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Influence of OMF Application Rates on Post Field Soil Fertility Status under Pawpaw (*Carica papaya* L.) Varieties

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Abstract**—**Field study was conducted to determine the post field soil fertility status responses of pawpaw (*Carica papaya* L.) var. homestead selection and sunrise-solo orchards to organo-mineral fertilizer (OMF) rates applied at 10, 20 40 t/ha where both the zero t/ha OMF and NPK 15:15:15 at 50 g/plant/month served as control. The result showed that all pawpaw orchards treated with OMF rates recorded significantly ($p \leq 0.01$) higher % P, % K, Na and % organic matter in soil compared to applied NPK which recorded lower Na. However, while orchards plated with sole pawpaw were higher in soil bulk density (SBD), orchards with homestead mixture were lower in SBD and significantly lower % organic matter compared to obtainable under sunrise crop mixture which recorded lower Na and Mg. In conclusion, as a result of loosening effect on soil particles, the homestead pawpaw probably due to more rooting activities as well as the addition of organic fertilizer to soils both had significant influence leading to lower SBD.

Keywords**—***Carica papaya* (L), growth and yield, organo-mineral fertilizer, soil fertility status.

I. Introduction

SUSTAINABILITY in organic farming encompasses not just conservation of non-renewable resources (soil, energy, minerals) but also issues of environmental and social sustainability [1]. Intercropping systems using biological methods of soil amendments including use of organic fertilizers are some of the other ways of sustainable agriculture [2] However also, organic farming methods with aid of organic fertilizers are characterized by quality of composting materials used and other aspects of biological pest control [1]. Positive effect of organic manure on pawpaw growth and yield [3] and ability to bind soils together absorb water and release nutrients steadily for vegetable crops [4] have been reported.

The influence of organic matter on soil biological and physical properties is well documented as it affects crop growth and yields either directly by supplying nutrients or indirectly by modifying soil physical properties [5]; [6], improve soil structures and water retentive capacity [7], increase infiltration rates [8] and decrease soil bulk density [9]. However, while high rate of nutrient release from fast decomposition occurs only when the organic substrate is rich in nutrients (low C:N and C:P ratios), the net nutrient release from organic matter is a function of decomposition ratios of organic matter fractions and uptake of nutrients by the growing biomass [10].

The application therefore of organic materials has a potential to increase plant yields to an extent above that based on the application of fertilizer equivalent nutrients [10]. The judicious use of composted organic fertilizers as sources of nutrient is essential to maintain soil health, improve efficiency of nutrients and obtain optimum crop yield. In this experiment, pawpaw cultivated with cucumber was supplied with Pace-setter OMF and NPK 15:15:15 fertilizers to determine the soil amendment influence on post cropping soil fertility status under intercropping systems.

II. Materials and Methods

The experimental conduced in 2008 was located at the Federal University of Agriculture, Abeokuta, Ogun State, Nigeria (latitude 7°12′N, longitude 3°20′E at 100m above sea level). The site had been previously cultivated and fallowed for three years before the trials. The weather data (Fig. 1) described the pattern of rainfall, mean air (maximum and minimum) temperatures, and relative humidity for the experimental period for the area. The composite analysis result (Table I) of the soil sample described the soil used at the 0-15 and 16-30cm.

