EFFECT OF FERTILIZER TYPE ON THE LEAF SPOT DISEASE OF SWEET POTATO (*Ipomoea batatas* (L.) Lam) IN MAKURDI AND OTOBI, BENUE STATE, NIGERIA

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SUMMARY

*A multi locational study was conducted at the Teaching and Research Farm of the JS Tarka University Makurdi and the National Root Crops Research Institute Otobi Sub-station, Otukpo Benue State, Nigeria to determine the effect of organo - mineral fertilizers on naturally occurring leaf spot, growth and yield of sweet potato during the 2018 cropping season. The experiment consisted of three rates of mineral fertilizer NPK 15:15:15 applied at 100, 150 and 200 kgha^{-1}, three rates of organo-mineral fertilizer (Fertiplus® ®) at 1, 2 and 3 tons ha^{-1} and three rates of poultry manure applied at 5, 10 and 15 tons ha^{-1} laid out in a randomized complete block design with three replicates and an untreated control. The data collected were subjected to analysis of variance. Results of the study showed that the application of organo-mineral fertilizer had no significant ($P \geq 0.05$) effect on the incidence of leaf spot disease of sweet potato at 4 and 6 weeks after planting and leaf spot severity at 10 and 12WAP in both locations. In Makurdi plots treated with Fertiplus® ® 3t/ha and poultry manure at 15t/ha produced significantly greater number of leaves (33.53 and 32.67). The application of poultry manure at 15t/ha recorded the highest yield of 13.39 t/ha and 7.50t/ha at Otobi and Makurdi respectively. Leaf spot incidence was positively correlated with leaf spot severity (0.620**). There was negative significant relationship between leaf spot severity and number of marketable tubers (-0.515**) at Otobi. The use of poultry manure at 15tons/ha and NPK 15:15:15 150kg/ha reduced the leaf spot incidence and severity on sweet potato in the study area.*

Keywords: Organo-mineral fertilizer, Sweet potato, leaf spot, poultry manure

SWEET POTATO *(Ipomoea batatas* (L.) Lam) is a popular root crop in Nigeria. Nigeria is ranked the third largest producer of sweet potato after China and Uganda and cultivated 2.5% of the sweet potatoes produced in 2010 with per capita annual consumption of 22.3 Kg (Egeonu and Akoroda, 2010; Bergh *et al*., 2012). Sweet potato in Nigeria is ranked after yam, cassava and cocoyam (Babatunde *et al*., 2005). Sweet potato can be consumed by boiling and eating with stew, drying and milling into flour, roasting, frying into chips, pounding and eating with soup, made into pottage or fermented to make a local drink 'kunu' (Egeonu and Akoroda, 2010; Bergh *et al*., 2012). The leaves are used for animal feed while it is used industrially for making starch, candy, noodles, ethanol and biofuel production (Bergh *et al*., 2012).

Benue State in the Southern Guinea savannah is known for sweet potato production in Nigeria (Marti and Mills, 2002). Sweet potato production has been impacted by low soil fertility and the incidence of leaf spot diseases (Ilondu, 2013). The introduction of synthetic inorganic fertilizers may increase soil fertility but with a corresponding increase in plant diseases (Hoitink and Boehm, 1999; Bailey and Lazarovits, 2003). The progression of leaf spot infections may cause yield losses due to the reduction of assimilates deposited at the sink (Ilondu, 2013). The combined application of organic manure and inorganic fertilizers enhances long-term cropping in the tropics (Ipimoroti *et al*., 2002). The application of animal manure, green manure, composts and peats improves the

soil fertility and also decreases the incidence of disease caused by soil- borne pathogens (Magid *et al*., 2001). The application of organic and inorganic fertilizer may help to reduce the incidence and severity of leaf spot disease on sweet potato thereby increasing yield.

This study was conducted to determine the effect of varying rates of organic and inorganic fertilizations on leaf spot severity, growth and yield of sweet potato in Makurdi and Otobi in Oturkpo Local Government Areas of Benue State.

