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The influence of cropping systems and maize-bean intercrop spatial patterns on companion crop yield, weed density and biomass.

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ABSTRACT: Intercrop spatial pattern has potential to influence crop yield by increasing radiation interception (RI), reduce weed density and biomass. Close spatial patterns reduce weed density biomass and dynamism after manual weeding 3 weeks after crop emergence (3 WACE) making resources that are normally taken up by weeds available for crop uptake. Intercropping is important for Smallholder (SH) farmers who face labour constraints as they have the potential to increase yield and reduce weeding frequency. The objective of this study was to assess the effect of cropping systems and maize-bean spatial patterns on yield of companion crops, weed density and biomass. Tested intercrop spatial patterns were intra-row, inter-row, both (intra and inter maize rows), random pure stands of bean and maize.Treatments were laid in a randomised complete block design (RCBD) over two seasons in 2013 and 2014. Cropping systems and intercrop spatial patterns significantly ($P<0.05$) influenced companion crop yield, weed density and biomass. Pure stands gave higher grain yield of component crops although the overal performance using land equivalent ratio showed LER>1.0 depicting that intercrops performed better than sole crops. Intercrop spatial patterns increased RI at 8 WACE by 74% compared to 59% in sole crops resulting in reduction of weed density by 7% and 21% for biomass after the first manual weeding. The results infer that maize-bean intercrop spatial patterns have the potential to reduce weed density and biomass.
Key words: companion crop, intercrop, spatial pattern, weed biomass, weed density

INTRODUCTION

Smallholder farmers in sub-Saharan Africa (SSA) and Zimbabwe face a myriad of crop production challenges that include; limited access to external inputs, erratic rainfall pattern and recurrent droughts (Ncube et al., 2009; Kurwakumire et al., 2014). Crop production by SH is largely rain fed. Rainfall in most of SSA is characterised by poor distribution, frequent dry spells, flooding and drought episodes which increase the risk of dryland farming especially in semi-arid areas of Zimbabwe (Ncube et al., 2009). In addition, poor soil fertility (Sanchez, 2002) and weed pressure (Mashingaidze et al., 2009) have exacerbated food security in this sector. In order to mitigate the risk associated with such constraints and ensure continuous food supply, SH farmers' could diversify crop production strategies through intercropping (Sullivan, 2003).

Intercropping is growing of two or more crops simultaneously on the same piece of land within the same season in order to maximize beneficial interactions while minimizing companion crop competition (Sullivan, 2003; Poodineh et al., 2014). The major benefits of intercrops are, high productivity and profitability (Yildirim and Guvence, 2005), improved soil fertility through addition of N fixing legumes (Hauggaard-Nielsen et al., 2001), improved forage quality (Agegnehu et al., 2006; Yilmaz, 2015), increased biodiversity and efficient use of environmental resources (Knudsen et al., 2004) as well as reduction in damage caused by insect pests, diseases and weeds (Banik et al., 2006). Furthermore, intercrops contribute to varied and balanced human diet making it more vital to promote and ensure success of intercrop system under SH farming sector.

Cereal-legume crop mixtures are common among SH farmers in semi-arid tropics including sorghum-soyabean, maize-cowpea and maize-bean (Mutungamiri et al., 2001). In SSA maize is a staple food crop that plays an important role in dietary requirements of 100 kg capita^{-1} year^{-1} (Smale and Jayne, 2003). The crop is characterized by high potential yields, fairly easy to produce, adaptable to different agro-ecological zones, varied uses and good storage characteristics making it a suitable intercrop companion crop (Yilmaz, 2007). Common bean (Phaseolus vulgaris L.) is an important protein source and valuable source of revenue for SH farmers in most African countries. The protein content of common bean varieties ranges from 17% to 22% (Singh et al., 2002). Common bean, therefore, plays an important nutritional role as substitute for protein source. Besides good nutrition, common bean crop fetch 10 to 20 times higher prices, on weight basis, than cereals and therefore becomes an important companion crop in an intercrop (Mutungamiri et al., 2001). Maize bean intercrop as a result becomes an ideal option for SH farmers in Zimbabwe.