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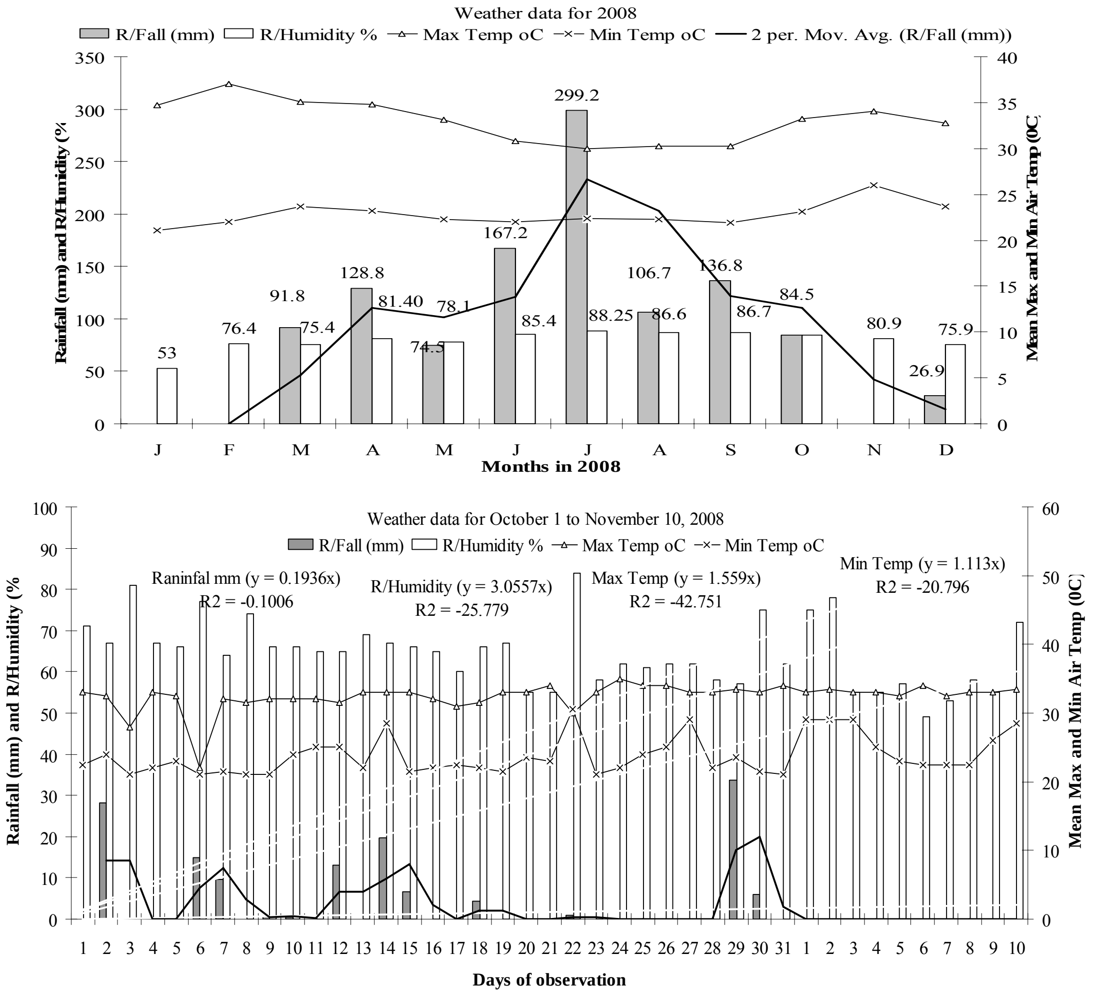


Fig. 1 The weather data of the experimental location (Source: Agromet Dept., University of Agriculture, Abeokuta, Location 7º12′N, 3°20′E)

The experiment was a split-split-plot design replicated three times. The main plot was the pawpaw varieties, the sub-plot was the crop mixtures and sub sub-plot was the fertilizer rates. The test crops included two varieties of *Carica papaya L.* var. homestead selection, a dioecious variety and sunrise solo, an hermaphrodite planted sole or mixed with cucumber and supplied with three OMF fertilizer rates at 10, 20 and 40 t/ha while zero (0) t/ha and NPK 15:15:15, both served as control. Each plot measured at 8m x 6m comprised of 12 pawpaw plants (2,500 plants / ha) and 32 cucumber plants (6,667 plants / ha). The cucumber (*Cucucmis sativus* L) var. Market-more, an creeping variety at a spacing 1.5m x 1m was introduced into plots of three months old pawpaw seedlings which were transplanted into already dug holes of 60 cm^3 size spaced at 2 m x 2m.

Soil samples were collected before planting and were dried, crushed, and sieved with a 2mm mesh before analysis. Weeding was done twice, staking of lodged pawpaw plants heavy with fruits was carried out when necessary, while pests and diseases were controlled, when virulent, using the methods described by [11]. Supplementary watering of pawpaw was done to offset the effect of the dry weather occurring between November and March (Fig. 1).