MATERIALS AND METHODS

The experiment was sited at the Teaching and Research Farm of the Joseph Sarwuan University, Makurdi, Benue State located between 7º45'01''N - 8º37'11''E 98m above sea level and the National Root Crops Research Institute Otobi Sub-station (7º11'10''N - 8º10'03''E) in Otukpo Local Government Area of Benue State, Nigeria in the Southern Guinea Savannah of Nigeria between August and October 2018.

The treatments consisted of three levels of mineral fertilizer NPK 15:15:15 applied at 100, 150 and 200 $kgha^{-1}$, three levels of organo-mineral fertilizer (Fertiplus®) at 1, 2 and 3 tons ha^{-1}, three levels of poultry manure applied at 5, 10 and 15 tons ha^{-1} and an untreated control. The experiment was laid out in a randomized complete block design with three replicates. Soil samples were collected from 0-30cm depth of the soil and analyzed for nutrient status using standard procedures (Table 1).

The poultry manure was cured for 7days and incorporated into the soil 2 weeks before planting. The inorganic fertilizer (NPK 15:15:15) and organo-mineral fertilizers (Fertiplus®) were applied 2 weeks after planting (WAP) using side placement method. The proximate nutrient composition for the poultry manure was pH 7.03, organic carbon 3.48%, OM 6.02%, N 1.96%,P 1.31 $Mgkg^{-1}$, K 0.36 Cmol, Na 0.40% , Mg 0.41%, 0.38% Ca,

Table 1: Chemical properties of the soil amendment materials used at experimental sites

Parameter	Fertiplus®	Poultry manure	NPK(15:15:15) %
pH	6.96	7.03	7.36
Organic carbon (%)	1.91	3.48	-
Organic manure (%)	3.30	6.02	-
Nitrogen (%)	1.56	1.96	13.72
Phosporus ($Mgkg^{-1}$)	4.80	1.31	10.75
Potassium (Cmol k)	0.27	0.36	9.70
Sodium	0.24	0.40	-
Magnesium	2.80	0.41	-
Calcium	3.10	0.38	-
Manganese (ppm)	69.00	32.6	-
Iron (ppm)	218.00	96.8	-
Copper (ppm)	71.00	2.98	-
Zinc (ppm)	134.00	28.4	-

Planting of sweet potatoes
The experiment was conducted on plots of 0.0012ha consisting of four ridges each 3 meters long. Planting was done using 25cm vine cuttings of sweet potato variety TIS-8164 sourced from National Root Crops Research Institute Umudike, Nigeria on the crest of the ridge at a spacing of 100cm by 30cm. Manual weeding was done at 4 WAP.

Data collection
Five plants were randomly selected and tagged from the two middle rows of each plot for data collection. Leaf spot incidence was determined as the number of infected plants per plot relative to the total number of plants per plot expressed as a percentage (Agrios, 2005). Disease severity was assessed on a scale of 0-4 (Onuegbu and Emiri, 2011) where,
0 - leaves without spot.
1 - Leaves with less than 5 spots.
2 - Leaves with 5-10 spots.
3 - Leaves with more than 10 spots.
4 - Dead leaves.

Growth and yield data collected included number of leaves, vine length, plant vigour, girth, leaf length and leaf width at 4, 6, 8, 10 and 12 WAP. Plant vigour was determined using the scale of 3-7 where 3= low, 5 = average and 7=good.

Data Analysis
The data collected were subjected to Analysis of Variance (ANOVA) using SAS statistical software (Statistical Analysis System, 2009) while significant means were separated using Duncan New Multiple Range Test (DNMRT) at 5% probability level. Correlation analysis was done using Pearson correlation at 0.05 and 0.01 level of significance.

