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Responses of 'Sunrise-solo' pawpaw, okra and cucumber components of pawpaw based cropping system to time of intercropping

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ABSTRACT

Between 2006 and 2007, field experiments were conducted at Abeokuta, Southwestern Nigeria to determine the response of 'Sunrise solo' pawpaw (*Carica papaya* L.) intercropping with okra (*Abelmoschus esculentus* L. Moench) var 'V35' and cucumber (*Cucumis sativa* L.) var 'Market-more' 3 weeks before transplanting (early), same-time (simultaneous) and 3 weeks after transplanting of pawpaw (late introduction). The experiment was a split plot design laid out in a randomized complete block design with three replicates. Vegetative and reproductive growth of pawpaw and intercrops were significantly retarded ($p \leq 0.05$) compared to monocrop in all components of the system. Planting vegetables before pawpaw or planting both simultaneously significantly enhanced flowering of pawpaw ($p \leq 0.05$) compared with intercropping pawpaw with vegetables 3 weeks after transplanting. Nonetheless, fruit yield of pawpaw was highest ($p \leq 0.05$) in late intercropping (42.7 t/ha) compared to simultaneous and early intercroppings (41.7 and 40.5 t/ha, respectively). Despite the yield reduction recorded under crop mixtures, higher land equivalent ratio (LER) of 1.61 and 1.94 was recorded for pawpaw in okra and cucumber mixtures, respectively and LER of 1.97, 1.67 and 1.68 for early, simultaneous and late introduction, respectively. The economic returns calculated indicated a profit margin of 67, 74 and 78% under one, two or three cropping times with cucumber compared to under sole pawpaw (64%), sole cucumber (56%) or sole okra (45%).

1. Introduction

The beneficial effects of intercropping systems compared to sole cropping with regard to increased productivity, weed control and diversification of outputs have been reported by many workers (Altieri, 1987; Aiyelaagbe and Jolaoso, 1992; Olasantan, 2001; Zhang and Li, 2003; Ofosu-Anim and Limbani, 2007). Although, cucumber and melon intercrops especially provide higher soil moisture content and cooler soil temperatures resulting in more conducive environment for improved growth and yield of the component crops (Ikeorgu, 1984; Ossom, 2003), physiologically related growth depression often observed in sole Homestead pawpaw (Aiyelaagbe et al., 1986; Olubode and Fawusi, 1998) at the physiological pawpaw transformation from vegetative growth to flowering/fruiting calls for an investigation on the most appropriate time to introduce intercrops in pawpaw crop mixtures, possibility raised a need to determine a safe period to introduce or not to introduce annual intercrops in pawpaw and thus necessitates more research into vegetable intercrops that could be compatible with pawpaw when grown as a major crop. The objective of this study therefore was to determine the best time to introduce a vegetable intercrop into a pawpaw orchard to enhance its productivity.

2. Materials and methods

The experiment was conducted between 2006 and 2007, at the University of Agriculture, Abeokuta, Ogun State, Nigeria (latitude 7°12′N, longitude 3°20′E at 100 m above sea level). The soil of the experimental plot was fine loamy at the 0–15 and sandy at 16–30 cm depth (Table 3). The moisture availability of the experimental location increased from 1153.4 mm in 2006 to 1201.6 mm in 2007. However, despite the triple peak in April, June and September of 2006 and the highest peak recorded in July of 2007, the means calculated for the location revealed a double peak rainfall pattern in June and September with a depression in August which is characteristic of the area. Sunrise solo pawpaw was intercropped with okra and cucumber planted 3 weeks before transplanting pawpaw (early), or at same time as pawpaw seedling or transplanted (simultaneous) or 3 weeks after pawpaw was transplanted (late). The experiment was a split plot laid out in a randomized complete block design with three replications. Main plot was crop mixture and sub-plot was the time of introduction. A mono-crop of pawpaw was planted separately as control. The sole treatment was

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Table 1
Parameters periods of measurement in component crops of pawpaw intercropped with okra or cucumber.

Crop component	Parameter measured	Interval
Pawpaw	Plant height (cm), stem girth (cm), number of leaves, leaf area (cm^2), canopy spread (cm).	Fortnightly
	Number of flowers, number of fruits and fruit yield (t/ha).	Every week
Okra	Plant height (cm), number of leaves, number of branches, leaf area (cm^2) (Asif, 1977).	Every week
	Number of pods, pod yield (t/ha).	Every week
Cucumber	Vine length (cm), number of leaves, number of side vines, leaf area (cm^2).	Every week
	Number of flowers, number of fruits and fruit yield (t/ha).	Every week

compared with intercropped pawpaw in a randomized complete block design replicated three times.

The two vegetables intercropped into pawpaw were okra (*Abelmoschus esculentus* L. Moench) var. 'V35′, an erect, day neutral and early yielding okra variety and cucumber (*Cucumis sativus* L.) var. 'Market-more', a creeping and downey mildew tolerant variety. The pawpaw (*Carica papaya* L.) variety planted was 'Sunrise solo', a hermaphrodite variety with pyriform red fleshed fruits, weighing 300–350 g. The choice of intercrops as based on their importance in local diets and their contrasting growth habits. The main plot was measured at 8 m × 6 m and was separated by 4 m-walk border. Pawpaw, okra and cucumber were spaced 2 m × 2 m, 0.50 m × 0.30 m and 1.5 m × 1 m, respectively. The intercrops were planted in the alleys of pawpaw leaving 50 cm from pawpaw seedlings. The plants were fertilized with Pace setter organo-mineral fertilizer (OMF) was applied at the rate of 10 t/ha.