However, SH farmers in the tropics especially SSA face serious weed challenge than any part of the world and spend 75% of their time battling with weeds in their fields (Mashingaidze et al., 2009). Weeds are defined as unwanted plants that are competitive, persistent, pernicious, and interfere negatively with human activities (Ross et al., (2001). Manual weed control is popular among SH farmers and is one of the most back breaking activity in this sector with two or more weeding cycles per season (Chui, et al., 1997). Faced with serious labour constraints in SH sector, farmers invariably weed large portions of crop late when it has already suffered significant yield damage (Mashingaidze et al., 2009). Cultural weed control can be an important integrated weed management option in this sector. The complementary effect of companion crops is believed to reduce weed pressure (Orluchukwu and Udensi, 2013). However, an ideal spatial pattern should be used with minimum influence on companion crop yield while it's able to suppress weeds. Common intercrop spatial patterns used world wide (Lithourgidis et al., 2011) are intra-row (within the same row), inter-row (alternating rows) and random (mixed). Planting pattern affect interaction between intercrop companion crops, affect their use of environmental resources and thus influence the outcome of intercrop compared to sole cropping system. However, the influence of cropping systems and intercrop spatial patterns on companion crop yield, weed density and biomass is poorly understood in Zimbabwe. The objective of this experiment was to evaluate effects of various intercrop spatial patterns on yield of companion crops, weed density and biomass.

MATERIALS AND METHODS

Site description

The study was carried out at University of Zimbabwe Marondera College of Agricultural Science and Technology (UZMCAST) research site (18^{o} 23' S and 31^{o} 47' E). The College is located 40 km south of Marondera town within Natural Region II. The area experiences sub-tropical climate with average summer temperatures of 25^{o}C and annual precipitation between 800 – 1 000 mm year^{-1}. Rainfall follows a unimodal pattern with rains received between October and May. The 2013/14 season received below normal rainfall (631mm) of which 64% of precipitation was received in 41 days, whereas 2014-15 seasons was characterised by poor rainfall distribution. A total of 722mm was received and again 64% of rainfall was received within 25 days from mid December to first week of January (Figure 1). The soils are coarse grained sandy soils derived from granite parent material which are characterized by low inherent fertility, poor water holding capacity and low organic matter content (Table 1).

Table 1. Soil analysis results for Marondera College of Agricultural Science and Technology trial site

Description	pH (Ca.Cl)	Total N %	Available P mg kg^{-1}	mg equivalent kg^{-1}		
				Potassium	Calcium	Magnesium
Site Soil	5.7	0.01	305	1.0	23.2	5.9

General fertility range interpretation

Adapted from Refs. [Tanner and Grant 1963; Grant, 1981]. Available-P (resin-extracted): <7=very low; 7-15=low; 15-30=medium; 30-50=high. Exchangeable-K: <0.15=very low; 0.15-0.3=low; 0.3-0.5=medium; >0.5=high. Exchangeable-Ca: <5=very low; 5-10=low to medium; >10=high f Exchangeable-Mg: <0.1=very low; 0.1-0.2=low to medium; >0.2=high.

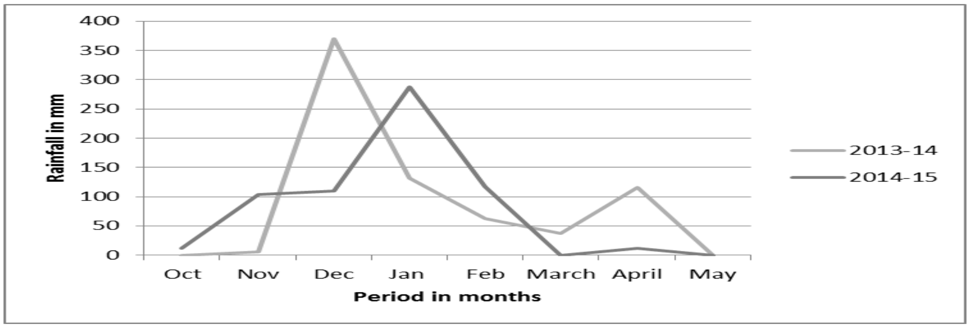

Figure 1. Rainfall data for UZMCAST during 2013-14 and 2014-15 seasons.

