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EVALUATION OF PLANTING PERIODS AND FERTILIZER TYPES ON GROWTH AND YIELD OF CUCUMBER INTERCROPPED WITH PAWPAW VARIETIES

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ABSTRACT

In a two phased field experiment conducted between 2006 and 2008 at the University of Agriculture, Abeokuta, the performances of cucumber (*Cucumber sativus* L.) var. Market-more introduced into pawpaw (*Carica papaya* L.) var: 'Homestead selection' and 'Sunrise solo' at the early, simultaneous and late times of introduction using 10 t/ha OMF as basal application was evaluated. Also in the mixture, the best fertilizer type involving 10 t/ha OMF or NPK 15:15:15 at 125 kg / ha / month using the zero (0 t/ha) application as control was determined. The factorial experiment was arranged in a randomized complete block design replicated three times. The results indicated that except at early cucumber introduction, growth and yield depression occurred in the crop mixture compared to the sole in the main vine length, leaf area, number of fruits, fruit yield and relative yield total (RYT). The cucumber performance was better in juvenile pawpaw (one year old) than in mature pawpaw (two year old). Both early and simultaneous introductions under juvenile and mature pawpaw were significantly better than late introduction. The cucumber with OMF was higher than those with NPK treatment in main vine length (101.6 cm and 53.3 cm respectively) and both were significantly better than the control (38.6 cm), though plants with OMF and NPK both were not different in leaf area (4,844 and 4,874 cm^2 respectively), while plants with NPK compared to OMF recorded higher number of fruits (16 and 14 respectively) and higher fruit yield (13.8 and 11.2 t/ha respectively). The LER > 1.0 recorded for both cucumbers in Sunrise or Homestead indicated yield advantages of the mixtures compared to the sole.

Keyword: *Carica papaya* L., *Cucumber sativus* L, crop productivity, cropping sequence, fertilizer types, intercropping systems.

INTRODUCTION

Cucumber (*Cucumis sativus* L.), a trailing crop that along with pumpkin and gourds belongs to the family cucurbitaceae., is usually grown for the fruit that can be eaten raw, cooked or fried and for other numerous properties which include the therapeutic of the fruit and diuretic of the seeds (Mitchell *et al*., 2000). The other uses include culinary and alternative medicine (Anonymous 2000 a, b, c, d; Grieve, 2004; Nunn, 2004). Cucumber has the world highest production from China 28,049,900MT followed by Iran 1,720,000MT and Turkey 1,674,580MT (FAO, 2007). However, being an exotic and elitist crop cucumber has an increasing but low production in Nigeria. Olasantan (2001) observed that vegetable crops including cucumber occupy a valuable ecological niche in tropical agriculture and play a significant role in the eco-physiology of mixed systems which corroborates Agboola (2000) earlier

reported that early yielding annual vegetable crops form part of the tropical farmer's choice as ground covers which when grown among the important fruit crops make up the multi-storey layer of the tropical farming systems. Studies on mixed cropping (Akinola *et al*., 1971; Willey and Osiru, 1972; Rao and Willey, 1980) have indicated that the practice not only produced more yield because of more efficient utilization of environmental resources than sole cropping, but it is also very advantageous in the maintenance of soil fertility through effective soil cover and amelioration of the environment.

Previous findings in intercropping systems involving cucumber have been reported to reduce weed infestation and increase LER in cucumber mixed with okra (Szumigalski and Acker, 2005; Ofosu-Anim and Limbani, 2007). Cucumber mixed in pawpaw recorded higher productivity in intercropping systems by more than unit LER (Aiyelaagbe and Jolaoso, 1992; Olubode *et al.,* 2008), but with reduced crop performances in growth and yield of component crops as reported in cucumber mixed in citrus seedlings (Olaniyan *et al*., 2006) and cucumber mixed with okra (Magdy *et al.,* 2007). Also Ikeorgu (1984) had reported improved crop performance under melon, a cucumber related specie due specifically to the attendant higher soil moisture content and cooler soil temperatures observed resulting in more conducive environment for improved growth and yield of the component crops. Furthermore, Ossom (2003) reported that soil surface temperatures under cucumber showed a general decrease with time but no clear relationship between fruit yield and soil temperature, and that the untrained cucumber effectively suppressed weed but trained or staked was better for reduced disease infestation.

However, the most suitable time of vegetable introduction in long duration and multi-season crops like pawpaw and the effect of organo-mineral fertilizers on crop production and productivity within different crop mixtures have not been investigated. This experiment therefore seeks to investigate, (i) the best time for cucumber introduction, (ii) best fertilizer type to adopt in cucumber/pawpaw mixtures, and (iii) the effect of two pawpaw varieties on growth and productivity of short duration cucumber vegetable when grown in crop mixtures with the long duration pawpaw.

MATERIALS AND METHODS

Field experiments were conducted between 2006 and 2008 at the University of Agriculture, Abeokuta, Nigeria, (latitude 7^0 12' N, longitude 3^0 20' E at 100 m above sea level). The two phased field experiment was conducted to determine the responses of cucumber (*Cucumber sativus* L.) var. Marketmore, a creeping and Downey mildew tolerant variety to cultivation in monoculture or mixture with two pawpaw (*Carica papaya* L.) var. Homestead selection and Sunrise solo. Table 1 shows the meteorological data of the experimental location during the period. Table 2 shows the pre-cropping physico-chemical properties of the site.

With exception of 2007, the land preparation ahead of field transplant commenced at the onset of the rains in April of each phase of experiment, viz: 2006 and 2008, where field operations of plough, plough and harrow were carried out. The crump soils and near leveled field were thereafter demarcated into blocks.