The data collected were subjected to the analysis of variance procedures [12]. Treatment means for each parameter measured were compared using the least significant difference technique [13].

TABLE I
THE RESULT OF ANALYSIS OBTAINED FOR THE SOIL USED IN PAWPAW FIELD

Depth (cm)	Particle size analysis			Chemical analysis					Exchangeable bases			
	% sand	% clay	% silt	Soil pH (H_2O)	% Org. C.	Org Matter	% N	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	7.74	1.24	2.14	0.086	7.98	0.25	0.54	4.77	0.95
16 – 30	82.6	9.35	8.05	7.18	0.87	1.50	0.065	8.05	0.16	0.42	2.16	0.48
Textural class: 0 -15cm: Sandy, 16 – 30cm: Sandy												

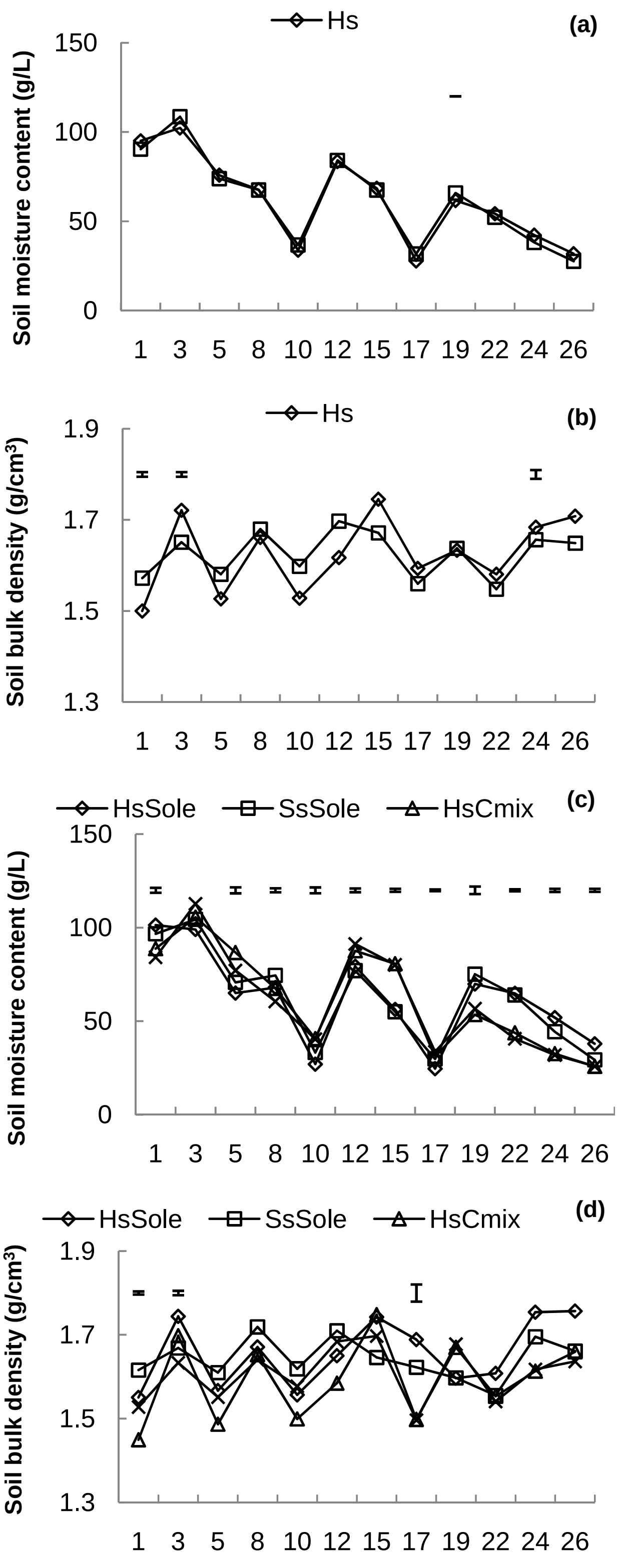
III. Results and Discussion

A. Post Cropping Soil Physical Status

With exception of higher soil moisture content (SMC) under sunrise at advanced stage of the trial, there was no significant difference in SMC under both varieties (Fig. 2 (a)). The initial SMC content had no consistent trend but at the wetter period crop mixture preserved moisture better than sole, while at a later period of the dry weather the moisture was preserved better in sole cropping compared to crop mixture (Fig. 2 (c)). This could be due to higher evapotranspiration under crop mixture at moderate rainfall or dry weather. The NPK was higher in SMC at initial period compared to OMF rates while unfertilized plot was least but as dry weather approached the OMF rates were better in SMC compared to NPK and the unfertilized plot (Fig. 2 (e)).