Land preparation and fertilizer application

Maize-bean intercrop trials were established in 2013/14 and 2014/15 seasons. The land used was fallow the previous season. Land was mechanically ploughed and conditioned to a fine tilth. For row spatial patterns planting furrows were marked out at 90 cm apart using hoes and basal fertilizer compound D (7% N: 14% P_2O_5: 7% K_2O) was applied at a rate of 300kg ha^{-1} and covered before seeding. Fertilizer rates were calculated based on soil analysis and target crop requirement (Table 1). Target maize crop nutrient supply was N 120 kg ha^{-1}, P_2O_5 42 kg ha^{-1} and K_2O 68 kg ha^{-1}. In random intercrop plots fertilizer was broadcasted and soil incorporated using a hoe followed by seeding. Tested cropping systems and spatial patterns are shown in (Table 2)

Experimental design and treatment description

A total of six treatments were laid out in a randomised complete block design (RCBD) with three replications. The gross plot size was 5 x 4.5 meters and the net plot was 2.7 x 2 meters. Short to medium season three-way maize hybrid SC 513 (Seed-Co Zimbabwe) was planted by placing two peeps per station using spacing provided in (Table 2). Thinning was done 2 WACE with a target sole maize and bean plant population of 44 000 and 220 000 plants ha^{-1} respectively. The intercrop composition was based on the replacement design (Snaydon, 1991) in which total population of intercrop components were half of their sole crops. Topdressing fertilizer was split applied at a rate of 150 and 125 kg ha^{-1} at 3 and 6 WACE respectively giving a total ammonium nitrate application rate of 275 kg ha^{-1}. Standard management practices for maize and bean production were followed.

Table 2. Cropping systems and maize-bean intercrop spatial patterns.

Treatment description	Maize spacing	Bean spacing
1. Row intercrop: (maize & bean in same row)	0.9m x 0.5m	0.9m x 0.10m
2. Alternate: (bean rows between maize rows)	0.9m x 0.5m	0.9m x 0.10m
3. Row & inter-row: (bean rows on both maize rows & inter-rows)	0.9m x 0.5m	0.45m x 0.20m
4. Random or mixed (no distinct rows)	80 maize seed (22.5 m^{-2}) target after thinning 50 plants	300 bean seed (22.5 m^{-2}) target after thinning 250 plants
5. Sole Maize	0.9m x 0.25m	Nil
6. Sole Bean	Nil	0.45m x 0.10m

Data collection and analysis

Weed species density and above ground biomass

Prior to each weeding at 3 and 6 WACE weed density (counts m^{-2}) and biomass (grams m^{-2}) were determined. Weed species density was measured by randomly throwing five quadrants measuring 0.3m x 0.3m into each plot; weeds were identified, counted and recorded by species. There after, weeds were cut at ground level, packed in khaki papers, oven dried at 70^{o} C for 48 hours and weighed to determine their biomass (grams m^{-2}). Weed smothering efficiency (WSE) was calculated using the formula:

WSE % = (WDwt in monocrop – WDwt in intercrop pattern) x 100

WDwt in monocrop

Where, WDwt is weed dry weight.

Photosythetically Active Radiation (PAR) and Leaf Area Index (LAI)

This was measured at 4 and 8 WACE. Percentage radiation interception (% RI) was calculated by subtracting (top reading minus bottom reading divided by top reading multiplied by 100. Mean data for two seasons is presented in this report. Readings were collected on a sunny day between 1200-1400hours. AccuPAR ceptometer model LP80 was used to measure above plant canopy and ground level from three positions of each (centre of crop rows and adjacent to crop row) within net plot. Mean PAR readings for top, bottom and LAI were all obtained from the meter.

