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Effect of Sowing Dates on Performance of Pepper and Cowpea in a Pineapple-based Intercropping System

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Authors' contributions

This work was carried out in collaboration between all authors. Authors AJA, SOA and OPA designed the study. Authors AJA and SOA performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors SOA and OPA managed the analyses of the study. Authors AJA and OPA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The effects of time of sowing cowpea into pineapple-pepper intercrop on growth and yields of cowpea and pepper in a pineapple-pepper intercropping system was investigated during the rainy and late seasons of 2011 and 2012 in Akure, a humid rainforest zone of Nigeria. The additive series of intercropping experiments were laid out in a randomised complete block design with three replications. Experimental treatments were based on varying time of sowing cowpea at three weeks intervals into pineapple-pepper intercrop in addition to the sole crop components. In the rainy-season planting, cowpea seed yields declined significantly by 80% with delayed sowing (at 6 and nine weeks) into the intercrop. In the late-season, cowpea seed yields dropped by over 50% with delayed planting. Pepper fruit yields also declined by 95% when cowpea was sown at the time of transplanting pepper in both the rainy and late season experiments. Cowpea yield components declined with delayed sowing while pepper yield components increased possibly via enhanced competition between pepper and cowpea. Sowing cowpea at the time of transplanting pepper

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lowered pineapple fruit yield. Land equivalent ratio values were more significant than one (>1) for all species mixtures indicating enhanced returns and complementarities among component crops.

Keywords: Intercrop; additive series; resource utilisation; competition; cropping season.

1. INTRODUCTION

Intercropping has been associated with several advantages such as higher yield stability, the variability of food supplies, increased return per unit area, a spread of labour and income and reduced dependency on one crop or diversified production [1,2,3]. Intercropping also ensures efficient resource utilisation and reduced the risk to the environment [4,5]. However, the efficiency of growth resources utilisation is a determinant of the success regarding the productivity of intercropping system [6]. The availability and optimisation of use efficiencies of resources also depend on the choice of component crops in an intercropping system. The choice of component crops, on the other hand, depends on the agro-ecological zones, preference of the grower and ability to complete growth cycle [7,8].

Pineapple is a long gestation crop which takes about 18 months from planting to fruit harvest. Initial slow growth characterises it during the establishment phase.

The lack of immediate returns on investment in the first year of cropping and challenges associated with management of the wide.

Spaces between the rows of pineapple pose severe problems to farmers. The single crop of pineapple may not efficiently use the growth resources (light, water, and nutrient) during its early growth stage due to initial slow growth and development. Poor capture and use efficiency of resources (water, radiation, and space) characterised establishment and senescence stage of the single crop [9]. The lost time to growth or resource lost during this step depends on the rate of growth and establishment of the plant. The use of agronomic practices can be useful in shortening this period to increase capture and efficiency in the use of resources [9,10,11]. Thus, the utilisation of the resources within the wide spacing of pineapple rows during the early growth phase can be achieved through intercropping. Complimentary use of support among component crops in the intercropping arrangement may result from differences in spatial and temporal use of environmental resources [12].

Intercropping pineapple with short duration food crops such as pepper (*Capsicum* spp), with upright growth habit and cowpea (*Vigna unguiculata*), may enhance the efficiency of resource use, provide food and income for the farmer, diversify production, and reduce dependency on one crop, and spread labour and income. Combination of specific crops may result in increased competition (for water, nutrients, light or combination of any of the three) among component crops with the resultant reduction in yield variables [13]. The intensity of competition for growth resources among the intercrop components could be ameliorated through the judicious use of crop sequence and time management for better utilisation of land and enhanced crop productivity. The performance of component crops in intercropping is influenced by time of planting, planting pattern and compatibility of component crops [14]. The stage of growth of the various intercrop component crops will enhance their competitive advantage; hence, it is imperative to determine the appropriate time to sow cowpea into the pineapple-pepper based intercropping system to minimise competition. A study of seasonal responses of pepper and cowpea growth and yields in a pineapple-pepper-cowpea intercropping system is thus essential. This study aims to determine the effects of time of sowing cowpea into pineapple-pepper intercrops on growth and yields of cowpea and pepper in the pineapple intercropping system under contrasting seasonal weather conditions.

2. MATERIALS AND METHODS

Two experiments were conducted in the rainy and late season of 2011 and 2012 at two locations in Akure (Lat: 7º14'N and long: 5º11'E), a humid rainforest zone of Nigeria. The meteorological data revealed a double peak of rainfall (bimodal distribution) of the area with the highest rainfall recorded in 2012 (Table 1). The composite analysis of samples of soil at the experimental sites is presented in Table 2. The soil pH of site 1 (FECA) in 2011 is slightly acidic.