In bulk density (SBD), though inconsistent in trend with an initial higher sunrise response, sunrise was significantly better either at the initial stage or at the final stage. This could mean that homestead had more rooting activity leading to lower soil bulk density (Fig. 2 (b)). In the crop mixture, most of the times homestead mixture had the least SBD compared to sunrise crop mixture while the sole cropping of homestead and sunrise both were higher in SBD (Fig. 2 (d)). In the fertilizer trials, the significant response recorded at the trials showed significantly higher initial response of 10, 20, 40 t/ha OMF and unfertilized plots while NPK had the least but eventually 10 t/ha OMF , NPK and unfertilized were not different but were higher than 40 t/ha while 20 t/ha was least. This indicated that addition of OMF to soils lowers SBD as a result of loosening effect on soil particles (Fig. 2 (f)).

In the temperature responses, there was no significant difference between homestead and sunrise in the soil morning (SMT) and soil evening temperature (SET) except for the higher sunrise in SET compared to homestead (Figs. 3 (a) & (b)). The dynamics of soil amelioration under sole and mixed cropping of pawpaw showed that SMT at initial stage was higher with sole of homestead or sunrise compared to mixtures, while the SET at initial stage was higher with crop mixture and eventually higher with sole cropping (Figs. 3 (c) & (d)). This indicated that sunrays were prevented by crop mixtures thus ameliorating the environment compared to direct or easy heat penetration in sole cropping. Both [14]; [15] had reported improved crop performance under melon and cucumber, due 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. In fertilizer trials both SMT and SET were higher for the OMF rates compared to NPK (Fig. 3 (e) and (f)), probably due to the opaque nature of OMF, hence higher in absorbing heat and slower in releasing heat.