Maize and bean grain yield

After physiological maturity, maize and bean plants were harvested from net plot 5.4 m^2 i.e. three central rows (2.7m x 2m). The cobs were sun dried in perforated harvesting bags, hand shelled and grain was weighed using a digital scale. The grain moisture content for each treatment was determined using Delmhorst G.7 moisture meter and maize yield for each treatment adjusted to 12.5% moisture content. A random sample of five maize cobs was selected from each treatment and cob length, number of rows ear^{-1}, number of grain ear^{-1} and weight 1000^{-1} seed were recorded. Likewise five bean plants were also randomly selected from each treatment to record number of pods $plant^{-1}$, seed pod^{-1} and weight 1000^{-1} seeds. Bean grain yield was adjusted to 11% moisture content before statistical analysis

Data analysis

Weed density (m^{-2}) data was transformed before statistical analysis (Steel and Torrie, 1984). Maize, bean yield and weed biomass were analysed (ANOVA) using Minitab version 16 statistical package and and means separated using + standard error of the difference when the F test showed significant treatment effect at P < 0.05**.**

Land equivalent ratio

LER compares yields from intercrop that is maize and bean with yields from growing the same crops as pure stands. LER = 1, means intercrop performance is the same as sole/pure crop performance. LER > 1 means intercrop performance is higher than sole crop performance and LER < 1 means intercrop performance is lower than sole crop performance.

LER = intercrop 1 + intercrop 2 sole crop 1 sole crop 2

Pearson correlation coefficient (Pearson's r)

Linear correlations (Pearson r) was determined from the mean data on weed biomass maize and bean yield variables to determine relationship which influence yield of intercrop of companion crops and weed dynamics.

RESULTS

Weed density

Twenty weed species were present on trial site. The site was dominated by broad leaf weeds (fifteen species) followed by grasses (four species) and sedge (one specie). Weed density m^{-2} was significantly (P< 0.05) affected by the intercrop spatial patterns and cropping systems (Table 3). At 6 WACE intercrop spatial patterns and cropping systems significantly (P=0.002) affected the weed species density in both seasons (Table 3). Mean transformed weed density for two seasons showed elevated weed density m^{-2} in sole maize (20 weeds m^{-2}) and random intercrop (19.39 weeds m^{-2}). Lower weed density was found in spatial patterns that had bean plants planted on both intra and inter maize rows (10.40 weed m^{-2}) and sole bean (12.36 weed m^{-2}) treatments (Table 3). However, at 3 WACE both cropping systems and intercrop spatial patterns did not significantly (P< 0.05) affect weed density.

Table 3. The effect of cropping system and intercrop spatial pattern on weed density (number m^{-2}).

Treatment	2013-14 season		2014-15 season		Mean for two seasons	
	3 WACE	6 WACE	3 WACE	6 WACE	3 WACE	6 WACE
1. Intra-row intercrop	23.92	21.59[b]	26.56	12.63[b]	25.24	17.11[b]
2. Alternate intercrop	20.10	18.88[c]	27.28	10.87[c]	23.69	14.87[c]
3. Both (intra & inter row)	18.48	13.00[e]	23.24	7.80[d]	20.86	10.40[d]
4. Random (mixed)	26.45	24.42[a]	24.84	14.36[a]	25.65	19.39[a]
5. Sole maize	22.57	25.88[a]	24.82	15.20[a]	23.70	20.84[a]
6. Sole bean	16.53	15.85[d]	24.24	8.86[d]	20.51	12.36[c]
P value	0.076	0.002**	0.800	0.001***	0.320	0.001***
+ S.e.d	ns	2.49	ns	1.44	ns	1.95
CV (%)	18.16	15.28	14.95	15.22	13.99	15.14

Same column means with different letters differ significantly at (P<0.05). * P <0.05; ** P<0.01; *** P <0.001; ns, not significant at P<0.05

Weed biomass

Weed biomass (g. m^{-2}) was significantly (P< 0.05) affected by cropping system and intercrop spatial pattern. Sole maize consistently had higher weed biomass across the periods of measurements than intercrop. Mean weed biomass for two seasons (Figure 2) showed that at 3 WACE, sole maize had the highest biomass (79.51 g. m^{-2}) which was not different from random (64.38 g. m^{-2}) and within row (intra-row) intercrop (76.42 g. m^{-2}). This was followed by sole bean (47.38 g. m^{-2}). Lowest weed biomass was recorded in alternate row intercrop and both (bean seed planted on both intra and inter maize rows) (32.96 & 32.84 g. m^{-2}) respectively. A similar trend was also recorded at 6 WACE with sole maize recording the highest biomass (89.26 g. m^{-2}) and lowest biomass recorded in intercrop spatial pattern, alternate row intercrop (21.19 g. m^{-2}) and spatial pattern with bean plants on both (within and inter maize rows) (5.26 g. m^{-2}).