The soil organic matter (SOM) content (14.8 g/kg) is low and is lower than the critical SOM content (< 20 g/kg). Nitrogen (N) content of the soil also falls below 1.5 g/kg critical value classified as low. The available phosphorus (P) fall within the medium range (8-20 mg/kg) of critical P and the exchangeable potassium (K) fall within the critical range (0.2 cm/kg) classed as low. The soil at FUTA experimental site in 2011 is slightly acidic with SOM content within the critical range (20-30 g/kg) classed as medium. The N content is high and greater than critical range (2.0 g/kg) while available P is low (value less than 8 mg/kg critical value of P for low class). The K content falls within the critical range (0.4 cm/kg) classified as high. The soils of the experimental sites (FECA and FUTA) in 2012 were both slightly acidic and SOM contents fall within the medium range (20-30 g/kg). The N content of the soils was within the range classed as medium (1.5-2 g/kg), available P of the soils is high with the critical range (> 20 mg/kg) while exchangeable K falls within the range (0.30 cm/kg) classified as medium. The soils of the four experimental sites were sandy clay loam with the sand, silt and clay content range of 52-56%, 29-33% and 14-15%, respectively.

The rainy-season planting experiments of 2011 and 2012 were conducted at the Experimental Station of the Federal College of Agriculture, Akure (FECA), while the late-season planting experiments of 2011 and 2012 were conducted at the Teaching and Research Farm, Federal University of Technology, Akure which is about 12km away from the FECA experimental station.

2.1 Experimental Design

The experiments which were laid out as a randomized complete block design with three replications adopted the additive series of the intercropping system with pineapple as the main crop while pepper and cowpea constituted the minor intercrop components. Experimental treatments were based on varying time of sowing cowpea into pineapple-pepper intercrops at three-week intervals in addition to sole crop components (pineapple, pepper, and cowpea). Experiments conducted in the rainy seasons of 2011 and 2012 at the same location comprised of four dates of sowing cowpea into pineapple-pepper intercrops namely: sowing of cowpea at the time of transplanting pepper seedlings into pineapple, sowing at 3, 6 and 9 weeks after transplanting (WAT) pepper seedlings into pineapple, pineapple-pepper intercrop without cowpea and the sole crops of pineapple, pepper and cowpea. In the experiments conducted in the late seasons of 2011 and 2012 at another location, only two dates of sowing cowpea into pineapple-pepper intercrops at three-week intervals (sowing cowpea at the time of transplanting pepper seedlings into pineapple and sowing at 3 weeks after transplanting pepper seedlings into pineapple), pineapple-pepper intercrop without cowpea and sole crops of pineapple, pepper and cowpea were considered due to length of season. The population density of the main crop (pineapple) in the intercropped plots was maintained at 100% as in sole plot while the intercropped minor crops (pepper and cowpea) were planted at lower population densities of 54 and 62.5% of their sole crops.

2.2 Field Establishment

The crops were planted into experimental plots that measured 4 x 6 m. Cured suckers of smooth cayenne varieties of pineapple were planted using the double row system of planting pineapple at a spacing of 90 x 60 x 30 cm (60 cm between each double row; 30 cm within the rows and 90 cm between two double rows (Plate 1). The suckers were planted on 2nd and 18th May for 2011 and 2012 rainy season experiments respectively while suckers were planted on 18th and 29th August for the 2011 and 2012 late season experiments, respectively. Five-week old pepper seedlings were transplanted at 1 plant /stand into the rows of pineapple using an inter-row spacing of 60 cm. Pepper seedlings were transplanted into the wider spaces between two-double rows of pineapple while the spaces within double row were alternated for planting only pepper and cowpea (Fig. 1, Plate 2). Pepper seedlings were planted at 60 x 60 cm in the sole pepper plots.