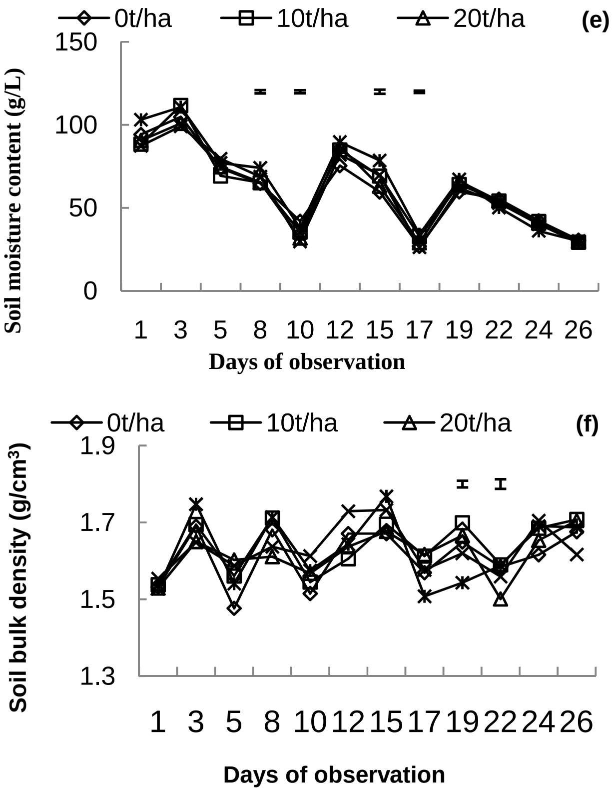
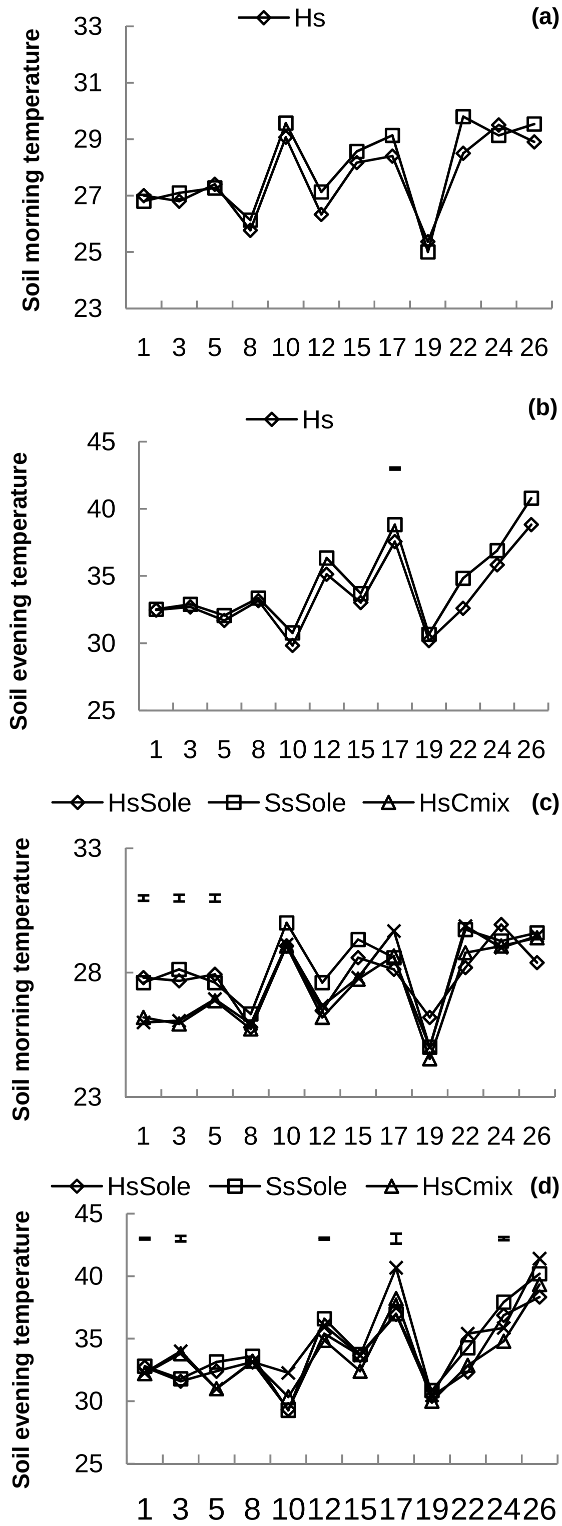


Fig. 2 Environmental changes in pawpaw orchards in responses to crop mixture with cucumber and applied organo-mineral fertilizer rates (OMF) showing ((a), (c) and (e)) Soil moisture effects on variety, crop mixture and OMF rates and ((b), (d) and (f)) Soil bulk density effects on variety, crop mixture and OMF rates. LSD to separate means at p≤0.05

In SAT and STR except for the higher response of sunrise at tail end of trial (Figs. 4 (a) & (b)), there was no significant difference between homestead and sunrise hence heat absorption and heat release were not different under both varieties. In crop mixture, during the wetter period, SAT was higher for sole compared to mixed cropping, while at drier period, SAT was higher for crop mixture (Figs. 4 (c) & (d)). This indicated that crop mixture moderated heat content of pawpaw orchards. The crop mixture while preventing SMC loss in wet periods equally prevent heat build-up but as it recorded more moisture loss in dry weather allows heat build-up which alongside competition for nutrient resources could have accounted for poor performances in growth and yield responses. However, most of the time, higher STR was recorded under crop mixture compared to under sole cropping due to lower heat in the morning and higher heat in the evening compared to sole cropping that had consistent continuous exposure to light transmission and heat build-up during the trials. Except for the lower SAT recorded for NPK, there was no significant difference in average temperature and in soil temperature ranges under the applied fertilizer types of rates. This indicated that at the early stage of the study higher heat accumulation occurred in plants treated with OMF rates probably due to lower organic matter of NPK. While the no significant difference in STR indicated that pawpaw plants under both treatments responded similarly in heat build-up and heat release (Figs. 4 (e) and (f)).