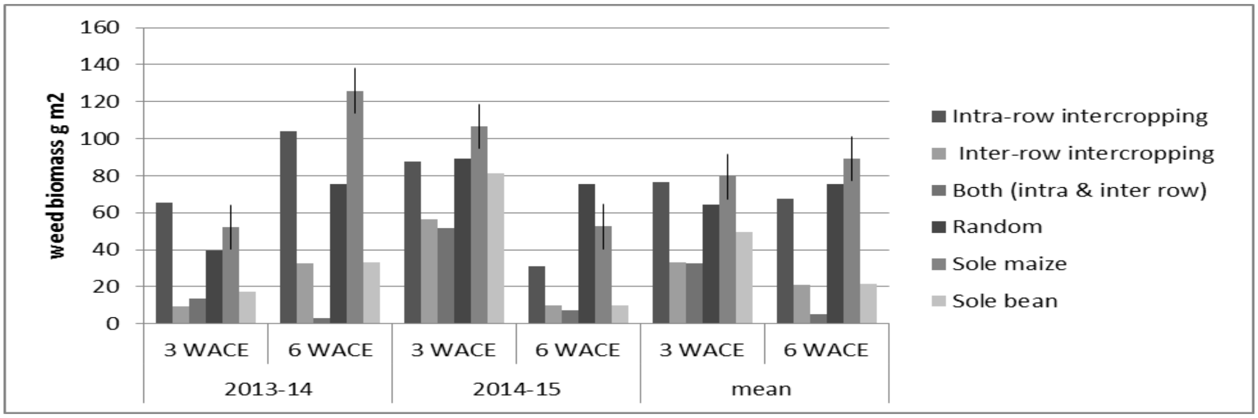

Figure 2. Mean weed biomass (grams m-2) at 3 and 6 WACE for 2013-14 and 2014-15 season.

Photosythetically Active Radiation (PAR) umol $m^{-2}s^{-1}$and leaf area index (LAI)

Radiation interception (RI) umol $m^{-2}s^{-1}$ and LAI was significantly (P< 0.05) affected by cropping systems and intercrop spatial patterns (Table 4). At 4 and 8 WACE, random, alternate and both (bean seed planted on both intra and inter maize rows) spatial patterns showed highest RI within the crop canopies and LAI followed by intra-row intercrop and sole bean. The lowest RI and LAI were found in sole maize. However, at 4 WACE RI was not significantly influenced by cropping system and spatial pattern (Table 4).

Table 4. The effect of intercrop spatial pattern on Photosythetically Active Radiation (PAR) umol $m^{-2}s^{-1}$and leaf area index (LAI)

	PAR and LAI measurements 4 WACE			PAR and LAI measurements 8 WACE		
	PAR umol $m^{-2}s^{-1}$		LAI	PAR umol $m^{-2}s^{-1}$		LAI
	Bottom	% RI	LAI	Bottom	% RI	LAI
1. Intra-row intercrop	429.7^{b}	66.44	1.177^{bc}	506.0^{b}	73.99^{b}	2.13^{c}
2. Alternate intercrop	355.3^{b}	65.77	1.340^{b}	397.7^{c}	77.55^{b}	2.61^{b}
3. Both (intra & inter row)	387.3^{b}	69.12	1.210^{bc}	353.3^{c}	83.22^{a}	3.01^{a}
4. Random (mixed)	172.0^{c}	77.68	2.540^{a}	326.0^{c}	85.85^{a}	3.25^{a}
5. Sole maize	525.0^{a}	61.35	0.68^{d}	752.0^{a}	65.75^{c}	1.81^{c}
6. Sole bean	329.3^{b}	71.40	1.570^{b}	511.0^{b}	72.88^{b}	2.79^{b}
P value	0.02*	0.079	0.001***	0.003**	0.003	0.036*
+ S.e.d	82.49	ns	0.25	84.85	4.77	0.41
CV (%)	27.56	7.32	21.61	21.90	7.72	19.44