Table 1: The weather data showing rainfall (mm) observed at the experimental area for the period between 2006 and 2008

Year / Rainfall (mm)	Month J	F	M	A	M	J	J	A	S	O	N	D	Total
2006	4.5	62.0	62.1	180.3	77.0	262.0	92.8	61.8	250.7	56.8	43.4	0.0	1153.4
2007	0.5	0.0	15.5	17.3	120.2	213.9	369.8	140.5	192.0	119.2	11.4	1.3	1201.6
2008	0.0	0.0	91.8	128.8	74.5	167.2	299.2	106.7	136.8	84.5	0.0	26.9	1116.4
Mean	1.7	20.7	56.5	108.8	90.6	214.4	253.9	103.0	193.2	86.8	18.3	9.4	1157.1

Source: Agro-meteorology Dept, UNAAB (latitude 7^{0}12' N, longitude 3^{0}20' E, altitude of 100m above sea level).

Table 2: The pre-cropping physico-chemical properties of the soil of the experimental sites

Soil depth (cm)	Particle size analysis % sand	% clay	% silt	Tex-tural Class	Chemical analysis pH (H_2O)	% Org. Matter	N (%)	Exchangeable bases P Ppm	K cmol kg-1	Na cmol kg-1	Ca cmol kg-1	Mg cmol kg-1
0 – 15	78.2	11.58	10.22	Sandy	7.74	2.14	0.09	7.98	0.25	0.54	4.77	0.95
16 – 30	82.6	9.35	8.05	Sandy	7.18	1.50	0.07	8.05	0.16	0.42	2.16	0.48

The experiments utilized two months old pawpaw seedlings which were transplanted into planting holes at 2 m x 2 m standard spacing for pawpaw. Seeds of cucumber vegetable were sown direct into the field at recommended spacing of 1.5 m x 1 m with a 2-m walk path/buffer zone demarcating the plots.

The two methods of fertilizer application adopted were based on the component crops growth habits and sizes, and were applied in 50: 50 ratio between pawpaw and vegetables at two splits occurring at the vegetative phase and at onset of pawpaw flowering. The pawpaw being semi-woody trees with extensive rooting system was supplied with OMF/NPK fertilizer using the ring application method at the radius of 30 cm away from the plant. The vegetable intercrop being an annual, planted in a regular closer spacing with definite row arrangement was supplied with OMF/NPK fertilizer using the band application methods at an interval of 1 m across the experimental plots.

The cucumber intercrop was harvested within 3 months after planting, while the pawpaw fruits were harvested at the colour breaking stage. The experiment was strictly rain-fed. Weeding and other agronomic practices like staking of lodged plants were carried out as at when necessary, while pests and diseases were controlled when virulent using the method described by Vereijken, (1990). Soil samples were collected before planting and at harvesting and these were dried, crushed, and sieved with a 2 mm mesh for analysis.

The first experiment involved cucumber intercropped with pawpaw at three times of vegetable introduction using a blanket application of 10 t/ha organo-mineral fertilizer (OMF) as soil amendment. The factorial experiment was arranged in a randomized complete block design (RCBD) replicated three times. The cucumber was introduced into juvenile homestead selection and sunrise solo pawpaw orchards at the early (3-weeks before pawpaw on 19th June 2006), simultaneous (same time with pawpaw on 10th July, 2006) and late (3-weeks after pawpaw on 31st July, 2006). A separate experiment which involved cucumber cultivated sole served as control. In April 2007, seeds of cucumber at a spacing of 1.5 m x 1 m were sown into the alleys of mature pawpaw at the onset of rains, 3 weeks before on 15th April, 2007, at same time on 2nd May, 2007 and at 3 weeks after flowering on 28th May, 2007 respectively.

The second experiment conducted in 2008 involved cucumber intercropped with pawpaw in three crop mixtures of cucumber sole, cucumber-in-Homestead and cucumber -in-Sunrise at simultaneous introduction with pawpaw using three levels of soil amendment which actually were three fertilizer types/levels. The fertilizer levels included unfertilized zero (0 t/ha) application, 10 t/ha OMF and NPK 15:15:15 at 50 g/plant/ month where zero application served as control. The factorial experiment arranged in randomized complete block design was replicated three times. In this second phase experiment, conducted on the 31st July 2008, two months old pawpaw seedlings were transplanted into the field at a spacing of 2 m x 2 m into already dug holes of 60 cm^3 sizes while seeds of cucumber were sown into the pawpaw orchards at the spacing of 1.5 m x 1 m.

The vegetative parameters of the sole and intercropped vegetable component plants

were monitored for data collection which included weekly measurement of main vine length (cm), number of leaves/plant, leaf area (cm^2) using non-destructive method from the following equation: cucumber, Y = 12.9 X - 54.31 (Aiyelaagbe and Adedokun, Unpublished paper) where 'X' = length of leaf breadth, 'Y' = leaf area (cm^2). The reproductive parameters which were measured on daily basis included the yield and yield components of both the sole and intercropped plots such as number of fruits/plant, fruit weight/plant (g/plant), fruit yield (t/ha), harvest frequency.

The pawpaw varieties were measured weekly for plant height (cm), stem girth (cm), number of leaves/plant, leaf area (cm^2) while reproductive parameters were measured daily for the number of flowers, number fruits and fruit yield while cumulative number fruits and fruit setting rate were calculated from the data collected. The leaf area was calculated using formula by Aiyelaagbe and Fawusi (1984): Y = 47.09 X – 316.06 where 'Y' = leaf area (cm^2 /plant), 'X' = sum of the length of median midribs (cm/plant). The productivity efficiency was evaluated by comparing the productivity of a given area of intercrop with that of the sole crops using the individual crop relative yield total (RYT) and land equivalent ratio (LER) described by Wiley (1979).