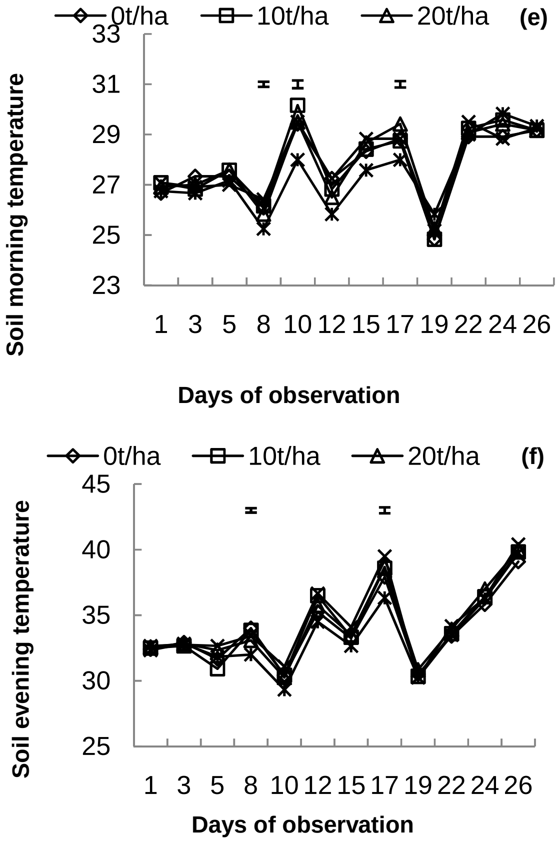
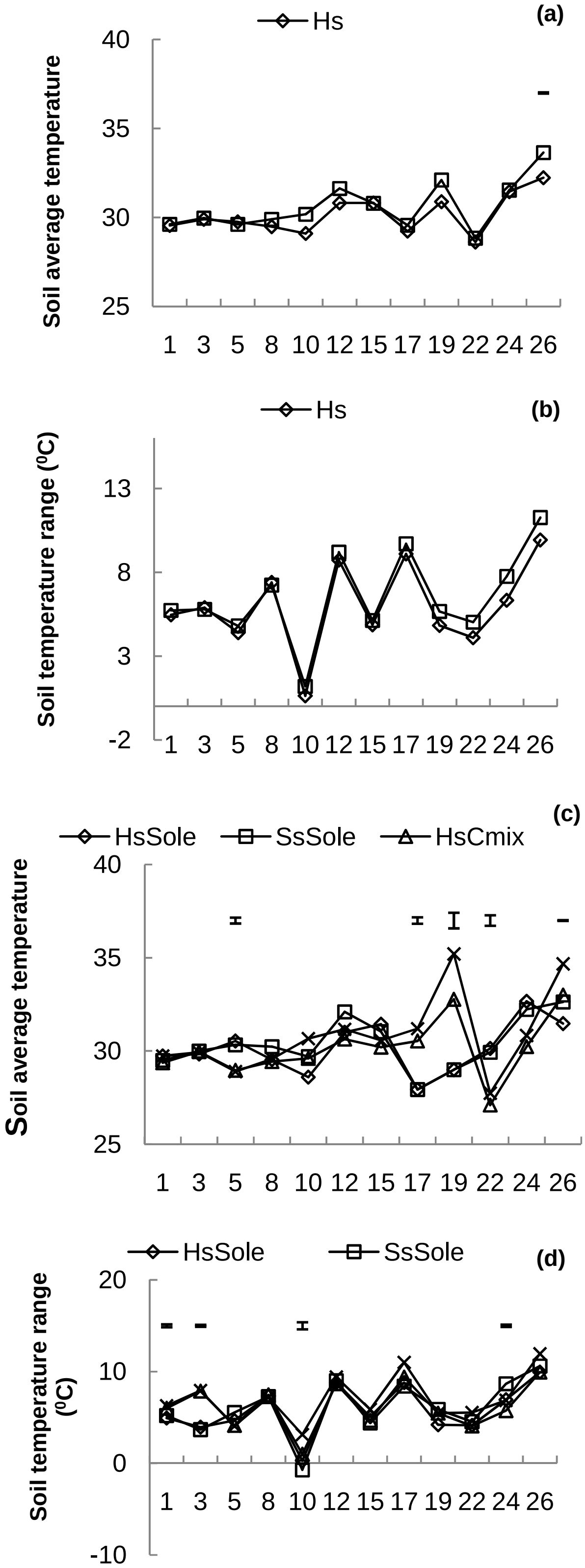


