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Growth and Forage Crops Yield and Mixture Productivity in Pearl Millet-Cowpea Intercropping System in Humid SouthWest Nigeria

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Abstract
The experiment aims to evaluate the growth and forage yield of component crops in a pearl millet-cowpea in a replacement intercropping system. The research was undertaken at the experimental site of the Department of Pasture and Range Management, Federal College of Agriculture Akure, Nigeria between June and November 2019. The experiment was carried out using a randomized complete block design with three replications. The intercropping experiment is based on the percentage of substitution of one of the intercrop components with the other. The treatments were sole pearl millet, sole cowpea, Intercrop of 50 % pearl millet + 50% cowpea, 75% pear millet+25% cowpea, 25% pearl millet+75% cowpea, 15% pearl millet + 85% cowpea. Seeds of the component crops were drilled into well-tilled plots each measuring 2 x 3m ($6m^2$). Growth parameters for pearl millet were measured at 3 and 5 weeks after planting while forage yields of component crops were evaluated at 8 and 16 weeks after planting and the crop mixture productivity was estimated. Data collected were analyzed using SAS version 9. The growth of component crops in the pearl millet-cowpea intercropping were mostly not significant ($p=0.05$). The crop mixture productivity indices were not significantly influenced when harvested at 8WAP. The relative yield total obtained was less than one (<1) which implied yield disadvantage in intercropping component crops at that stage of harvest. Harvesting at 16WAP resulted in significant crop mixture productivity with a more positive contribution and significant relative yield of cowpea in intercropped plots. The relative yield total obtained was greater than (>1) which is an indicative of yield advantage when forage mixtures were harvested at 16WAP. Crop mixture productivity was enhanced with delayed harvesting. Pearl-cowpea mixture for forage production at 25% pearl millet + 75% cowpea and 15 % pearl millet +85% cowpea are recommended with delayed harvesting up to 16WAP.
Keywords: Forage, substitutive intercropping, herbage yield, competition, yield advantage

Introduction

Intercropping, the most common form of multiple cropping is the growing of two or more crops simultaneously on the same piece of land (Andrews and Kassam, 1976; Famaye *et al*., 2011). The practice of intercropping allows component crops to grow close at the same time during the same season (Geiler *et al*., 1991; Ijoyah, 2012). Intercropping will positively impact the future food problems in developing countries as it has many advantages related to the complementary use of environmental resources by component crops, stable yield, better nutrient recycling, in the soil and increased biodiversity (Crews and People, 2004). Intercropping is adopted by farmers as a strategy to reach high productivity and promote sustainability. One way of increasing production by small farmers is to efficiently use all resources available in the production process (Mesike *et al*., 2009). Appropriate intercropping should therefore combine crops that have different demands from the environment. Cereal intercropping with legumes plays an important role in subsistence food production in both developed and developing countries (Tsubo *et al.,* 2015). Cereal and legumes both for forage and grains are the most common intercrops. Cereal-legume intercropping is among the most economical and effective agronomic strategies to boost forage biomass production, nutritional quality and monetary returns. Forages are important in the world's food resources as plant materials contain amounts of structured carbohydrates (Eskandari *et al*., 2009). Numerous studies have confirmed that more fodder produced from the combined production of cereals and legumes gave additional benefits of high provisions quality portions as measured against cereal fodder alone. Forage intercropping is reported to yields higher than sole crops (Serena and Brintha (2010). Pearl millet (*Pennisetum glaucum* (L.) R. Br.) is a dual-purpose annual crop mainly in drier areas of the tropics (Hanna and Torres-Cardona, 2001) and are rich source of food and fodder (Kheya *et al*., 2023). Pearl millet hybrids produce high forage yield but are mostly used in the United States, India and Australia Hanna and Torres-Cardona, 2001). In the southwestern part of Nigeria, the use of pearl millet as a cereal crop is not as common as it is for other major food crops which make it a suitable crop to be grown as a forage crop in the ecological zone as it does not compete with humans for use as food. Ajayi (2012) asserted that the non-cultivation of Pearl millet as forage crops in Southwestern Nigeria offers the crop to be grown as annual forage crops which can be grazed and/or conserved as silage as a substitute for maize. Pearl millet has the potential for high forage yield especially "Maiwa" and "Dauro" millet types grown in Nigeria. This is due to the photoperiod sensitivity which gives more room for extended vegetative growth before attaining the flowering stage. Intercropping with legume helps in increasing yield through the use of resources (Keatings and Carberry, 1993; Morris and Garrity, 1993). Intercropping pearl millet with legumes like cowpea (*Vigna unguiculata*) will increase the forage output and improve the nutritive value of the total biomass obtained. Cowpea, a leguminous crop from the family Fabaceae fixes Nitrogen and is also a good fodder crop having high protein content. Cowpea is one of the most widely used legumes and useful for its dual purpose (Cook *et al*., 2005). The distribution of crops in time and space has a significant influence on radiation interception. This tends to increase in intercropping with increased radiation interception through complete ground cover and improved canopy pattern (Ennin *et al*., 2002). Evaluating the planting pattern and crop combinations that might provide optimum forage yield as well as improve the forage quality is imperative. This research was conducted to evaluate the growth and forage yield of component crops in a pearl millet-cowpea in a replacement intercropping system.