RESULTS
Soil chemical and physical properties of experimental site
Results of the soil analysis from the two locations are presented in Table 2. The physical and chemical analyses showed that the soil of the experimental site was sandy loam with high proportion of sand 69.80 %, 10.00 % silt and 20.20 % clay in Otobi while the soil in Makurdi had 73.08 % sand, 11.92 % silt and 15.00 % clay with a neutral soil pH of 6.59 and 6.43, respectively. The soils from both locations were low in Nitrogen with 0.13% in Otobi and 0.10% in Makurdi. The phosporous content of the experimental soil in Otobi (3.80 mg $kg^{-1}$and Makurdi (3.00 mg kg^{-1}) were below the required amount of 6.80 mg kg^{-1}. The soil at Otobi had higher amount of exchangeable Ca, K and base saturation. Soil organic C and total N was also higher at Otobi.

Table 2: Physical and chemical properties of the surface soil at the experimental sites before planting

Soil Properties	Percent composition	
	Otobi	Makurdi
Particle Size distribution		
Clay (%)	20.20	15.00
Silt (%)	10.0	11.92
Sand (%)	69.80	73.08
Soil pH	6.59	6.43
Textural class	Sandy loam	Sandy loam
Exchangeable bases (Cmol kg^{-1})		
Potassium	0.23	0.21
Sodium	0.21	0.18
Magnesium	2.80	2.40
Calcium	3.00	2.70
Exchangeable base	6.24	5.49
Exchangeable Acid	1.10	1.00
CEC	7.34	6.49
Base saturation (%)	85.01	84.59
Chemical properties		
Organic carbon (%)	1.08	0.74
Organic manure/matter	1.86	1.28
Nitrogen (%)	0.13	0.10
Phosphorus (mg kg^{-1})	3.60	3.00

Table 3 shows the meteorological data at the experimental site during the period of the experiment. The total amount of rainfall recorded at the weather station in the experimental area between June and October 2018 was 722.2 mm with the highest rainfall recorded in August (245.8mm) while the lowest rainfall was recorded in July 2018 (44.1 mm). The minimum temperature (June to October) ranged between 22.0 ^{o}C in August to 22.5 ^{o}C in June while the maximum temperature ranged from 32.6 ^{o}C in October to 30.8 ^{o}C in August. The relative humidity ranged from 74 % in July to 93 % in September.

Table 3: Meteorological data at the experimental site during the 2018 cropping season.

Month	Rainfall (mm)	Rel. humidity (%)	Min. temperature (^{o}C)	Max. temperature (^{o}C)
June	139.1	80	22.5	32.1
July	44.1	74	22.2	31.3
August	245.8	83	22.0	30.8
September	219.3	93	22.4	31.4
October	73.9	79	22.2	32.6

Source: Tactical Air Command, NAF Base Makurdi

Effect of organo-mineral fertilizer on leaf spot incidence and severity

Table 4 shows the effect of fertilizer type and rates on the incidence of leaf spot disease of sweet potato at Otobi and Makurdi during the period of the study. The result showed that the application of organo-mineral fertilizer had no significant ($P \geq 0.05$) effect on the incidence of leaf spot disease of sweet potato at 4 WAP and 6 WAP at both locations. Similarly, the percentage leaf spot incidence was not significantly different across the soil amendment types and rates of application in Otobi at 8 and 10 WAP. At 8 WAP, the leaf spot incidence on sweet potato plants at Makurdi was significantly lower ($P \leq 0.05$) on plants where poultry manure was applied at 10 tons/ha (35.00 %) compared with the control (53.67%) while at 10 WAP, it was significantly lower ($P \leq 0.05$) when poultry manure was applied at 5 tons/ha (41.25 %) and NPK was applied at 150 kg/ha (46.98 %) compared with the control (62.50 %).

At 12 WAP in Otobi, leaf spot incidence was significantly lower ($P \leq 0.05$) on sweet potato plants treated with 15tons/ha of poultry manure (76.67 %) compared with other soil amendment types and rates and the control which recorded the highest leaf spot incidence of 98.33%. In Makurdi at 12 WAP, sweet potato plants where Fertiplus® was applied at the rate of 1ton/ha significantly ($P \leq 0.05$) reduced percentage leaf spot incidence by 21.77 % while the application of poultry manure at 5 tons/ha and 15tons/ha reduced leaf spot incidence by 12.09 %.

Table 4: Effect of fertilizer type and rates on the incidence of leaf spot disease of sweet potato at Otobi and Makurdi in 2018 cropping season.