Data collected were subjected to the analysis of variance procedures (SAS, 1990). Treatment means of each of the parameters measured were compared using the least significant difference technique (Steel and Torrie, 1980).

RESULTS

Responses of cucumber to crop mixture with pawpaw

The cucumber response to crop mixture at the time of introduction under the juvenile pawpaw is shown in Table 3. Significantly higher response was recorded for early cucumber/homestead in main vine length at 5 and 9 weeks after planting (WAP), number of leaves at 5 WAP, and for early cucumber/ sunrise in main vine length at 9 WAP, number of leaves at 5 and 9 WAP compared to cucumber sole. The cucumber sole, early and late cucumber/ homestead were higher in leaf area at 5 and 9 WAP, with higher responses also obtained for early cucumber/ sunrise introduction at 5 WAP compared to late cucumber/homestead introduction, simultaneous or late cucumber/sunrise introduction, while simultaneous and late cucumber/sunrise introduction were higher at 9 WAP compared to early cucumber/sunrise introduction.

Early introduction into cucumber/ homestead along with simultaneous and late introduction into cucumber/sunrise mixture were lower in LAI at 5 WAP and only early introduction into cucumber/sunrise was lower in LAI at 9 WAP. There was no significant difference in number of fruit except for the lower response at simultaneous introduction into cucumber/sunrise at 5 WAP. The fruit weight/plant was not different except for the lower response recorded for simultaneous introduction into cucumber/ homestead introduction at 5 WAP and late introduction into cucumber/homestead introduction at 9 WAP. The fruit yield recorded higher response only for cucumber at early introduction into either homestead or sunrise compared to cucumber sole and other crop mixtures but no significant difference recorded for fruit yield at 9 WAP.

Table 3: Effect of times of vegetable introduction on growth and yield responses of cucumber intercropped in juvenile pawpaw

Treatments	Vegetative growth								Reproductive growth					
	Main vine length (cm)		Number of leaves/ plant		Leaf area (cm2)		LAI		Number of fruits/ plant		Fruit weight/ plant (g/plt)		Fruit yield (t/ha)	
	5†	9†	5†	9†	5†	9†	5†	9†	9†	11†	9†	11†	9†	11†
Cucumber Sole	71	174	18	58	1797	3838	1.2	2.6	1	4	521	522	1.7	8.7
Cucumber before Homestead	91	202	19	62	2353	4730	1.6	3.2	1	4	523	522	2.7	8.8
Cucumber same-time Homestead	71	172	17	53	1809	4030	1.2	2.7	1	4	507	522	1.4	9.7
Cucumber after Homestead	60	169	16	52	1718	3970	1.1	2.6	1	3	517	521	1.7	7.6
Cucumber before Sunrise	61	181	21	74	1776	3280	1.2	2.2	1	4	523	523	2.4	9.7
Cucumber same-time Sunrise	79	163	16	44	1651	3610	1.1	2.4	0	4	522	522	1.0	8.2
Cucumber after Sunrise	63	159	18	65	1476	3410	1.0	2.3	1	3	525	523	1.3	8.1
LSD 0.05	11.9	27.9	2.4	10.3	633.1	1396.1	0.42	0.93	0.39	2.0	16.6	1.6	0.92	4.66

† = weeks after planting; LAI = leaf area index

The cucumber response to crop mixture at the time of introduction under the mature pawpaw is shown in Table 4. Compared to sole, higher responses were recorded in crop mixture at the early introduction into cucumber/homestead in main vine length and early introduction into cucumber/sunrise at 5 and 9 WAP, higher number of leaves at early introduction into cucumber/sunrise, lower leaf area at the simultaneous and late introduction into cucumber/homestead and late introduction into cucumber/sunrise, higher number of fruit at early introduction into cucumber/sunrise compared to sole or other times of introduction, higher cucumber fruit weight/plant for the homestead compared to lower response for sunrise while fruit yield was higher at early introduction into cucumber/homestead and early introduction into cucumber/sunrise compared to sole and other times of introduction.

Interaction responses of cucumber to crop mixture with pawpaw

The interaction responses of crop mixture to fertilizer trials are shown in Table 6. In main vine length at both 5 and 9 WAP, interaction responses was higher for the 10 t/ha OMF of cucumber/sunrise, and 10 t/ha OMF or NPK of cucumber/homestead which were higher compared to lower responses from zero t/ha. In number of leaves, only NPK of cucumber sole interaction responses was lower compared to higher responses recorded for cucumber/sunrise or cucumber /homestead. In LAI at 5 WAP, interaction responses showed that the 10 t/ha OMF and NPK of cucumber/homestead were higher than both 10 t/ha OMF and NPK of cucumber/sunrise which was also higher than 10 t/ha OMF and NPK of zero t/ha. The performances were in the trend of cucumber/homestead mixture > cucumber/sunrise mixture > cucumber sole. In LAI at 9 WAP, interaction responses showed that the 10 t/ha OMF was higher than NPK and higher than zero in that order under cucumber/homestead but for cucumber/sunrise, NPK was higher than 10 t/ha OMF application than zero t/ha while no significant difference in fertilizer application responses was observed for zero t/ha application. In the number of fruits/plant at 5 WAP, interaction responses showed that both NPK of cucumber/homestead and cucumber/sunrise were higher than both 10 t/ha OMF of cucumber/homestead and cucumber/sunrise followed by zero t/ha application of cucumber/sunrise, and 10 t/ha OMF or NPK of cucumber sole while zero t/ha application of both cucumber/homestead and cucumber sole were least. In the fruit yield at 5 WAP, interaction responses showed that both NPK of cucumber/homestead and sunrise were higher than NPK and 10 t/ha OMF of cucumber sole which was also higher than 10 t/ha OMF of cucumber/sunrise, followed by 10 t/ha OMF of cucumber/homestead and zero t/ha application of cucumber/sunrise which were also higher than both zero t/ha application of cucumber/homestead and cucumber sole which were least. In the fruit yield at 9 WAP, interaction responses showed that both NPK of cucumber/homestead and sunrise were higher than 10 t/ha OMF of cucumber/sunrise and cucumber/homestead alongside NPK and 10 t/ha OMF of cucumber sole while all the zero t/ha application were least in the trend of cucumber/sunrise, cucumber/homestead and cucumber sole. Interaction occurred also in the crop mixture only in RYT of pawpaw and in RYT of both cucumber and pawpaw in the fertilizer trials.