Ife brown cultivar of cowpea characterized by semi-erect growth and intermediate maturity period was sown at two seeds per stand into the pineapple-pepper intercrops at 3-week interval starting with the simultaneous sowing of cowpea at the time of transplanting pepper into the pineapple. In the alley between two double rows, cowpea seeds were sown into the spaces between the transplanted pepper and the adjacent row of pineapple while cowpea sown into spaces within two rows of pineapple alternated with pepper were planted 50 cm apart. Sole cowpea plot was sown at a spacing of 75 x 25 cm. In 2011 rainy season experiment, cowpea seeds in the intercropped plots were sown on 9th

Table 1. Monthly rainfall at Akure during the period of the experiments

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total annual rainfall
Rainfall (mm)													
2011	3.2	87.0	49.6	66.9	133.6	128.3	190.5	197.4	230.0	204.0	45.0	0.0	1335.5
2012	13.8	64.8	56.8	115.6	131.0	229.7	192.0	164.9	303.3	214.5	69.2	42.0	1597.6
2013	43.6	52.9	141.8	182.7	168.3	154.7	168.4	67.2	210.9	160.5	154.8	40.7	1546.5

Table 2. Pre-cropping soil physical and chemical properties at federal college of agriculture Akure (FECA) and the federal university of technology, Akure (FUTA) in 2011 and 2012

	$pH(H_20)$	OM	N	Av. P	Exchangeable bases				Particle size analysis		
		----g/kg----		mg/kg	K	Na	Ca	Mg	Sand	Silt	Clay
					--------------cmol/kg-------------				-------------%-------------		
FECA 2011	5.13	14.80	1.00	15.33	0.12	0.10	1.60	1.20	56.00	30.00	14.00
FECA 2012	6.05	26.60	1.80	33.52	0.31	0.36	0.90	0.60	52.00	33.00	15.00
FUTA 2011	5.75	28.50	2.20	7.19	0.46	0.42	2.00	1.10	56.00	29.00	15.00
FUTA 2012	6.12	29.30	2.00	39.59	0.34	0.38	2.40	1.20	53.00	32.00	15.00

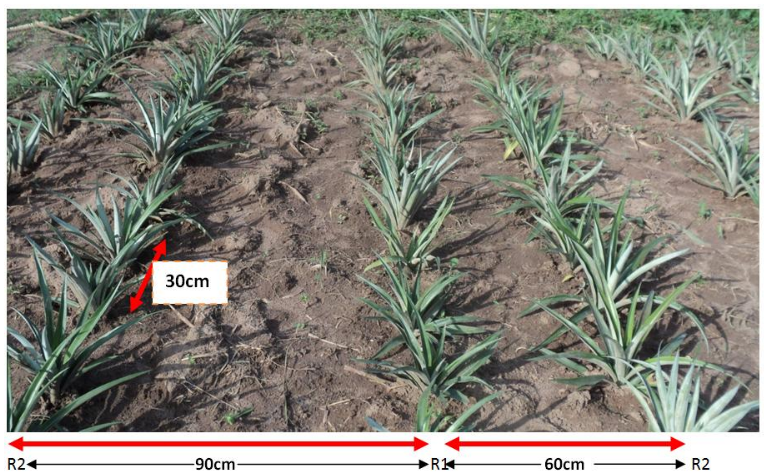

Plate 1. Double row system of planting pineapple

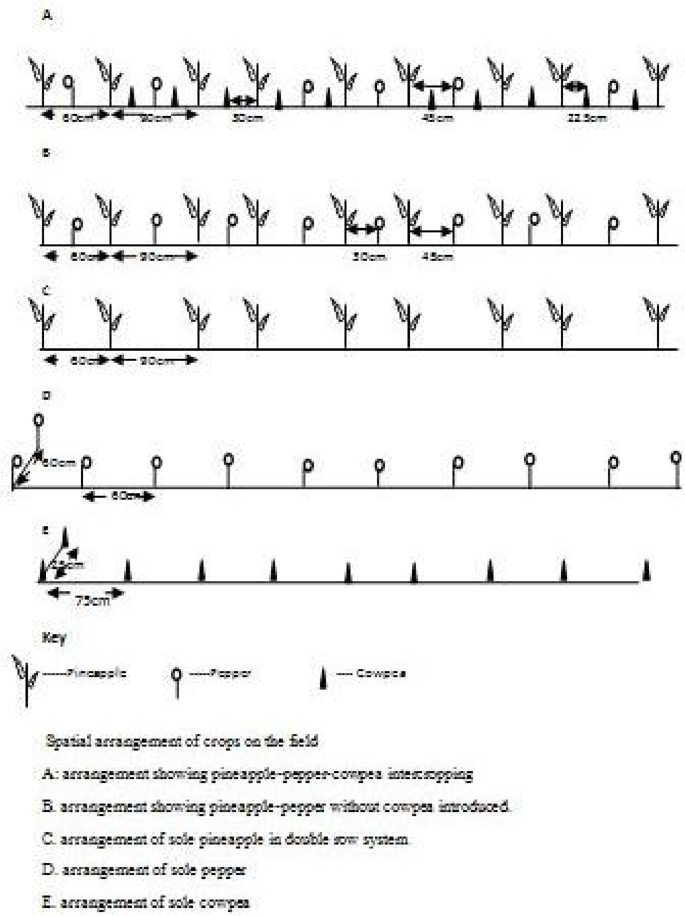

Fig. 1. Spatial arrangement of crops on the field

Plate 2. Growth and the physical arrangement of the plot with cowpea sown at the time transplanting of pepper. Annotation with the red dotted line indicated the location of pepper