The leaf area (cm^2) of pawpaw, okra and cucumber were determined non-destructively using regression equations $Y = 47.09\ X - 316.06$ for pawpaw (Aiyelaagbe and Fawusi, 1984), $Y = 115\ X - 1050$ for okra (Asif, 1977) and $Y = 12.9\ X - 54.31$ for cucumber (Aiyelaagbe and Adedokun, unpublished data). In these equations, '*Y*' is the leaf area (cm^2) and '*X*' is the sum of the media midrib (cm/plant). The fruit yield was determined by extrapolation of harvestable yields from female and hermaphrodite trees at 1850 per hectare assuming a 1:2:1 male to female to hermaphrodite ratio in the field. Monetary value was calculated at the current price while profit margin was obtained as the difference between production cost and revenue. The experiment was managed as an organic plot. The harvesting of the okra and cucumber intercrops commenced at 6 weeks after sowing (WAS), while the pawpaw fruits were harvested at the colour breaking stage. The experiment was strictly rain-fed. However, supplementary watering was done to offset soil moisture stress during the dry weather.

2.1. (a) Pawpaw okra cucumber trial – experiment I

In 2006, two-month-old pawpaw seedlings were transplanted into already dug 60 cm^3 sized holes. The juvenile pawpaw intercropped with okra and cucumber using the early, simultaneous and late sequences as described earlier. The early vegetable introduction three weeks before transplanting of pawpaw (19th June 2006), the simultaneous vegetable introduced at same time with pawpaw (10th July 2006), and the late vegetable introduced at three weeks after pawpaw establishment (31st July 2006).

2.2. (b) Pawpaw okra cucumber trial – experiment II

In 2007, seeds of okra and cucumber were sown into the alleys of mature pawpaw at the onset of rains, 3 weeks before, same time and 3 weeks after flowering respectively. The early vegetable introduced at three weeks before flowering (15th April 2007), the simultaneous vegetable introduced at same time with flowering (2nd May, 2007), and the late vegetable introduced at three weeks after pawpaw flowering commenced (28th May, 2007).

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) (Wiley, 1979a,b). The profit margins were calculated in percentage of the profit based on the totality of farm resource inputs (labour, energy, organo-mineral fertilizer costs) in the year to determine the profitability of the cropping system.

Data collections by measurement of plant vegetative and reproductive growth parameters was made on the component crops which are described in Table 1. These were subjected to the analysis of variance procedures (SAS, 1990). Treatment means for each parameter measured were compared using the least significant difference (Figs. 1–3) and standard error technique (Tables 2–4) (Gomez and Gomez, 1984).

3. Results and discussion

3.1. Vegetative growth response of component crops

Intercropping juvenile pawpaw with okra or cucumber significantly decreased ($p \leq 0.05$) plant height and canopy diameter of pawpaw, but it did not significantly influence Leaf Area Index (LAI). The effects of intercropping with okra or cucumber did not differ significantly from one another (Fig. 1A–C). The sequence of intercropping with vegetables (before, simultaneously or after transplanting pawpaw) did not have consistent effects on the vegetative growth of juvenile pawpaw (Fig. 1D–F).

With the exception of the initial higher plant height and higher leaf area of early introduced okra in juvenile pawpaw, sole okra was higher ($p \leq 0.05$) in leaf area (Table 5), but sole okra was not different from early or simultaneous okra introductions while both were better than late okra. The sole cucumber was significantly better ($p \leq 0.05$) in main vine length and leaf area in juvenile pawpaw (Table 5), but was not different from cucumber early in main vine length. The lower responses were recorded by cucumber early, simultaneous and late introductions in leaf area.

Though there are several factors that contribute to inter-annual variations of LAI (Martens et al., 1993), the LAI as an indicator of stress can be used to compare canopy development over time (Marschner, 1986; Correia et al., 2004). In pawpaw, the higher responses of sole pawpaw in plant height and canopy spread indicated that crop mixtures retarded juvenile pawpaw growth but the reduced LAI of the intercrops indicated significant stress imposition by the pawpaw. The trend of pawpaw plant depression observed in okra mixtures indicated nutritional stress at the juvenile pawpaw stage but a physiological stress at mature pawpaw.

Palaniappan (1985) and Olasantan and Lucas (1992) have both separately described taller and shorter component crops responses to light interception in mixtures. The effects of intercropping mature pawpaw with cucumber on plant height did not differ significantly from those of sole pawpaw. However, intercropping mature pawpaw with okra significantly decreased ($p \leq 0.05$) its plant height compared with sole pawpaw or intercropping with cucumber which indicated that either cucumber in pawpaw had an ameliorative effect on the microclimate which confirms Ikeorgu