Table 4: Effect of times of vegetable introduction on growth and yield responses of cucumber intercropped I n mature pawpaw

Treatments	Vegetative growth								Reproductive growth					
	Main vine length (cm)		Number of leaves/ plant		Leaf area (cm^2)		LAI		Number of fruits/ plant		Fruit weight/ plant (g/plt)		Fruit yield (t/ha)	
	5†	9†	5†	9†	5†	9†	5†	9†	9†	11†	9†	11†	9†	11†
Cucumber Sole	16	23	7	12	611	1377	0.4	0.9	1	1	196	258	0.9	1.5
Cucumber before Homestead	20	31	6	9	605	1407	0.4	0.9	1	1	201	296	1.0	1.8
Cucumber same-time Homestead	12	19	6	9	523	1219	0.3	0.8	1	1	178	260	0.6	1.2
Cucumber after Homestead	9	14	6	9	449	1050	0.3	0.7	1	1	174	254	0.7	1.2
Cucumber before Sunrise	15	22	10	17	790	1736	0.5	1.2	2	2	207	243	1.4	2.3
Cucumber same-time Sunrise	23	33	8	14	725	1591	0.5	1.1	1	1	193	229	0.7	1.1
Cucumber after Sunrise	16	23	8	14	571	1256	0.4	0.8	1	1	212	247	0.7	1.2
LSD 0.05	3.02	4.14	0.83	1.25	187.5	411.7	0.13	0.27	0.46	0.60	45.5	47.9	0.43	0.71

† = weeks after planting; LAI = leaf area index

Table 5: Growth and yield responses of cucumber intercropped in pawpaw to fertilizer types/ rates

Treatments	Vegetative growth								Reproductive growth					
	Main vine length (cm)		Number of leaves/ plant		Leaf area (cm^2)		Leaf area index		Number of fruits/ plant		Fruit weight/ plant (g/plt)		Fruit yield (t/ha)	
	5†	9†	5†	9†	5†	9†	5†	9†	9†	11†	9†	11†	9†	11†
Cucumber sole	19.9	57.1	16	23	2602	3787	1.73	2.52	6	8	269	244	7.2	9.0
Cucumber / Homestead	47.2	65.5	18	24	4090	4787	2.73	3.19	11	14	150	161	7.2	10.2
Cucumber / Sunrise	49.9	70.8	21	26	3501	4707	2.33	3.14	13	17	138	143	8.2	11.1
LSD cmix	3.7	6.7	2.3	2.1	553	563	0.4	0.4	0.9	1.1	28.9	22.4	0.6	0.6
0t/ha OMF	18.8	38.6	16	23	2534	3564	1.69	2.38	6	9	158	150	4.2	5.4
10t/ha OMF	61.2	101.6	22	28	3678	4844	2.45	3.23	11	14	184	189	7.5	11.2
NPK 15:15:15	37.0	53.3	17	21	3980	4874	2.65	3.25	13	16	216	209	10.9	13.8
LSD fert	3.7	6.7	2.3	2.1	553	563	0.4	0.4	0.9	1.1	28.9	22.4	0.6	0.6
Cmix x fert	**	**	Ns	**	*	*	*	*	**	**	**	**	**	**

* P = 0.05, ** P = 0.01, ns = not significant, † = weeks after planting, Cmix = crop mixture, fert = fertilizer type/rate, LSD at ≤ 0.05

Table 6: The interaction effect of crop mixture x fertilizer types on growth and yield of cucumber vegetable

Interaction effect		Vegetative growth							Reproductive growth					
		Main vine length (cm)		No of leaves / plant	Leaf area (cm2)		Leaf area index		Fruit weight/ plant (g/plt)		No of fruits/ plant		Fruit yield (t/ha)	
Crop Mixtures	Fertilizer types	5†	9†	9†	5†	9†	5†	9†	9†	11†	9†	11†	9†	11†
Cucumber Sole	0 t/ha	10.3	31.8	25	1891	3633	1.26	2.42	169	184	5	6	3.4	5.1
	10 t/ha	32.8	101.8	27	3017	3879	2.01	2.59	311	255	7	10	8.7	10.9
	NPK	16.5	37.7	17	2898	3849	1.93	2.57	328	292	6	9	9.3	11.1
Cucumber / Homestead	0 t/ha	20.9	35.8	19	2567	3273	1.71	2.18	162	158	5	8	3.8	5.4
	10 t/ha	65.5	87.7	27	4359	5129	2.91	3.42	116	160	12	15	6.2	10.8
	NPK	55.2	73.1	26	5345	5960	3.56	3.97	171	167	15	20	11.6	14.6
Cucumber / Sunrise	0 t/ha	25.3	48.1	26	3145	3785	2.10	2.52	142	110	8	12	5.3	5.8
	10 t/ha	85.2	115.2	30	3659	5523	2.44	3.68	125	151	14	17	7.7	11.8
	NPK	39.3	49.2	21	3698	4814	2.47	3.21	148	168	18	21	11.7	15.7
LSD 0.05		0.57	1.06	0.33	86.9	88.7	0.06	0.06	4.6	3.5	0.1	0.2	0.09	0.10