and 31st May, 21st June and 2nd July 2011, respectively. During the 2012 rainy season experiment, cowpea seeds were sown into the intercropped plots on 19th May, 9th June, 30th June and 21st July respectively. Cowpea seeds in the intercropped plots were sown on 8th and 28th September 2011 and 10th August and 12th September 2012 for the late season experiment.

2.3 Data Collection

The growth parameters of pepper measured include number of days to 50% flowering, total plant leaf area at 50% flowering, the total dry weight of biomass. The total plant leaf area at 50% flowering was determined by destructive sampling of two plants per treatment. The leaves were separated and measured with the leaf area meter (Delta-T windies 3 version 3.1 model). At maturity, cowpea yield component measured were a number of pods per plant, the weight of pods per plant, the weight of seeds per pod, the weight of seed per plant and seed yield. For pepper, at maturity number and weight of fruits per plant, cumulative number and weight of fruits per plant and fruit yield were measured. Pineapple growth was assessed through a destructive sampling of two samples per treatment for biomass accumulation after intercropping phase. Data collected were subjected to analysis of variance using Statistical Analysis System version 9 [15]. Means were separated using Tukey's Honestly Significant Difference (HSD) test at 5% probability level. Combined analysis appropriate for a randomized complete block design was conducted separately for the rainy season and late season experiments due to an unequal number of sowing dates. Thus the seasonal effects were not analyzed.

3. RESULTS

3.1 Yield Response of Cowpea

Significant yield decline was recorded in values of cowpea yield components with its delayed sowing (Table 3). The yield components declined with the delayed sowing of cowpea. Sowing date x year interaction was significant for cowpea yield components during the rainy season. In the late season experiments, significantly higher cowpea yield components were recorded in 2011 when sown at the time of pepper transplanting (Table 4). The cowpea seed yield also reduced significantly with delayed sowing.

3.2 Growth and Yield Response of Pepper

The total plant leaf area of pepper at 50% flowering was significantly influenced by time of sowing cowpea in 2011 rainy season (Table 5). The number of days to 50% flowering in pepper was significantly prolonged when cowpea was sown at the time of transplanting pepper into pineapple in the rainy season of 2011. However, the number of days to 50% flowering was not significantly influenced in the late season experiments. The dry biomass and yield components of pepper were significantly reduced by early sowing cowpea into pineapple-pepper intercrop during the rainy season (Table 5). Sowing date x year interaction was significant for total plant leaf area, days to 50% flowering, number and weight of fruits per plant. The growth indicators (total plant leaf area and pepper dry biomass) and yield components were significantly influenced by sowing date in the dry season experiments (Table 6). The weight of fruit per plant in the late season experiments was imparted significantly by sowing date although, the sowing date x year interaction was not significant. There was the absence of significant effect of sowing date on a number of days to 50 % flowering in pepper.

3.3 Growth and Yield Response of Pineapple

The effect of sowing time was not significant on pineapple total plant biomass (dry weight) (Tables 7 and 8). The weight of pineapple fruit was significantly reduced when cowpea was sown at the time of transplanting pepper into pineapple in the rainy season of 2011. Delayed sowing of cowpea into pineapple-pepper intercrop by 3 to 9 weeks resulted in up to 280% increase in weight of pineapple fruit. However, the effect of sowing time was not significant in the rainy season of 2012 (Table 7). The weight of pineapple fruit was only significantly reduced when cowpea was sown at the time of transplanting pepper into pineapple in the late season of 2012 (Table 8).