Materials and Methods

The intercropping experiment was carried out at the experimental site of the Department of Pasture and Range Management, Federal College of Agriculture, Akure (Latitude 7°14ꞌ N and longitude 5°11ꞌ E). Akure is located in the humid rainforest zone of Nigeria characterized by bimodal rainfall. The rainfall data for the year is shown in table 1. Pre-cropping soil sampling was undertaken on the experimental plot and analyzed.

Experimental Design

The intercropping experiment conducted between June and November 2019 is based on the percentage of substitution of one of the intercrop components with the other. The experiment comprised of six treatments arranged in a randomized complete block design and replicated three times. The treatments were sole pearl millet, sole cowpea, Intercrop of 50 % pearl millet + 50% cowpea, 75% pear millet+25% cowpea, 25% pearl millet+75% cowpea, 15% pearl millet + 85% cowpea.

Establishment and Management

The seeds of "Dauro, a photoperiod sensitive cultivar of pearl millet were drilled into well-tilled experimental plots with each experimental unit measuring each measuring 2 x 3m ($6m^2$). The seeds were drilled at the rate of 10 kg/ha. The experimental plots measured $225m^2$. In the intercropped plots, the pearl millet seeds were drilled between the rows of cowpea planted or cowpea sown between the rows of pearl millet according to the substituted components. Planting was done on June 15, 2019. The experimental plots were weeded 4 weeks after planting and repeated at intervals based on weed growth incidence. Pest control on cowpeas was done using appropriate pesticides.

Establishment and Management

Growth parameters were measured at 3 and 5 weeks after planting. Data collected were pearl millet height, number of leaves per plant, stem girth, leaf area and number of tillers per plant. The forage yields were determined at 8 and 16 weeks after planting. Half of each treatment plot (equivalent to $3m^2$) was harvested at 8 weeks after planting while the remaining half of the plots were allowed to grow further and harvested at 16 weeks after planting when 50% of the population of pearl millet was at the boot stage (the stage grasses produce flag leaf which wrap the emerging tassel/inflorescences). The herbage components from the pearl millet and cowpea for each harvest were measured separately. The pearl millet herbage was assessed for its components by separating each one into leaves and stems. Measure of productivity for the forage intercropping was assessed using the relative yield and relative yield total indices. Relative Yield and Relative Yield Total are as expressed by De Wit (1960), De Wit (1965) and Anders *et al*. (1996).

Relative Yield (RY) = ya/yb

Where ya is the yield of a species in intercropping while yb is the yield in sole cropping.

Relative yield total (RYT) which is the sum of relative yields is expressed as:

RYT = rya + ryb + -----+ ryn

Where rya, ryb and ryn are the relative yields of species a, b and n, respectively.

Data obtained from the experiment were analyzed to estimate the variance using Statistical Analysis System version 9 (SAS, 2003). Where significance exist, the means were separated using Tukey's Honestly Significant Difference (HSD) test at a 5% probability level.

Results and Discussion

The result of soil analysis revealed that the experimental plot soil is slightly acidic with pH 5.05 (Table 2). The organic matter (OM) content (9.22g/kg) is examined to be low and below the critical OM content (< 20 g/kg). The soil Nitrogen (N) content is above the 1.5 g/kg critical value classified as low. The available phosphorus (P) is lower than the critical range value for available P (8-20 mg/kg) while exchangeable Potassium is classified as high (critical range >0.4 cmol/kg). The experimental soil is classified as sandy loam.