Fertilizer type and rate	Percentage leaf spot incidence									
	4WAP		6WAP		8WAP		10WAP		12WAP	
	Otobi	Makurdi	Otobi	Makurdi	Otobi	Makurdi	Otobi	Makurdi	Otobi	Makurdi
Control	12.50a	13.20a	39.17a	24.40a	55.00a	53.67a	75.83a	62.50ab	98.33a	69.67abc
NPK 100kg/ha	9.17a	13.43a	32.50a	26.50a	58.33a	44.75abcd	73.33a	65.83a	88.33ab	66.00abc
NPK 150kg/ha	10.83a	9.87a	24.17a	23.10a	43.33a	45.25abcd	67.33a	46.98ef	83.33ab	72.50ab
NPK 200 kg/ha	13.33a	11.34a	26.67a	23.60a	49.17a	46.75abc	73.33a	53.25cde	90.00ab	68.50abc
PM 5t/ha)	9.17a	12.67a	30.83a	21.40a	55.00a	37.25cd	73.33a	41.25f	93.33ab	61.25cg
PM 10t/ha)	7.33a	13.37a	30.67a	20.40a	54.17a	35.00d	73.33a	50.50de	92.50ab	76.00a
PM 15t/ha)	11.67a	10.30a	31.67a	23.70a	52.50a	38.75bcd	69.00a	56.75bcd	76.67b	61.25cd
Fplus 1t/ha)	10.00a	9.33a	38.33a	19.20a	58.33a	49.00ab	76.67a	50.83de	83.33ab	54.50d
Fplus(2t/ha)	9.17a	9.74a	27.50a	18.00a	49.83a	42.80abcd	65.00a	59.33abc	94.17ab	73.17ab
Fplus3t/ha)	9.17a	8.87a	32.50a	20.50a	59.17a	39.13bcd	78.33a	49.15e	95.83a	65.50bc

PM= Poultry manure; Fplus= Fertiplus®. Values with the same letter(s) within the same column are not significantly different using DNMRT at 5% probability.

Table 5 shows the effect of fertilizer type and rates on the severity of leaf spot disease of sweet potato at Otobi and Makurdi during the 2018 cropping season. Data presented in Table 5 shows a 100 % increase of the severity of leaf spot disease in Makurdi from 1.00 at 4WAP to 2.00 (Leaves with 5-10 spots) at 6WAP in all treatments except in sweet potato plants treated with NPK at the rate of 100 kg/ha and 150kg/ha. In Makurdi at 8WAP, leaf spot disease was more severe in sweet potato plots treated with poultry dung at 10t/ha with a severity rating of 3.00. Although there were no significant effect of fertilizer type and rates on leaf spot severity at 10 WAP and 12WAP, the least leaf spot severity was recorded on sweet potato plants with the application of Fertiplus® at

the rate of 3t/ha 12 WAP with severity rating of 2.00 followed by the application of NPK at the rate of 100kg/ha and poultry manure at 15t/ha with severity rating of 2.33 in Makurdi. At Otobi, poultry manure applied at 15t/ha and Fertiplus® applied at 1t/ha recorded the least leaf spot severity rating of 2.00.

Table 5: Effect of fertilizer type and rates on the severity of leaf spot disease of sweet potato at Otobi and Makurdi during the 2018 cropping season.