† = weeks after planting

Responses of pawpaw to crop mixture and fertilizer trials

The pawpaw response to crop mixture is shown in Table 7. Higher response of homestead/cucumber was recorded in plant height, stem girth and leaf area at 28 WAP, but sunrise/cucumber was higher in number of flowers at 88 WAP, number of fruits/plant and fruit setting rate at 96 WAP and in fruit yield at 108 WAP. There was no significant difference in plant height, stem girth and leaf area at 64 WAP. Both early and were higher in plant height, stem girth, leaf area at 28 WAP, but at 64 WAP only early introduction was highest in plant height, stem girth and leaf area at 64 WAP followed by simultaneous introduction while late introduction was least but no significant difference was recorded in number of fruits/plant and fruit yield. However, while number of flowers was higher with early > simultaneous > late introduction in that order the reverse was recorded in fruit setting rate with late > simultaneous > early introduction in that order.

The pawpaw interaction response to crop mixture is shown in Table 8. The responses indicated growth and yield retardation under pawpaw/cucumber mixture compared to sole pawpaw, where retardation of the growth was more under sunrise/cucumber compared to homestead/cucumber and yield retardation was more under homestead/cucumber compared to sunrise/ cucumber. This indicated that despite growth retardation homestead was more aggressive in mixture compared to sunrise, while despite the yield retardation sunrise had more prolific flowering and better yield than homestead. While homestead was higher in vegetative growth of plant height, stem girth and leaf area at 28 WAP, sunrise solo was higher in the reproductive growth of number of flowers, fruit setting rate, number of fruits and fruit yield (Table 9). Early and simultaneous introduction times shown in Table 8 recorded higher responses in the plant height and stem girth at 28 WAP, also in leaf area at 28 and 64 WAP, while early introduction time alone was higher in plant height and stem girth at 64 WAP, and number of flowers compared to simultaneous and late times of vegetable introduction. Pawpaw in simultaneous introduction was higher in plant height at 64 WAP compared to late, simultaneous introduction was also higher in number of flowers compared to late, while late introduction recorded higher fruit setting rate compared to simultaneous which was higher than early introduction, but no significant difference was recorded in number fruits and fruit yield. Sole pawpaw shown in Table 9 was higher in plant height, stem girth and leaf area at 20 and 36 WAP, fruit setting rate, number fruits and fruit yield.

The pawpaw response to soil amendment is shown in Table 9. Pawpaw responses showed that 10 t/ha OMF was higher in plant height, stem girth and leaf area at 20 and 36 MAT, number of flowers, number fruits and fruit yield but least in fruit setting rate compared to zero t/ha and NPK. The NPK was higher compared to zero t/ha in plant height, stem girth and leaf area at 20 and 36 MAT, number of flowers, number fruits and fruit yield but lower and least in fruit setting rate while zero t/ha recorded the highest fruit setting rate.

Productivity responses of component crops in crop mixture and fertilizer trials

Under the pawpaw variety there was no significant difference in crop productivity with relative yield total (RYT) of cucumber in sunrise or homestead at the different

Table 7: Growth and yield responses of pawpaw to time of intercropping with cucumber

Treatments	Vegetative growth						Reproductive growth			
	Plant Height (cm)		Canopy Spread (cm)		Leaf area (x '000 cm^2)		Number of flowers	Fruit setting rate (%)	Number of fruits	Fruit yield (t/ha)
	28†	72†	28†	72†	28†	72†	88†	96†	96†	108†
Main Crop Variety										
Homestead / Cucumber	81.9	239.7	97.2	307.5	16.4	73.7	85	48	41	34.9
Sunrise /Cucumber	64.8	237.4	66.3	346.7	8.6	85.3	96	59	56	37.4
LSD	6.67	Ns	8.4	ns	2.4	ns	1.25	0.22	0.30	0.47
Time of introduction										
Early introduction	82.0	285.7	101.2	367.8	16.1	91.2	98	50	49	36.6
Same time introduction	76.3	229.8	93.3	344.2	16.3	82.3	92	52	48	36.0
Late introduction	61.7	200.3	50.8	269.3	50.3	64.9	81	59	49	35.7
LSD	6.64	22.11	8.8	22.7	3.8	20.4	1.50	1.48	1.01	1.15
V x T	ns	ns	ns	ns	ns	ns	ns	**	**	**

* P= 0.05, ** P= 0.001, ns = not significant, V = Variety, T = time of introduction, † = weeks after planting

Table 8: Growth and yield responses of sole and pawpaw mixed with cucumber

Treatments	Vegetative growth						Reproductive growth			
	Plant height (cm)		Leaf area (1,000 cm^2)		Canopy spread (cm		No of flowers	Fruit setting rate (%)	No of fruits	Fruit yield (t/ha)
	28†	72†	28†	72†	28†	72†	88†	96†	96†	108†
Homestead Sole	83.8	252.2	15.7	97.2	101.2	323.1	67	72	48	41.2
Homestead / cucumber	81.9	239.7	16.4	73.7	97.2	307.5	85	48	41	34.9
Sunrise solo Sole	77.7	240.2	10.2	86.5	89.3	353.3	89	87	77	51.3
Sunrise solo / cucumber	64.8	237.4	8.6	85.3	66.3	346.7	96	59	56	37.4
LSD	7.41	22.59	0.29	1.49	1.8	1.4	2.86	2.69	3.06	2.01