Means in the same column followed by different letters differ significantly (P<0.05) * P <0.05; ** P<0.01; *** P <0.001; ns, not significant at P<0.05 PAR (Photosythetically active radiation), LAI (leave area index), %RI (percentage radiation interception)

Bean yields

Bean grain yield and yield parameters were significantly (P<0.05) affected by cropping systems and intercrop spatial patterns (Table 5). Mean pod numbers $plant^{-1}$ for the two seasons was significantly (P< 0.001) affected by cropping system and intercrop spatial patterns (Table 5). High mean pod numbers $plant^{-1}$ were observed in sole bean treatment followed by intercrop spatial pattern, while bean plants planted on both intra & inter maize rows had similar pod numbers like the alternate row intercrop. The lowest number of pods $plant^{-1}$ was recorded in random or mixed intercrop and intra-row intercrop treatment (Table 5). Cropping system and intercrop spatial pattern had no effect (P< 0.05) on mean seed numbers pod^{-1} and mean weight 1000^{-1} seed at 11% moisture content. Mean bean yield for two seasons was significantly (P< 0.001) affected by cropping systems and intercrop spatial patterns (Table 5). Higher bean yield was recorded in sole treatment (1.972 t ha^{-1}) followed by intercrop spatial patterns, alternate row, intra-row and bean plants planted in both intra and inter maize rows. The lowest bean yield was recorded in mixed or random spatial pattern (0.750 t ha^{-1}). Land equivalent ratio for three intercrop spatial pattern was above 1.0 (Table 5) meaning that the intercrop spatial patterns outperformed sole crops. The only intercrop spatial pattern with LER 0.718 was mixed or random intercrop meaning sole crops performed better than this spatial intercrop.

Table 5. Effect of spatial pattern on bean grain yield, yield parameters and LER for 2013-14 and 2014-15 seasons

Treatment	Mean pods $plant^{-1}$	Mean seed pod^{-1}	Mean weight grams 1000^{-1} at 11% mc	Mean yield (t. ha^{-1}) at 11% mc	Land Equivalent ratio (LER)
1. Intra-row intercrop	11.67[c]	4.68	283.21	1.046[b]	1.138[a]
2. Alternate intercrop	12.80[c]	4.66	237.33	1.063[b]	1.251[a]
3. Both (intra & inter row)	17.73[b]	5.04	278.32	0.968[c]	1.142[a]
4. Random (mixed)	12.07[c]	4.82	275.73	0.750[d]	0.718[b]
5. Sole bean	26.87[a]	5.12	328.75	1.972[a]	-
P value	0.001***	0.399	0.314	0.001***	0.032*
+ S.e.d	2.37	ns	ns	0.10	0.15
CV (%)	17.87	7.03	17.18	10.60	20.77

Same column means with different letters differ significantly at (P<0.05). * P <0.05; ** P<0.01; *** P <0.001; ns, not significant at P<0.05

Maize yields

Maize yield and yield parameters were significantly (P< 0.05) affected by cropping systems and intercrop spatial patterns (Table 6). Maize cob length was significantly (P< 0.01) affected by cropping systems and intercrop spatial patterns. Sole maize had the highest cob length followed by three intercrop spatial pattern alternate rows, intrarow and intercrop pattern with bean seed planted in both intra and inter maize rows which were not significantly different (Table 6). The lowest cob length was recorded in the random intercrop treatment. Mean number of rows cob^{-1}, kernels cob^{-1} and maize grain weight 1000^{-1} seeds were not significantly (P< 0.05) affected by cropping system and intercrop spatial pattern. Mean maize grain yield tonnes ha^{-1} was significantly (P< 0.01) affected by cropping system and intercrop spatial pattern. Sole maize gave highest maize grain yield (8.431t ha^{-1}) followed by three spatial patterns inter-row intercrop (5.599t ha^{-1}), both (intra and inter row) intercrop (5.378t ha^{-1}) and intra-row intercrop (5.024t ha^{-1}) which were not significantly different. Lowest maize grain yield was recorded in random intercrop (2.665 t ha^{-1}) treatment.