Fertilizer type and rate	Severity of leaf spot disease									
	4WAP		6WAP		8WAP		10WAP		12WAP	
	Otobi	Makurdi	Otobi	Makurdi	Otobi	Makurdi	Otobi	Makurdi	Otobi	Makurdi
Control	1.00a	1.50ab	1.33a	2.67a	2.00a	2.67ab	2.67a	2.67a	2.67a	2.67a
NPK 100kg/ha	1.00a	1.00b	1.00b	1.33b	1.33ab	2.67ab	2.00a	2.00a	2.33a	2.33a
NPK 150kg/ha	1.00a	1.00b	1.00b	1.33b	1.33ab	2.67ab	2.33a	2.33a	2.33a	2.67a
NPK 200kg/ha	1.00a	1.07b	1.00b	1.67b	1.33ab	2.67ab	2.00a	3.00a	2.33a	2.67a
PM 5t/ha	1.00a	1.10b	1.00b	2.00ab	1.33ab	2.67ab	2.33a	2.67a	2.33a	2.67a
PM 10t/ha	1.00a	1.43ab	1.00b	2.00ab	1.33ab	3.00a	2.33a	2.67a	2.33a	2.67a
PM 15t/ha	1.00a	1.50ab	1.00b	2.00ab	1.00b	2.67ab	1.67a	2.33a	2.00a	2.33a
Fplus 1t/ha	1.00a	1.83a	1.00b	2.00ab	1.00b	2.00b	1.67a	2.33a	2.00a	2.67a
Fplus 2t/ha	1.00a	1.33ab	1.00b	2.00ab	1.33ab	3.00a	1.67a	2.33a	2.33a	2.67a
Fplus 3t/ha	1.00a	1.33ab	1.00b	2.00ab	1.33ab	3.00 a	2.33a	2.67a	2.33a	2.00a

PM= Poultry manure; Fplus = Fertiplus®. Values with the same letter(s) within the same column are not significantly different using DNMRT at 5% probability.

Table 6 shows the effect of fertilizer types and rates on number of leaves of sweet potato at Otobi and Makurdi in 2018. Data presented in Table 6 shows that at 4 WAP sweet potato plants produced the highest number of leaves when poultry manure was incorporated at 15tons/ha at both locations (22.13 and 14.87 at Otobi and Makurdi, respectively). At 6WAP the number of leaves produced by sweet potato plants treated with 15tons/ha of poultry manure was significantly higher ($P \leq 0.05$) with a value of 27.67 in Otobi and 29.73 in Makurdi compared with the number of leaves produced by plants treated with all other soil amendment types and the control at both locations. At 8WAP the number of leaves produced by sweet potato plants treated with 15tons/ha and 5tons/ha of poultry manure was significantly higher ($P \leq 0.05$) compared with all other soil amendment materials and the control at both locations. At 10WAP the number of leaves of sweet potato plants was not significantly different ($P \geq 0.05$) across the soil amendment types and rates applied at Otobi. In Makurdi, sweet potato plants in the plots where poultry manure was applied at 10t/ha (33.40) and 15t/ha (32.40) produced the highest number of leaves while NPK applied at 150kg/ha produced the least number of leaves (26.33). Number of leaves was not significantly different at Otobi 12 WAP. In Makurdi plots treated with Fertiplus® 3t/ha and poultry manure at 15t/ha produced significantly greater number of leaves (34.53 and 32.67) compared with plots where NPK was applied.

Table 6: Effect of fertilizer types and rates on number of leaves of sweet potato at Otobi and Makurdi in 2018.

Fertilizer type and rate	Number of Leaves									
	4WAP		6WAP		8WAP		10WAP		12WAP	
	Otobi	Makurdi	Otobi	Makurdi	Otobi	Makurdi	Otobi	Makurdi	Otobi	Makurdi
Control	7.53c	9.80c	20.20b	21.73bc	26.73b	24.27c	34.27a	29.00ab	36.33a	31.13abcd
NPK 100kg/ha	9.07c	1.07bc	23.87ab	27.33ab	30.87ab	29.40ab	33.40a	30.13ab	35.27a	30.93abcd
NPK 150kg/ha	9.00c	9.37c	23.40ab	21.80bc	32.27ab	29.40ab	34.80a	26.33b	35.07a	27.87bcd
NPK 200kg/ha	9.73c	10.53bc	22.87ab	25.27abc	30.93ab	30.40ab	34.67a	29.07b	33.67a	26.33d
PM 5t/ha	12.67bc	12.27abc	24.07ab	21.80bc	33.73a	31.13ab	39.20a	30.53ab	38.07a	32.53ab
PM10t/ha	16.47b	12.80ab	24.47ab	27.87a	30.67ab	29.67ab	36.40a	33.40a	36.47a	31.93abc
PM15t/ha	22.13a	14.87a	27.67a	29.73a	35.27a	32.60a	38.07a	32.40a	34.53a	32.67ab
Fplus1t/ha	11.13bc	11.67bc	26.47ab	25.20abc	32.20ab	27.33bc	34.73a	31.47a	32.53a	26.93cd
Fplus2t/ha	8.93c	9.93bc	22.00ab	21.33c	31.00ab	24.27c	35.53a	29.27ab	36.80a	31.40abcd
Fplus3t/ha	11.73bc	10.33bc	25.40ab	26.20abc	31.20ab	27.73abc	35.07a	31.80a	33.00a	33.53a