Effect of intercropping on the growth of component crops

The pearl millet-cowpea intercropping combinations adopted in the experiment have no significant effect on the pearl millet height at 3 and 5 weeks after planting (WAP). However, the pearl millet height differed significantly at harvest (Table 3). The tallest pearl millet was obtained from the intercropped plot with 15% pearl millet and 85% cowpea density. This could be as a result of reduced clustering of the millet associated with low density. The least plant height was obtained in the intercropped plot with 25% pearl millet and 75% cowpea. The stem girth was only significantly affected by the intercropping at 5WAP with intercropped plots 75% pearl millet and 25% cowpea and sole pearl millet plots having significantly higher stem girths but not significantly different from 25% pearl millet and 75% cowpea intercropped plots. At 3WAP, the number of leaves per plant obtained from intercropped plot with the combination of 75% pearl millet and 25% cowpea differ significantly from that of plot intercropped with 50% pearl millet and 50% cowpea. The number of leaves on pearl millet plants was not different at 5WAP. Number of tillers produced by the pearl millet was only significant at the time of harvest at 8WAP. Intercropped plots with 75% pearl millet and 25% cowpea recorded a significantly higher number of tillers per plant.

Effect of intercropping on the growth of component crops

With regards to the growth of cowpea in the intercropped plots, at 5WAP, cowpea plant height differs significantly with the highest obtained from the intercropped plots with 75% pearl millet and 25% cowpea but not significantly different from sole cowpea and plots with 85 and 75% cowpea density (Table 4). Intercropping with cowpeas influenced the leaf area significantly with the least leaf area recorded in the sole cowpea plot and significantly different from the intercropped plot with 15% pearl millet and 85% cowpea component with the highest leaf area. The pearl millet forage yield component of the intercrops was significantly influenced by intercropping. At 8 weeks after planting, the total forage yield obtained per plot was highest with sole pearl millet which is significantly higher than intercropped plots with lower density of pearl millet. The total forage obtained declined significantly with the higher percentage of reduction in the density of pearl millet in the intercrop. This trend was the same with the total herbage yield expressed per hectare basis.

The least forage yield obtained was from intercropped plots with 15% pearl millet and 75% cowpea but not different significantly from plots with 25% pearl millet + 75% cowpea and 50% pearl millet + 50% cowpea. At 16 weeks after planting, the total forage yield obtained per plot was also highest with sole pearl millet significantly higher than intercropped plots with a lower density of pearl millet. The forage biomass obtained from the pearl millet in the intercropped was not significantly different. The pearl millet leaf-to-stem ratio which is an indicator of forage quality was not influenced significantly at 8 and 16 WAP. The proportion of leaves was higher than the stem at 8 weeks after planting while the forage biomass at 16 weeks had a higher proportion of stem (0.67-0.77) compared to proportion of stem (0.28-0.48) at 8 weeks after planting.

The highest cowpea forage biomass at 8 weeks after planting was obtained from sole cowpea plots and significantly higher than those obtained from intercropped plots (Table 5). The least cowpea forage biomass was obtained from a plot intercropped with the least cowpea density (intercropped plot with 75% + 25% cowpea). The trend was the same with the total herbage yield expressed in tons per hectare. At 16 weeks after planting, cowpea biomass accumulated was highest with sole cowpea which is significantly higher than cowpea biomass obtained from plots with 75 and 85% cowpea components in the intercrop system. The least cowpea biomass was obtained from intercropped plots with a 25% cowpea component.

The intercrop productivity was significantly influenced by intercropping cowpea with millet at various density substitutions. The relative yield total (RY) for pearl millet forage component at 8WAP was highest in the plot with 75% pearl millet + 25% cowpea (Table 6). This decline significantly with increased density substitution with cowpea. However, other intercropped plots were not different for the relative yield of pearl millet. The measure of cowpeas productivity in intercrop (relative yield) was not significantly affected by the cropping system. At 16WAP, the measure of forage millet productivity with relative yield was influenced by the intercropping. Plot with 25% pearl millet + 75% cowpea recorded significantly higher relative yield although not different from 15% pearl millet + 85 % cowpea mixture. 75% pearl millet + 25 % cowpea mixture had the least relative yield.

The relative total yield (RYT) also technically referred to as land equivalent ratio was significantly influenced by the forage intercropping for harvesting done at 8 weeks after planting. It follows the same trend with the relative yield of pearl millet with the highest relative yield total obtained from the plot with 75% pearl millet + 25% cowpea combination and significantly higher than the RYT from the other intercropped plots. For harvesting done at 16 weeks after planting, the forage plots with 25% pearl millet + 75% cowpea resulted in significantly higher RYT while plot with 75% pearl millet + 25% cowpea combination recorded the least RTY.