Table 6. Effect of spatial pattern on maize grain yield and yield parameters for 2013-14 and 2014-15 seasons

Treatment	Mean cob length (cm)	Mean number of rows cob^{-1}	Mean number of kernels cob^{-1}	Weight of 1000 seed @ 12.5% mc	Maize yield tonnes ha^{-1} @12.5% mc
1. Intra-row intercrop	17.73[a]	13.26	488.2	301.53	5.024[b]
2. Inter-row intercrop	18.07[a]	13.86	523.67	300.51	5.599[b]
3. Both (intra & inter row)	16.77[bc]	13.60	456.53	306.91	5.378[b]
4. Random (mixed)	15.39[c]	12.80	431.40	319.02	2.665[c]
5. Sole Maize	18.73[a]	13.53	528.13	323.24	8.431[a]
P value	0.007**	0.257	0.164	0.952	0.002**
+ S.e.d	0.71	ns	ns	ns	0.93
CV (%)	4.99	4.17	10.48	14.23	21.03

Same column mean with different letters differ significantly at (P<0.05). * P <0.05; ** P<0.01; *** P <0.001; ns, not significant at P<0.05

Pearson correlation coefficient (Pearson's r) for selected variables

Pearson's correlation coefficient (Pearson's r) was significant (P<0.05). Positive correlations (Table 7) were found in the following variables: bean yield ~ PAR, maize yield ~ PAR and maize yield ~ LAI, and negative correlation observed between PAR and LAI. However, weed biomass and weed density, bean yield, maize yield, PAR and LAI. Weed density with bean yield, maize yield, PAR and LAI and bean yield and LAI were not significantly (P< 0.05) correlated.

Table 7. Linear correlation (Pearson r) among variables weed biomass, weed density, maize yield, bean yield, PAR and LAI.

	Weed biomass	Weed density	Bean yield	Maize yield	PAR	LAI
Weed biomass	0	x	X	x	x	X
Weed density	0.83 ns	0	X	x	x	X
Bean yield	-0.31 ns	0.47 ns	0	x	x	X
Maize yield	-0.54 ns	0.14 ns	0.93*	0	x	X
PAR	-0.21 ns	0.36 ns	0.94*	0.93*	0	X
LAI	0.29 ns	-0.15 ns	-0.83 ns	0.92*	-0.96*	X

*significant at P<0.05, **significant at 0.01, ns not significant

DISCUSSION

Weed density and Biomass

Weed density was influenced by cropping system and intercrop spatial pattern. Sole maize and intra-row maize-bean spatial pattern recorded higher weed densities than other spatial patterns primarily because of wider row spacing. As observed by Orluchukwu & Udensi (2013) high weed densities in sole maize plots were attributed to wider row and sparse canopy which encourages weed growth and development. These results were similar to what was recorded in this study. High weed populations exhibited in this study may have been due to low radiation interception (RI). Sole crop canopies had a mean RI of 59 % compared 74% in intercrop spatial canopies. Henrik et al. (2003) reported that intercrop reduced weed density and biomass compared to sole cropping probably due to smothering of weeds by denying them light. Iqbal et al. (2007) found out that soyabean-sesame and sorghum-cotton significantly decreased weed density and biomass due to radiation interception. Low weed density in intercrop system and more so inter-row (alternate) and both (intra and inter maize row) clearly showed advantages of dense canopy in covering of soil surface by companion crops with different leaf shapes and crop height. Results showed high LAI in intercrop systems compared to sole crop. At 4 WACE, mean LAI for various intercrop spatial patterns was 1.56 compared to 1.13 for sole crops maize. Correspondingly at 8 WACE mean LAI for intercrops was higher 2.75 compared to 2.3 for sole crop. The increase in LAI translate into high RI and decrease amount of light reaching the surface therefore depriving photoblastic weeds of the much needed light for germination and development. The findings are similar to those observed by (Agahiu et al., 2011) on effectiveness of intercrop system in reducing weed density as a result of high RI and possible interference from component crops in addition to ground cover effect. Similarly Tsub et al. (2001) reported high RI. in maize-bean intercrop compared to sole crop resulting in high shading, reduction in soil temperature and micro-climate within the crop canopy thereby affecting weed germination and dynamism of late emerging weeds.