* P= 0.05, ** P= 0.001, ns = not significant, † = weeks after planting

Table 9: Growth and yield responses of pawpaw to crop mixture and fertilizer types

Treatments	Vegetative growth						Reproductive growth			
	Plant height (cm)		Leaf area (1,000 cm^2)		Canopy spread (cm)		No of flowers/ plant	Fruit setting rate (%)	No of fruits/ plant	Fruit yield (t/ha)
	20†	36†	20†	36†	20†	36†	48†	52†	52†	64†
Main Crop Variety										
Homestead	114.1	161.8	24.5	33.7	132.9	152.5	20	69	15	12.5
Sunrise solo	115.5	149.4	25.9	34.0	129.3	147.8	43	55	23	8.7
LSD V	1.46	3.53	0.2	0.8	ns	ns	0.95	0.90	2.11	0.43
Crop Mixture										
Sole Pawpaw	121.6	161.5	28.5	34.3	142.2	163.3	32	71	21	11.8
Pawpaw / cucumber	108.1	149.6	21.9	33.3	120.1	137.0	32	53	17	9.4
LSD C	4.66	6.83	0.8	1.2	6.1	5.0	ns	1.75	2.36	0.75
Fertilizer type										
0ton/ha OMF	105.3	146.5	20.7	29.5	117.6	135.4	20	68	12	6.4
10ton/ha OMF	123.9	168.1	30.3	38.6	142.0	160.8	45	55	25	14.2
NPK 15:15:15	115.2	152.1	24.7	33.4	133.8	154.3	30	63	20	11.2
LSD F	2.46	3.31	0.9	1.3	2.4	2.5	0.57	0.55	1.73	0.30
V x C	Ns	ns	*	ns	ns	ns	**	ns	Ns	ns
V x F	**	ns	*	*	*	ns	**	ns	**	ns
C x F	Ns	**	ns	ns	**	**	**	*	**	*
V x C x F	Ns	ns	ns	ns	ns	ns	**	ns	Ns	ns

* P= 0.05, ** P= 0.01, ns = not significant, V = Variety, C = Crop Mixture, F = Fertilizer type, † = weeks after planting

period of production in juvenile or matured or in combined yield assessments under total cucumber yield and the eventual land equivalent ratio (LER). The RYT recorded for pawpaw was significant higher in cucumber/homestead than cucumber/sunrise mixture. The time of introduction trials showed that there was no significant difference in RYT of vegetables at the different times of introduction in cucumber under juvenile pawpaw. However, significant difference was recorded for early introduction time which was higher than both the cucumber sole and cucumber in simultaneous or late introductions at mature pawpaw stage. The total cucumber RYT however also recorded higher responses in early introduction compared to sole cucumber.

Significant difference occurred in RYT of pawpaw component with sole cropping higher than crop mixture at the early, simultaneous and late times of introduction which were all not different in responses. Significant difference occurred in both RYT of cucumber total yield and LER where in both occurrences the early vegetable introduction was higher than both simultaneous and late introduction times which were also higher than cucumber sole.

The crop mixture in fertilizer trials showed that there was significant difference in cucumber RYT with cucumber/sunrise higher than cucumber/homestead which in turn was higher than sole crop, RYT of pawpaw component in sole crop was higher than in cucumber/sunrise and in cucumber/homestead which were not different. Significant difference occurred in final LER with a trend of cucumber/sunrise mixture > cucumber/homestead mixture > cucumber sole. The main effect of fertilizer trials showed that there was significant difference in RYT of cucumber component where NPK facilitated productivity in cucumber. Also significant difference was recorded in RYT of pawpaw component which was higher under 10 t/ha OMF than under NPK but not different from zero t/ha application. However no significant difference was recorded in LER under the fertilizer trials.

DISCUSSION

Crop mixture

Cucumber intercropped at the pawpaw immature stage had little but significant interference from juvenile pawpaw component while at the pawpaw mature stage there was a highly significant competitive effect in the mixture by virtue of mature pawpaw size. Specifically, at juvenile pawpaw stage, cucumber's response was higher in vegetative growth of main vine length, leaf area and LAI under the higher and more vigorous homestead pawpaw which led to a higher initial fruit yield though eventually not different from sunrise. The higher vegetative growth response was purely plant etiolation responses to light transmission which confirmed findings of Olasantan and Lucas (1992), while the higher number of leaves and fruit weight responses under cucumber/sunrise was as a result of better light transmission under the less aggressive growth of sunrise pawpaw. Compared to the sole cropping, early or simultaneous introduction of cucumber into pawpaw produced higher main vine length and number of leaves. Compared to sole cropping leaf area and LAI were retarded by late intercropping in homestead, but number of fruit were not different except at early fruit development stages of cucumber introduced simultaneously into homestead and in the later stages in cucumber introduced late into homestead. The fruit yield was however higher with early

cucumber introduction of both pawpaw varieties compared to sole cropping and other crop mixtures.