3.4 Relative Yield and Relative Yield Components

In the rainy season experiments, significantly higher relative yield (RY) was only obtained when cowpea was sown at the time of transplanting pepper into pineapple. The time of sowing x year interaction was significant in cowpea for relative yield (Table 9). Significantly lower RY was obtained with early introduction of cowpea into the pineapple-pepper intercrop especially when cowpea was sown at the time of transplanting pepper. However, the time of sowing x year interaction was not significant for the pepper relative yield. The RY for pineapple and the relative yield total (RYT) also known as a land equivalent ratio (LER) which is an indication

Table 3. Effect of time of sowing cowpea into pineapple-pepper intercrops on cowpea growth and yield characters (rainy season crop)

Treatments	Number of pods per plant		Weight of seeds per pod (g/pod)		Weight of pods per plant (g/plant)		Weight of seeds per plant (g/plant)	
	2011	2012	2011	2012	2011	2012	2011	2012
Cowpea sown @ 0WAT	19.32a	10.84a	1.05a	0.95b	26.08a	13.40a	20.44a	10.56a
Cowpea sown @ 3WAT	13.74a	11.84a	0.96a	0.93b	16.28ab	14.57a	13.25ab	11.00a
Cowpea sown @ 6WAT	5.08b	8.63a	0.73a	1.20ab	4.97b	12.14a	3.72b	10.01a
Cowpea sown @ 9WAT	4.92b	8.67a	0.76a	1.43a	5.05b	15.42a	3.74b	12.38a
Sole cowpea	14.10a	9.66a	0.86a	0.86b	15.86ab	10.43a	12.21ab	8.32a
Time of sowing * year interaction	*		*		*		*	

Means with the same letter(s) within column and season are not significantly different (P=0.05)
*WAT = Weeks after transplanting; ns = not significant; * = significant*

Table 4. Effect of time of sowing cowpea into pineapple-pepper intercrops on cowpea growth and yield characters (late season crop)

Treatments	Number of pods per plant		Weight of seeds per pod (g/pod)		Weight of pods per plant (g/plant)		Weight of seeds per plant (g/plant)	
	2011	2012	2011	2012	2011	2012	2011	2012
Cowpea sown @ 0WAT	27.81a	23.65a	0.88a	0.99a	31.98a	27.81a	24.79a	23.03a
Cowpea sown @ 3WAT	12.99b	16.19a	0.51a	0.88a	11.83b	27.85a	7.36b	14.53a
Sole cowpea	12.47b	13.53a	0.78a	0.96a	13.50b	16.78a	10.38b	13.07a
Time of sowing * year interaction	ns		ns		ns		ns	

Means with the same letter(s) within column and season are not significantly different (P=0.05)
WAT = Weeks after transplanting; ns = not significant

Table 5. Effect of time of introducing cowpea into pineapple-pepper intercrops on growth and yield characters of pepper (rainy season crop)

Treatments	Total plant leaf area @ 50% flowering (m^2)		Days to 50% flowering (DAT)		Pepper dry biomass (g/plant)		Number of fruits/plant		Weight of fruit/plant (g/plant)	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Cowpea sown @ 0WAT*	0.05b	0.08a	118.67a	59.00a	10.67b	4.53b	3.57c	1.77b	27.57c	10.33a
Cowpea sown @ 3WAT	0.40b	0.18a	55.33b	61.33a	22.13ab	8.80ab	7.97bc	2.53b	71.03bc	15.42a
Cowpea sown @ 6WAT	1.14ab	0.17a	57.00b	58.00a	21.80ab	7.47ab	14.47ab	10.83ab	103.73bc	69.52a
Cowpea sown @ 9WAT	1.05ab	0.14a	57.67b	67.33a	26.03ab	8.83ab	24.07ab	16.73a	208.80ab	112.27a
Pineapple-pepper intercrop	1.81a	0.20a	54.33b	57.33a	40.90a	8.90ab	35.68a	10.67ab	257.1a	72.60a
Sole pepper	2.01a	0.21a	51.67b	58.00a	42.90a	11.63a	37.35a	16.97a	275.73a	98.06a
Time of sowing * year interaction	*		*		*		*		*	

Means with the same letter(s) within column and season are not significantly different (P= 0.05)
*WAT = Weeks after transplanting; * = significant*

Table 6. Effect of time of introducing cowpea into pineapple-pepper intercrops on growth and yield characters of pepper (late season crop)

Treatments	Total plant leaf area @ 50% flowering (m^2)		Pepper dry biomass (g/plant)		Number of fruits/plant		Weight of fruit/plant (g/plant)	
	2011	2012	2011	2012	2011	2012	2011	2012
Cowpea sown @ 0WAT	0.12b	0.07a	9.70b	5.47b	5.90c	18.63c	18.80b	73.61c
Cowpea sown @ 3WAT	0.63a	0.12a	34.28ab	8.57ab	8.63bc	45.10b	43.20a	181.08b
Pineapple-pepper Intercrop	0.43ab	0.15a	20.83ab	10.10ab	10.72b	72.23a	54.43a	249.43a
Sole pepper	0.66a	0.19a	43.77a	14.60a	18.22a	70.07a	72.89a	236.88ab
Time of sowing * year interaction	*		*		*		ns	