Fig. 3 Environmental changes in pawpaw orchards in responses to crop mixture with cucumber and applied organo-mineral fertilizer rates (OMF) showing ((a), (c) and (e)) Soil morning evening temperatures (TºC) effects on variety, crop mixture and OMF rates and ((b), (d) and (f)) Soil evening temperatures (TºC) effects on variety, crop mixture and OMF rates. LSD to separate means at p≤0.05

B. Post Cropping Soil Chemical Status

There was no significant difference in per cent sand, clay and macro or micro nutrient content of the soil under pawpaw varieties, however significant lower silt content in sunrise and higher soil pH and organic matter was recorded in sunrise pawpaw (Table II). This indicated that the lower silt but higher organic matter under sunrise could be an indication of a nutrient release from the silt content of the soil. The lower organic matter in homestead plot indicated that the variety could be a heavy feeder compared to sunrise. The higher % K and organic matter in sole indicated nutrient depletion in the crop mixture. In OMF rates, there was a heavy dilution of sand content with a resultant lower per cent sand in 20 and 40 t/ha OMF compared to NPK, 10 t/ha OMF and unfertilized plot. The silt content in the trend of 20 t/ha > 40 t/ha > 10 t/ha corresponded with trend of organic matter. This indicated the level of nutrient release which was lowest in 10 t/ha due to level of manure content where the lower release in 40 t/ha OMF compared to 20 t/ha could be due to rate of mineralization as described by [10.]. The lower soil pH of 40 t/ha alongside NPK was indicative of the inorganic content producing the acidic effect on soil. The corresponding higher P, K, Na and Ca in 40 t/ha compared to 20 t/ha or NPK indicated the available nutrient content commensurate with level of bulkiness.



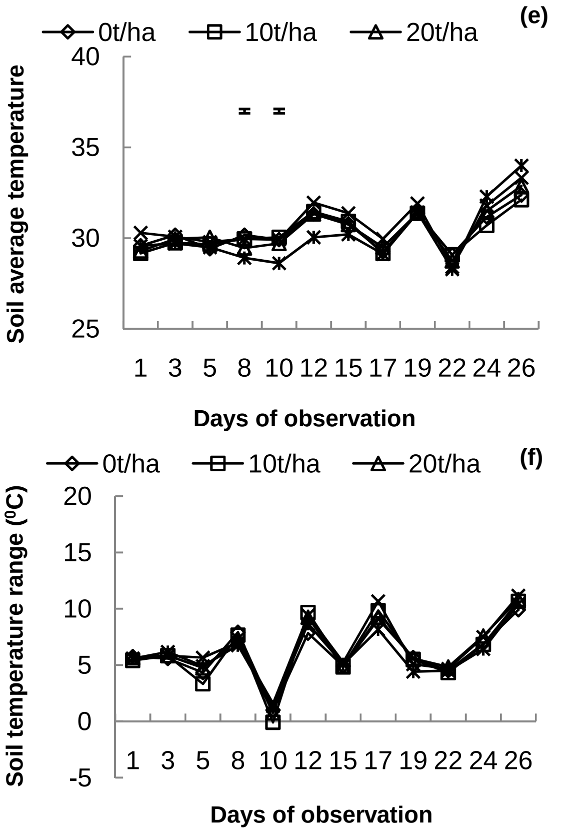


Fig. 4 Environmental changes in pawpaw orchards in responses to crop mixture with cucumber and applied organo-mineral fertilizer rates (OMF) showing ((a), (c) and (e)) Average soil temperature (T^0C) effects on variety, crop mixture and OMF rates and ((b), (d) and (f)) Soil temperature range (T^0C) effects on variety, crop mixture and OMF rates. LSD to separate means at p≤0.05