At immature pawpaw stage, the higher responses of cucumber introduced early into pawpaw compared to cucumber cultivated sole was indicative of competition for light more than for nutrient alone. The lower responses in cucumber introduced simultaneously or late into pawpaw mixture compared to cultivated sole was indicative of competition for both light and nutrient under simultaneous and competition for nutrient more than light alone under the late introduction. This growth and yield retardation responses confirmed the findings of Aiyelaagbe and Jolaoso, (1992) that the high productivity evidenced by LER > 1.0 notwithstanding, component crops in mixtures have consistently recorded growth and yield retardation in pawpaw mixtures, but as observed here time of introduction can positively or negatively influence crop productivity. Magdy *et al.,* (2007) had reported that intercropping based on simultaneous planting of cucumber in okra depressed okra pod yield to 83.2% and cucumber to 71% yield as percent of sole, and recommended that cucumber be planted simultaneously on the same date of planting okra in order to benefit from the mixture. Olaniyan *et al.,* (2006) also observed that cucumber population above 2,500 plants ha^{-1} significantly retarded growth of the citrus Cleopatra mandarin rootstock seedlings in nursery. Nonetheless, crop mixture improved number of flowers of pawpaw which was more in sunrise than in homestead and more in early than in simultaneous and late introductions. Thus the lower vegetative growth but higher fruit setting rate responses of cucumber in sunrise pawpaw and cucumber introduced early into pawpaw favoured allocation of nutrient assimilates into reproductive growth with corresponding higher cucumber fruit weight/plant and subsequent higher fruit yield compared to higher vegetative growth but lower fruit setting rate under homestead and cucumber sole, simultaneous or late introduction respectively.

At mature pawpaw stage, the higher cucumber/sunrise responses in vegetative growth of cucumber in main vine length, number of leaves, leaf area and LAI indicated etiolation growth which was a response to reduced light transmission under the more vigorous growth of sunrise pawpaw. The early introduced cucumber was better in vegetative and reproductive growth compared to sole indicative of little or no competitive effect from the pawpaw component. Also the no significant difference between simultaneously introduced cucumber compared to cucumber cultivated sole in main vine length, number of leaves and leaf area indicated no competitive effect from the pawpaw component, or that both pawpaw and cucumber components mining a source of nutrient not available to the other (Fukai and Trenbath, 1993).

The poor and least vegetative or reproductive growth responses of cucumber introduced late into pawpaw could be due to both the effect of competition for nutrient and light. The late introduction was least in number of leaves and leaf area compared to early introduced cucumber indicative of a better access to nutrient by the early introduction compared to simultaneous and late introduction which was as a result of nutrient depletion by the earlier introduced component crop causing negative response later introduced crop. This confirms the presence of zones of depletion earlier reported by Goldberg and Werner (1983). Also, the difference

in yield responses of cucumber observed at the different times of introduction under juvenile and mature pawpaw confirmed the observation of Marschner (1986) that flower formation and hence fruit yield is often affected to a much greater extent by the time and/or form of N application than by the level of N supply.

