattern (1.25). Intercropping systems had total LER values higher than the sole meaning intercropping was more efficient than the sole cropping (Jackson 2009). Crop differ in the way they use environmental resources and complement each other and make better use of resources when they grow together than when they are grown separately (Long *et al.*, 2011). Partial LER revealed that *Naad-kohblug* variety and MC (1:1) cropping pattern were more productive. *Naad-kohblug* and MC (1:1) cropping pattern resulted to greater LER of 1.44 and 1.41, respectively. Abera *et al.* (2005) also observed that, in terms of food production per unit area, the LER values ranged from 1.15 to 1.42 suggesting higher productivity and land use effectiveness of intercropping.

Table 4. Effects of pearl millet-cowpea on partial land equivalent ratio of cowpea (PLERc), partial land equivalent ratio of pearl millet (PLERm) and land equivalent ratio (LER)

Treatment	Partial land equivalent ratio of cowpea	Partial land equivalent ratio of pearl millet	Land equivalen ratio
Variety			
Akad-kom	0.43	0.88	1.31
Kaanati	0.52	0.78	1.30
Naad-kohblug	0.59	0.85	1.44
Waapp-naara	0.42	0.82	1.24
LSD (p=0.05)	0.09	0.15	0.13
Cropping pattern			
MC (1:1)	0.57	0.84	1.41
MC (2:1)	0.42	0.83	1.25
LSD (p=0.05)	0.07	0.11	0.09
CV (%)	15.7	15.2	7.90
V * CP	NS	0.22	0.18

NS = No significance difference

Pearl millet grain yield negatively correlated with *Striga* count (r = -0.42) and 1000 grain weight (r = -0.59) (**Table 5**). However, grain yield positively correlated with number of tiller count/plant, panicle girth and panicle weight/plant (r = 0.13 to 0.40). *Striga* biomass negatively correlated with panicle length, stover yield, grain yield and 1000-grain weight (**Table 5**).

Conclusion

Pearl millet varieties and cropping patterns have proved to manage *Striga* by reducing *Striga*

Table 5. Relationships between pearl millet agronomic parameters and *Striga* counts

Parameter	1	2	3	4	5	6	7	8	9	10
Cumulative *Striga* count	-									
Striga biomass (kg/ha)	0.95***	-								
Tiller count	0.40**	0.39**	-							
Productive tiller count	-0.01	0.05	0.25*	-						
Panicle length (cm)	-0.04	-0.07	-0.17	-0.23*	-					
Panicle girth (cm)	0.05	0.05	0.29*	0.23*	-0.91***	-				
Panicle weight (g)	0.13	0.09	0.05	-0.02	0.36**	-0.31*	-			
Stover yield (kg/ha)	-0.19	-0.24*	-0.04	-0.02	0.36**	-0.03	0.17	-		
Grain weight (g)	-0.59***	-0.46**	-0.19	0.28*	0.16	-0.11	-0.13	0.15	-	
Grain yield (kg/ha)	-0.42**	-0.39**	-0.06	-0.04	0.04	0.07	-0.28*	0.24*	0.48**	-

* = significant (p=0.05), ** = significant (p= 0.01), *** = significant (p=0.001). Values without asterisk(s) have no significant linear correlation

emergence, seed bank and *Striga* biomass resulting to improved grain yield and land equivalent ratios greater than one (LER > 1). *Striga* tolerance pearl millet varieties (*Akad-kom* and *Naad-kohblug*) are recommended in *Striga* infested field in the Sudan Savannah for reduced *Striga* seed bank and improved millet yield. For improved yield and best land productivity or LER, small holder farmers could plant *Naad-kohblug* using MC (1:1) cropping pattern.

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