Discussion

In a multiple cropping systems, several factors such as date of establishment or planting, density of planting, cultivars planted, soil management and agricultural practices adopted contributes to the productivity of component crops (Tsubo *et al.,* 2003). Establishing pearl millet with different densities of component crops in intercropping resulted in reduced performance of the component crops possibly due to a lack of differential timing in the introduction of the component crops. Superior and quality forage were obtained at 8WAP than at 16WAP as indicated by the leaf-to-stem ratio which is an indicator of forage quality and is expected for younger forage crops. The plant accumulates more cellulose as the plant ages and builds more stem.

Competition among the components for the finite poll of growth resources resulted in the decline in the growth and yield character (Iqbal *et al.*, 2019).

However, the magnitude of competition in an intercrop is determined by the level of complementary and supplementary relationships that exist (Ofori and Gamedoaghao, 2005). The lower yields obtained in intercropping shows that the crops in the intercropping crops did not complement each other in the use of resources.
One of the indices for measuring crop productivity in intercropping system is relative yield total (RYT) also referred to as land equivalent ratio (LER). LER in this case pointed out that there is the advantage of intercropping with efficient resource utilization over plant the respective crops as sole (Maitra *et al*., 2020). The RYT/LER obtained (<1) at 8WAP reflected disadvantages of intercropping pearl millet with cowpea. By implication it would be more desirable to plant the component crops as sole crops rather than growing them in intercrop if harvesting is sustained at 8WAP. Delaying the harvest which is a compromise for quality resulted in RYT/LER values greater than unity (>1) in intercropped plots with 50% or more substitution of pearl millet with cowpea in the forage mixture. RYT/LER obtained (>1) at 16WAP also reflected advantages of intercropping pearl millet-cowpea with an extended vegetative growth period. To overcome these challenges of reduced crop mixture productivity at the early harvesting stage when quality is expected to be higher due to the expected higher proportion of leaves, there may be a need to consider issues like variation in time planting component crops to minimize the competitive effect of component crops on yields. Differences in growth duration among intercrop components affect their resource use and can be maximized by deliberate manipulation of the time of planting. This is consistent with the assertion of Fukai and Trenbath (1993) on processes determining productivity in intercropping.

Conclusion

Forage crops production is important to the livestock industry in Nigeria and the need to produce sufficient and quality forage for ruminant animals without jeopardy for food for human consumption is critical. Evaluation of diverse intercrop combinations of pearl millet-cowpea mixture for biomass production was undertaken. While herbage yield was obtained from the two-component crops, the intercrop combinations resulted in varying biomass yield based on different densities of the crop mixture. The measure of mixture productivity (relative yield and relative yield total) showed that the different combinations of pearl millet and cowpea based on density substitution are not advantageous when harvested at 8WAP. It is more advantageous to grow the component crops separately if harvesting for forage is to be done at the young and vegetative phase. However, crop mixture productivity is enhanced at 16WAP in forage mixture with 50 % or more forage millet substituted with cowpea. Crop mixture productivity was enhanced with delayed harvesting. Planting Pearl millet-cowpea mixture for forage production adopting 25% pearl millet density with 75% cowpea and 15 % pearl millet density with 85% cowpea are recommended with delayed harvesting up to 16WAP.

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Table 1: Rainfall and temperature data of Akure in 2019

Month	Rainfall (mm)	Temperature(ºC)
January	39.1	33.8
February	143.94	33.09
March	93.08	31.76
April	146.47	32.22
May	417.84	29.86
June	468.58	27.34
July	431.32	26.15
August	358.32	25.88
September	480.9	26.57
October	628.18	26.87
November	170.05	30.22
December	17.17	33.22

Source: Weather and Climate (https://weatherandclimate.com/nigeria/ondo/akure)

Table 2: Pre-cropping physico-chemical properties

Parameter	Values
Soil pH	5.05
Total Nitrogen	2.80
Organic Matter	9.22
Available Phosphorus (mg/kg)	3.85
Exchangeable K (cmol/kg)	0.54
Exchangeable Na (cmol/kg)	2.96
Exchangeable Ca (cmol/kg)	1.92
Exchangeable Mg (cmol/kg)	1.05
Sand (%)	70.0
Silt (%)	14.0
Clay (%)	16.0
Textural class	Sandy loam

Table 3: Influence of intercropping on growth of pearl millet in pearl millet -cowpea intercropping system