Means with the same letter(s) within column and season are not significantly different (P=0.05)
*WAT = Weeks after transplanting; ns = not significant; * = significant*

Table 7. Effect of time of introducing cowpea into pineapple-pepper intercrops on growth weight of pineapple (rainy season crop)

Treatments	Weight of dry plant biomass (g/plant)		Weight of fruit (kg/plant)	
	2011	2012	2011	2012
Cowpea sown @ 0WAT	22.37a	46.80a	0.33b	1.48a
Cowpea sown @ 3WAT	43.00a	58.53a	1.06ab	1.72a
Cowpea sown @ 6WAT	37.87a	67.90a	1.04ab	1.75a
Cowpea sown @ 9WAT	41.00a	75.58a	1.17a	1.48a
Pineapple-pepper intercrop	40.35a	70.93a	1.25a	1.91a
Sole pineapple	37.87a	85.88a	1.10a	1.93a
Time of sowing * year interaction	ns		ns	

Means with the same letter(s) within column and season are not significantly different (P=0.05)
WAT = Weeks after transplanting; ns = not significant

Table 8. Effect of time of introducing cowpea into pineapple-pepper intercrops on growth and weight of pineapple (late season crop)

Treatments	Dry weight of total biomass (g/plant)		Weight of whole fruit (kg/plant)	
	2011	2012	2011	2012
Cowpea sown @ 0WAT	25.98a	24.62a	1.60a	1.38b
Cowpea sown @ 3WAT	19.53a	28.17a	1.71a	1.87ab
Pineapple-pepper intercrop	29.10a	28.39a	1.76a	2.12a
Sole pineapple	29.35a	25.34a	1.79a	2.24a
Time of sowing * year interaction	ns		ns	

Means with the same letter(s) within column and season are not significantly different (P>0.05)
WAT = Weeks after transplanting; ns = not significant.

Table 9. Effect of time of introducing cowpea into pineapple-pepper intercrops on growth and yield characters of pepper (rainy season crop)

Treatments	Relative yield of cowpea		Relative yield of pepper	
	2011	2012	2011	2012
Cowpea sown @ 0WAT*	0.82a	0.74a	0.05b	0.07b
Cowpea sown @ 3WAT	0.62ab	0.87a	0.15ab	0.11b
Cowpea sown @ 6WAT	0.21b	0.79a	0.21ab	0.49a
Cowpea sown @ 9WAT	0.21b	0.89a	0.44a	0.77a
Pineapple-pepper intercrop	-	-	0.80a	0.66a
Time of sowing * year interaction	*		Ns	

Means with the same letter(s) within column and season are not significantly different (P=0.05)
*WAT = Weeks after transplanting; ns = not significant; * = significant*

of land utilization efficiency were not influenced significantly by time of sowing during the rainy season. Nevertheless, the time of sowing x year interaction was significant for cowpea and pineapple relative yield and the relative yield total.

In the late season experiments, significantly lower RY was recorded for pepper and pineapple in 2012. The relative yield totals were not significantly influenced by sowing date. The time of sowing x year interaction was not significant for the RY and RYT components in the late season (Table 10).

3.5 Effects on Soil Chemical Properties at Cowpea and Pepper Maturity

The results of the analysis of soil chemical properties at the maturity of cowpea and pepper showed no consistent pattern in the chemical properties (Tables 11 and 12). The properties were not significantly (P=0.05) influenced by the intercrop combinations in the rainy and late season experiments of 2011 and 2012 except for soil pH which was significant in the late season of 2012. A slight increase in soil pH was observed after the intercropping phase except at the rainy season of 2012 when soil pH declined slightly across the treatments below the initial soil pH. The soil organic matter (SOM) and nitrogen (N) increased slightly over the initial values except for sole cowpea where the reduction was observed. However, the SOM and N declined below the initial values in the rainy season of 2012. In the late season of 2011, the SOM and N also declined below the initial soil status except for sole cowpea. The soil phosphorus (P) content decline generally. However, the soil P increased above the initial P status. The soil cations also declined below the initial soil cations content except higher soil Magnesium and Sodium obtained in the rainy season of 2012.