Weed biomass in intercrop system was lower than sole maize crop for similar reasons, this observation is similar to findings by Eskandari and Ghanbari (2010) who reported reduced dry weed biomass in intercrop systems compared to sole crop. Following first weeding at 6 WACE results showed weed smothering efficiency of 76.90% from both (intra and inter maize row intercrop), 67.48% from inter-row (alternate) compared to 16.85% and 14.52% for random (mixed) and intra-row intercrop respectively. This was contrary to findings by Orluchukwu & Udensi (2013) who reported higher weed smothering efficiency in random (mixed) intercrop. Results from the current study however, clearly show that intercrop spatial pattern greatly influence the ability of the crop to smother late emerging weeds after the first weeding with closer spatial pattern having a higher smothering efficiency than wider spatial pattern and random pattern. Likewise Maereka et al. (2009) reported a reduction in weed pressure in maize-pumpkin intercrop because of reduced resource consumption by weeds. Orluchukwu & Udensi (2013) further highlighted that the morphological and physiological differences among companion crops occupy different niches and thus cause more efficient utilization of natural resources by intercrop stands compared to pure (sole) stands.

Grain yield

Cropping system and intercrop spatial pattern affected both maize and bean grain yield. Pure stand gave higher grain yield e.g. maize (8.43 t ha^{-1}) and bean 1.97 t ha^{-1} compared to intercrop (Table 4 and 5). In intercrop maize grain yield reduction of between 33 – 40% of the sole crop was recorded from intra-row, inter-row and both (intra and inter-maize row). Random (mixed) intercrop showed highest maize grain yield reduction of 68% compared to sole maize crop. The cause to such reduction in companion crop yield is reduced companion crop population and competition for limiting resource especially moisture due to dry spell (Mutungamiri et al., 2001). Our results also showed that bean grain yield was influenced by cropping system and intercrop spatial pattern. Similarly bean yield from intercrop system was lower than pure stands. Bean plants are of lower stature than maize and are likely to suffer from maize shading effect. More so under dry spell conditions like those experienced during 2014-15 season, intercrop stands showed visual signs of moisture stress more than pure stands suggesting competition for moisture in such treatments. Our results also showed that spatial pattern influenced bean yield with random treatments showing 61% lower than sole bean yield and other spatial pattern between 47% - 51% compared to sole crop. However, despite yield reduction of companion crops the overall intercrop performance was higher than sole or pure stands.

Cropping system productivity

Despite reduction of maize and bean component crops in intercrops, the overall land equivalent ratio (LER) for this cropping system was higher than sole crops. Land utilization efficiency of intercrop patterns measured by LER values of intercrops was higher than 1.0 in all spatial patterns except the random pattern which had (0.718). LER of greater than one (LER>1.0) has been reported in various maize intercrop (Yilmaz et al., 2007). Intercrop spatial pattern influenced the LER with highest LER of 1.25 recorded in inter-row (alternate) compared to lowest LER of 0.72 in random (mixed) spatial pattern suggesting that sole cropping is superior when one uses mixed spatial pattern.

CONCLUSION

This study has demonstrated that cropping system and intercrop spatial pattern significantly affected grain yield of companion crops, productivity, weed density at 6 WACE and biomass. Despite high grain yield of sole crops compared to intercrop companion crops, the overall performance showed higher productivity LER>1.0 in intercrop compared to sole crop. Intercrop spatial pattern showed increased light interception by crop canopies and a reduction in weed density and biomass. High RI was recorded in spatial patterns with closer spacing's i.e. random, alternate, and both (intra and inter maize row) intercrop resulting in low weed biomass and density after the first weeding at 3WACE. It can therefore be concluded that intercrop spatial patterns reduce weed density biomass and dynamism after the first manual weeding of an intercrop system.

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