In conclusion, observation in this trial indicated that pawpaw responds well to fertilization, however the two varieties did not differ in nutritional requirements, while the optimum yield could be obtained with 10 t/ha OMF lower rates, though earlier report using poultry manure obtained moderate 20 t/ha as optimum [3]. Also, the positive effect of OMF on post cropping soil fertility status was observed whereby soil acidity levels were moderated and decreased by the increased Ca and Na addition to the soil. However, the non-significance of nitrogen and phosphorus showed the relative inadequacy of OMF to supply these nutrients to pawpaw regarded as a heavy feeder indicating that pawpaw in better performance in OMF compared to NPK was purely due to the supply of other nutrients which were not present in NPK. Moreover, the higher soil temperatures and lower soil moisture content under the sole cropping compared to mixed cropping indicated that pawpaw at a certain stage of the growth would need a companion crop to stabilize the microclimate. Notwithstanding the retardation effects on growth and yield and economic benefit of early income from the intercrop, the ameliorative effect of cucumber on the microclimate alongside productivity advantages also showed that cucumber could be adopted by pawpaw growers as a relatively compatible intercrop of pawpaw.

TABLE II
POST CROPPING SOIL PHYSICAL AND CHEMICAL PROPERTIES OF PAWPAW ORCHARDS IN RESPONSE TO CROP MIXTURE WITH CUCUMBER AND APPLIED OMF APPLICATION RATES

Treatments	Soil physical properties			Soil chemical properties		Macronutrients			Micronutrients		
	% Sand	% Clay	% Silt	pH (H_2O)	% O.M.	% N	P ppm	K cmol kg^{-1}	Na cmol kg^{-1}	Ca cmol kg^{-1}	Mg cmol kg^{-1}
Homestead	78.6	14.7	6.6	4.7	4.7	0.10	2.53	9.3	4.5	0.86	0.68
Sunrise	79.3	15.0	5.7	5.0	5.3	0.10	2.73	10.2	4.2	0.84	0.66
LSD var	ns	ns	0.1	0.05	0.02	ns	ns	ns	ns	ns	ns
Sole pawpaw	78.4	14.9	6.7	4.7	4.5	0.12	2.37	10.2	4.4	0.81	0.67
Pawpaw in mixture	79.5	14.9	5.5	5.1	5.4	0.07	2.88	9.3	4.3	0.89	0.67
LSD cmix	ns	ns	0.3	0.05	0.2	ns	ns	0.3	0.06	ns	ns
0 t/ha OMF	80.3	15.0	4.5	5.1	4.7	0.07	1.53	7.0	4.2	0.79	0.64
10 t/ha OMF	80.2	13.9	5.9	4.8	4.7	0.13	2.69	9.8	4.7	0.83	0.66
20 t/ha OMF	76.9	15.1	7.9	5.0	6.0	0.13	3.07	11.9	4.4	0.88	0.69
40 t/ha OMF	77.6	15.6	6.8	4.7	5.5	0.08	3.86	12.8	5.3	0.92	0.70
NPK 15:15:15	79.6	14.8	5.6	4.7	3.9	0.07	1.99	7.3	3.2	0.83	0.67
LSD fert	0.7	ns	0.5	0.09	0.2	ns	0.2	0.7	0.2	0.03	ns
Interactions											
var x cmix	*	ns	**	ns	**	ns	ns	ns	**	ns	ns
var x fert	ns	ns	ns	ns	**	ns	**	ns	ns	ns	*
cmix x fert	*	ns	*	ns	*	ns	ns	ns	**	*	**
var x cmix x fert	ns	ns	**	ns	**	ns	*	ns	**	**	ns

* = significant at 0.01, ** = significant at 0.05, ns = not significant, var = variety, fert = fertilizer cmix = crop mixture

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