4. DISCUSSION

The delay in sowing cowpea into pineapple-pepper intercrops during the rainy and late seasons reduced biomass accumulation in pepper. Sowing cowpea at the time of transplanting pepper into pineapple resulted in delayed flowering for pepper during 2011 rainy season planting possibly due to early suppression by vigorous cowpea biomass. However, delay in sowing cowpea into the intercrop enhanced pepper's competitive advantage over cowpea possibly in terms of peppers ability to capture growth resources (Plate S1 – S8). The early establishment of pepper seedlings could have enhanced the capture of growth resources, and thus competitive ability [4]. A few days' difference in sowing date could allow farmers to alter the competitive balance among intercropped species [16]. The stage of development of pepper at which cowpea was introduced can give an initial advantage in competition among intercropped species and determine the degree of compatibility. The weight of cowpea seed per plant and seed yield declined with the delayed sowing of cowpea. On the other hand, pepper biomass, total plant leaf area at 50% flowering, fruit yield and yield component of pepper increased with the delayed sowing of cowpea. The reduction in the growth and yield character of pepper when cowpea was sown early in the intercrop translated to low fruiting because of the reduced assimilate in the plant. Early introduction of okra gave significantly fewer pods and greater weight per pod than a simultaneous or late introduction into pawpaw [17]. However, cultural manipulation such as variation in time of planting can adjust the balance of intercrop yields and intercropping productivity is greater when the component crops differ markedly in growth duration so that their maximum requirements for growth resources occur at a different time [14]. Resource sharing and niche complementarity enable mixtures or polyculture to yield more than their corresponding monocultures [18,19] as niche complementarity allow maximal exploitation of light and soil resources between species with contrasting short and tall shoot architectures, or shallow and deep root architectures [20,21,22]. Functionally diverse species in plant communities tend to record higher biomass production due to complementary use of resources such as nutrient and water [23]. The pineapple yield reduction observed with sowing of cowpea at the time of transplanting pepper emanated from the decrease plant biomass in pineapple. This could be the effect of shading from intercrop components [24]. Biomass production in species diverse system yields 1.7 times more than monoculture [25]. The LER values greater than 1 indicated greater productivity per unit land area. Crop combinations yielded more than growing the same number of stands of each crop as sole crops due to complementary use resources [26]. The complementary use of resources tends to be better with delayed sowing of cowpea as a result of better establishment of pepper at the time of cowpea introduction thus giving better competitive ability to pepper plants. Intercropping advantage from productivity indices of okra-pawpaw mixture reported by [17] indicated better use of resources by mixture than monocrops. Improved utilization of plant growth resources with intercropping was reported by [20] and [27] when LER was greater than unity as in pea-barley and Persian walnut-wheat intercropping respectively. The increase observed in the SOM, and N in the rainy season of 2011 could be attributed to higher vegetative biomass obtained from the vigorous growth of cowpea and pepper and its subsequent addition to the soil as leaf fall and residual biomass which decay after crop maturity. The decline observed in SOM, and N in rainy and late seasons of 2012 could be as a result of lower vegetative biomass from cowpea and pepper coupled with the density of crops in the intercropped plots. Also, the decline in the soil cations could be due to higher plant uptake by the component crops.

Table 10. Effect of time of introducing cowpea into pineapple-pepper intercrops on growth and yield characters of pepper (rainy season crop)

Treatments	Relative yield of cowpea		Relative yield of pepper		Relative yield of pineapple		Relative yield total	
	2011	2012	2011	2012	2011	2012	2011	2012
Cowpea sown @ 0WAT*	1.30a	1.01a	0.11a	0.14b	0.79a	0.61b	2.21a	1.76a
Cowpea sown @ 3WAT	0.51a	0.45a	0.48a	0.41ab	0.87a	0.81ab	1.87a	1.67a
Pineapple-pepper intercrop	-	-	0.75a	0.84a	0.83a	0.94a	1.57a	1.78a
Time of sowing * year interaction	ns		ns		Ns		ns	

Means with the same letter(s) within column and season are not significantly different (P=0.05)
WAT = Weeks after transplanting; ns = not significant.

Table 11. Effect of time of sowing cowpea into pineapple-pepper intercrop on soil chemical properties (2011 experiment)