	Plant height (cm)			Stem girth (cm)		Number of leaves		Number of tillers		
	3	5	At harvest	3	5	3	5	3	5	At harvest
Treatment		WAP*		………….. Weeks after planting………………						
75% pear millet+25% cowpea	42.92a	68.50a	102.79ab	4.29a	7.67b	16.75b	35.08a	3.58a	7.33a	15.33b
50 % pearl millet + 50% cowpea	38.75a	71.33a	105.30ab	2.21a	5.00a	7.67a	26.17a	1.33a	3.67a	7.67a
25% pearl millet+75% cowpea	38.50a	67.42a	99.00a	2.75a	6.33ab	11.42ab	31.00a	2.33a	4.67a	9.00a
15% pearl millet + 85% cowpea	40.33a	74.33a	109.00b	3.17a	4.83a	9.83ab	25.33a	1.67a	4.00a	7.33a
Sole pearl millet	43.17a	69.92a	104.30ab	3.21a	7.50b	14.42ab	27.17a	3.58a	5.33a	9.00a

Means with the same letter(s) are not significantly different (P= 0.05)
WAP = Weeks after Planting

Table 4: Influence of intercropping on growth of cowpea in pearl millet -cowpea intercropping system

	Plant height (cm)		Stem girth (cm)		Leaf area (cm^2)	
	3	5	3	5	3	5
Treatment	………………. Weeks after planting……………….					
75% pear millet+25% cowpea	14.25a	30.04a	1.46a	3.25a	22.30a	67.73ab
50 % pearl millet + 50% cowpea	14.00a	38.23b	1.42a	3.54a	25.53a	67.23ab
25% pearl millet+75% cowpea	13.50a	34.25ab	1.33a	3.25a	22.87a	65.64ab
15% pearl millet + 85% cowpea	13.00a	31.95ab	1.33a	3.42a	21.30a	75.97b
Sole cowpea	12.75a	31.88ab	1.17a	3.08a	21.28a	56.12a

Means with the same letter(s) are not significantly different (P= 0.05)

Table 5: Influence of intercropping on yield of component crops in pearl millet -cowpea intercropping system

Treatment	Total weight (kg)	Proportion of leaves	Proportion of stem	Herbage yield (t/ha)	Total weight (kg)	Proportion of leaves	Proportion of stem	Herbage yield (t/ha)
	------8 WAP------				------16 WAP------			
Pearl millet component								
75% pear millet+25% cowpea	1.97b	0.61a	0.39a	10.67b	6.93a	0.32a	0.67a	6.93a
50 % pearl millet + 50% cowpea	1.24ab	0.72a	0.28a	7.11ab	5.17a	0.30a	0.70a	5.17a
25% pearl millet+75% cowpea	0.90a	0.61a	0.39a	4.67a	7.23a	0.27a	0.73a	7.23a
15% pearl millet + 85% cowpea	0.86a	0.68a	0.32a	4.22a	5.17a	0.22a	0.77a	5.17a
Sole pearl millet	3.55c	0.52a	0.48a	20.22c	22.77b	0.32a	0.67a	22.77b
Cowpea component								
75% pear millet+25% cowpea	4.00a	0.41a	0.59a	24.22a	7.60a	0.31a	0.69a	46.02a
50 % pearl millet + 50% cowpea	5.70b	0.39a	0.61a	34.22b	13.50b	0.29a	0.71a	81.05b
25% pearl millet+75% cowpea	5.63b	0.39a	0.61a	32.44b	22.43c	0.29a	0.71a	129.24c
15% pearl millet + 85% cowpea	5.30b	0.49a	0.51a	29.11b	22.63c	0.39a	0.61a	124.29c
Sole cowpea	9.87c	0.49a	0.51a	59.56c	24.10d	0.39a	0.61a	143.97d

Means with the same letter(s) within column and intercrop components are not significantly different (P= 0.05)
WAP = Weeks after Planting

Table 6: Influence of intercropping on measure of productivity in pearl millet-cowpea intercropping system

Treatment	Relative yield		Relative yield total	Relative yield		Relative yield total
	8 WAP			16 WAP		
	Millet	Cowpea		Millet	Cowpea	
75% pear millet+25% cowpea	0.53b	0.30a	0.83b	0.41a	0.32a	0.73a
50 % pearl millet + 50% cowpea	0.35a	0.20a	0.58a	0.57a	0.56b	1.13b
25% pearl millet+75% cowpea	0.23a	0.32a	0.55a	0.54a	0.90c	1.44c
15% pearl millet + 85% cowpea	0.21a	0.20a	0.41a	0.49a	0.86c	1.35bc

Means with the same letter(s) within column are not significantly different (P= 0.05)
WAP = Weeks after Planting