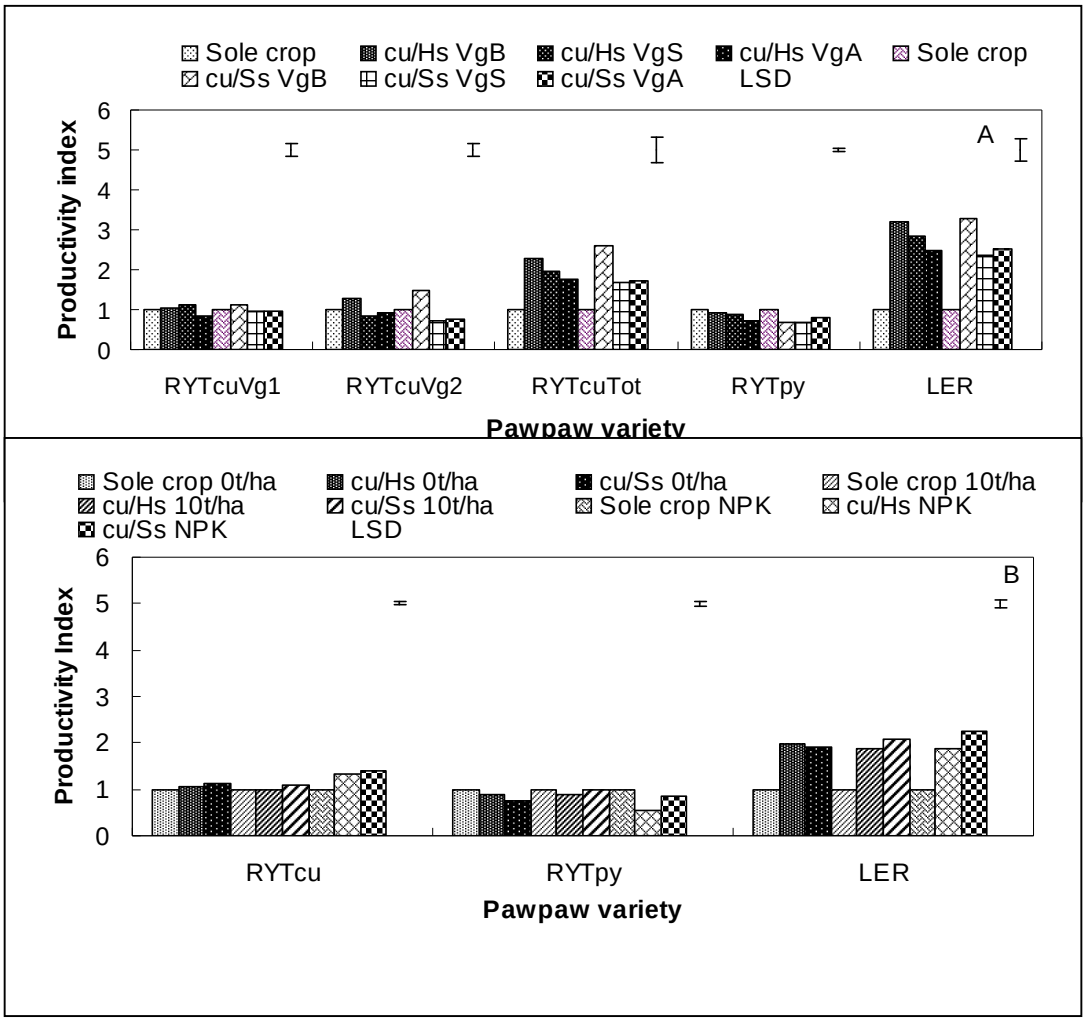

Fig 1: Productivity responses of cucumber intercropped in pawpaw varieties showing: (A) sole crop and cucumber/pawpaw varieties cv. Homestead (Hs) and Sunrise (Ss) at different times of introduction and (B) sole crop and cucumber/pawpaw and different rates/types of fertilizer application.

cu / Hs = cucumber in Homestead, cu / Ss = cucumber in Sunrise, OMF = organo-mineral fertilizer, Vg B = vegetable-before-pawpaw, Vg S = vegetable-simultaneous-pawpaw, Vg A = vegetable-after-pawpaw, RYT cu Vg = relative yield total of vegetable, RYT py = relative yield total of pawpaw, LER = land equivalent ratio. LSD at $p<0.05$.

Fertilizer trial

Under the fertilizer trials, higher number of leaves, number of fruits/plant and fruit yield was recorded in cucumber/sunrise mixture due to better access to nutrient and light transmission under sunrise pawpaw compared to under homestead pawpaw. This was due to difference in crop growth patterns of both pawpaw varieties. Homestead was aggressive in growth at the juvenile pawpaw stage while sunrise in reverse was more aggressive at the mature pawpaw stage. The cucumber cultivated sole thus recorded lower vegetative growth due to absence of competition and a subsequent low yield response compared to cucumber in mixture probably due to a synergy effect of leaf shading and nutrient resources resulting in higher cucumber yield in crop mixtures compared to sole cropping.

Under fertilizer trials, higher cucumber vegetative growth responses under the 10 t/ha OMF which confirmed the findings of Adeoye *et al.,* (2008) could be due to the better influence of the more complete nature of OMF in both macro and micro nutrient elements compared to NPK. The NPK however produced better influence on cucumber reproductive growth of higher fruit weight/plant, number of fruits and fruit yield due to the quick release nature and better effect of N which was higher in NPK compared to OMF. The higher release of N in NPK significantly influenced reproductive growth and eventual final yield of cucumber compared to OMF, while least response of zero t/ha application indicated that cucumber responded well to nutrient application and zero t/ha fertilizer should be discouraged in cucumber production.

Productivity responses of component crops

Relatively cucumber components responded equally in yield to crop mixture with pawpaw varieties irrespective of pawpaw ages while the pawpaw component responded differently due to varietal differences in vegetative growth pattern and differences in the corresponding contributive fruit biomass. The significant difference in productivity responses of the cucumber component at mature pawpaw stage and in cucumber total yield alongside the pawpaw component was as a result of yield retardation caused by matured size of pawpaw. Thus mature size had significant influence on cucumber access to light transmission while in pawpaw nutritional stress at simultaneous and physiological stress late introduction occurred at the times of vegetable introduction.

The component crops at the early introduction however, had higher productivity due to the different advantages accruing from minimal interference from competitive effects in crop mixture. Thus cucumber had access to more nutrients and hence had completed more part of its critical growth before pawpaw was introduced, while the pawpaw benefitted by tapping light and nutrient resources through taller height and probably reciprocal deeper roots (Fukai and Trenbath, 1993). The cucumber component had RYT retardation under homestead compared to higher RYT recorded under sunrise. The pawpaw recorded reduced RYT in crop mixture compared to sole crop. The LER of cucumber/sunrise was better than that of cucumber/homestead and both had productivity advantages of LER > 1.0 compared to sole crop and of either of the components crops alone. The cucumber component responded better to NPK while pawpaw component responded better to OMF rates. The

no significant difference in LER showed that though in productivity crop mixtures were higher in responses the differences compared to sole crop was not significant.

Interaction effects

The interaction effects of crop mixture x fertilizer rates indicated that NPK fertilizer significantly influenced cucumber growth and yield in homestead pawpaw more than in sunrise pawpaw. The NPK alone significantly influenced yield of cucumber in sunrise pawpaw more than the vegetative growth while the OMF had influence more on cucumber vegetative growth than on yield of both pawpaw varieties. The sole cucumber recorded lower responses to fertilizer types/rates compared to crop mixture which also had lower responses with zero t/ha application but had higher responses under 10 t/ha OMF and NPK fertilizer.

In conclusion, the crop mixture due to a synergy effect of shading and nutrient produced higher cucumber yield and performed favorably well compared to sole cucumber. In the consideration of economic land utilization and crop productivity, cucumber in pawpaw mixture with an approach of cucumber before pawpaw introduction would better the lot of cucumber growers. The higher and quick release of N in NPK which had significant influenced on cucumber reproductive growth and eventual final yield compared to OMF rates would be better for cucumber growers while the reverse was the case for pawpaw. However, the least response of zero t/ha application in growth and yield was indicative that cucumber responded well to nutrient application and that the zero t/ha fertilizer application should be discouraged in cucumber production. Moreover, intercropping advantage derived from the RYT and LER indices indicated that cucumber/pawpaw mixture could be profitably grown.

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