Treatments	pH	Organic carbon	Organic matter	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium	Sodium
		g/kg			mg/kg	cmol/kg			
Rainy season crop									
Cowpea sown @ 0WAT	5.84a	13.70a	23.60a	1.80a	17.30a	0.17a	1.40a	1.15a	0.13a
Cowpea sown @ 3WAT	5.81a	10.40a	17.90a	1.40a	13.33a	0.15a	1.15a	0.80a	0.10a
Cowpea sown @ 6WAT	5.61a	9.30a	16.00a	1.20a	7.15a	0.10a	1.10a	0.85a	0.08a
Cowpea sown @ 9WAT	5.84a	12.90a	22.20a	1.60a	15.41a	0.14a	1.25a	1.00a	0.09a
Pineapple-pepper intercrop	5.65a	11.00a	17.20a	1.30a	6.91a	0.10a	0.85a	0.65a	0.07a
Sole pineapple	5.66a	9.70a	16.70a	1.30a	5.94a	0.11a	0.80a	0.60a	0.08a
Sole pepper	5.81a	12.90a	17.20a	1.30a	6.85a	0.11a	0.85a	0.60a	0.09a
Sole cowpea	5.85a	7.00a	12.00a	0.90a	4.52a	0.10a	0.85a	0.55a	0.08a
Late season crop									
Cowpea sown @ 0WAT	6.28a	13.60a	23.40a	1.80a	20.09a	0.16a	1.35a	0.90a	0.12a
Cowpea sown @ 3WAT	6.36a	12.00a	20.70a	1.60a	19.44a	0.19a	1.40a	0.95a	0.14a
Pineapple-pepper intercrop	6.11a	12.90a	22.00a	1.70a	23.50a	0.16a	1.35a	1.05a	0.12a
Sole pineapple	6.17a	16.60a	28.60a	2.20a	30.97a	0.32a	1.70a	1.25a	0.22a
Sole pepper	6.30a	12.20a	21.50a	1.60a	21.55a	0.15a	1.15a	0.85a	0.12a
Sole cowpea	6.19a	19.20a	33.30a	2.50a	38.18a	0.34a	1.75a	1.35a	0.25a

Means with the same letter(s) within column and season are not significantly different (P=0.05)

Table 12. Effect of time of sowing cowpea into pineapple-pepper intercrop on soil chemical properties (2012 experiment)

Treatments	pH	Organic carbon	Organic matter	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium	Sodium
		--------------------g/kg------------------			mg/kg	-------------------------------cmol/kg---------------------------			
Rainy season crop									
Cowpea sown @ 0WAT	5.72a	11.10a	19.10a	1.40a	12.75a	0.13a	1.05a	0.85a	0.09a
Cowpea sown @ 3WAT	5.83a	12.30a	21.20a	1.60a	13.59a	0.13a	1.00a	0.85a	0.08a
Cowpea sown @ 6WAT	5.76a	7.60a	13.10a	1.00a	4.38a	0.09a	0.85a	0.60a	0.07a
Cowpea sown @ 9WAT	5.51a	11.80a	20.30a	1.50a	14.49a	0.15a	1.20a	0.90a	0.11a
Pineapple-pepper intercrop	5.55a	10.00a	17.20a	1.30a	6.91a	0.10a	0.85a	0.55a	0.07a
Sole pineapple	5.55a	8.30a	14.30a	1.10a	5.22a	0.10a	0.75a	0.50a	0.06a
Sole pepper	5.76a	10.80a	18.60a	1.40a	13.00a	0.13a	1.15a	0.85a	0.09a
Sole cowpea	5.97a	13.20a	22.70a	1.70a	17.15a	0.17a	1.60a	1.05a	0.13a
Late season crop									
Cowpea sown @ 0WAT	6.35c	14.80a	25.30a	1.90a	23.99a	0.25a	1.60a	1.15a	0.19a
Cowpea sown @ 3WAT	6.47bc	17.40a	30.00a	2.20a	33.39a	0.32a	1.95a	1.50a	0.23a
Pineapple-pepper intercrop	6.84a	14.00a	24.10a	1.80a	24.38a	0.17a	1.35a	0.90a	0.12a
Sole pineapple	6.57abc	14.00a	24.10a	1.80a	22.68a	0.30a	1.50a	1.10a	0.21a
Sole pepper	6.64ab	12.90a	24.10a	1.60a	26.16a	0.14a	1.10a	0.80a	0.11a
Sole cowpea	6.65ab	21.90a	37.70a	2.80a	45.71a	0.44a	2.25a	1.65a	0.27a

Means with the same letter(s) within column and season are not significantly different (P=0.05)

5. CONCLUSION

Based on the findings of the study, it can be recommended to pineapple farmers to introduce pepper into the spaces between the rows of pineapple as soon as the pineapple field is established. However, sowing of cowpea should be delayed up to six weeks after transplanting pepper during the rainy-season planting and three weeks during the late-season planting in order to reduce competition and to enhance the complementary use of resources by the component crops in the mixture. The pineapple based intercropping system will increase income base from the minor component crops (pepper and cowpea) while the main crop (pineapple) is getting established.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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