PM= Poultry manure; Fplus= Fertiplus®. Values with the same letter(s) within the same column are not significantly different using DNMRT at 5% probability.

Effect of fertilizer type on plant vigour

Data presented in Table 7 shows the effect of fertilizer type on plant vigour. At 6 WAP the application of poultry manure at the rate of 15tons / ha produced sweet potatoes plants with significantly good vigour of 7.00 at Otobi and 6.33 at Makurdi compared with the control with low vigour of 3.00. Sweet potato plants where Fertiplus® was applied at the rate of 1tons / ha, 3tons / ha and NPK at the rate of 150 kg/ha recorded a plant vigour of 5.00 classified as average vigour. At 8WAP all sweet potato plants where the soil was amended in Otobi recorded significantly higher ($P \leq 0.05$) plant vigour ranging from 5.67 to 7.00 (average to good) compared with the low vigour recorded in unamended control plants (3.00). In Makurdi, soil amendment with NPK fertilizer at the rate of 200kg/ha and poultry manure at the rate of 10tons/ha and 15tons/ha produced sweet potato plants with significantly higher vigour of 6.33 compared with those treated with the three rates of Fertiplus® and the control with low vigour (3.00). At 10 WAP in Otobi, the sweet potato plants which received soil amendment had good vigour (6.33 to 7.00) compared with the control which had low vigour (4.33). At Makurdi, plant vigour ranged from average vigour in control plants and plants in soils amended with Fertiplus® to good vigour of 7.00 obtained in plots amended with poultry manure at 10t/ha, 15t/ha and NPK at 200kg/ha. At 12 WAP plots amended with Poultry manure and NPK were more vigorous than the unamended control plot at both locations.

Table 7: Effect of fertilizer type on the Plant vigour of sweet Potato plants at Otobi and Makurdi

Fertilizer Type and rate	Plant vigour							
	6WAP		8WAP		10WAP		12WAP	
	Otobi	Makurdi	Otobi	Makurdi	Otobi	Makurdi	Otobi	Makurdi
Control	3.00c	3.00b	3.00b	3.00d	4.33b	5.00b	5.00b	5.00c
NPK 100kg/ha	4.33bc	4.33ab	7.00a	5.67ab	7.00a	5.67ab	7.00a	7.00a
NPK 150kg/ha	5.00abc	5.00ab	6.33a	5.67ab	7.00a	6.33ab	6.33 a	6.33ab
NPK 200kg/ha	4.33bc	5.00ab	7.00a	6.33a	6.33a	7.00a	6.33 a	7.00a
PM 5t/ha	4.33bc	5.67a	5.67a	4.33bcd	6.33a	6.33ab	6.33 a	6.33ab
PM 10t/ha	6.33ab	6.33a	7.00a	6.33a	7.00a	7.00a	7.00 a	7.00a
PM 15t/ha	7.00a	6.33a	7.00a	6.33a	7.00a	7.00a	7.00 a	7.00a
Fplus 1t/ha	5.00abc	5.67a	5.67a	4.33bcd	6.33a	5.00b	6.33 a	6.33ab
Fplus 2t/ha	4.33bc	4.33ab	7.00a	3.67cd	7.00a	5.00b	7.00 a	5.67bc
Fplus3t/ha	5.00abc	4.33ab	7.00a	5.00abc	7.00a	5.67ab	7.00 a	7.00a

PM= Poultry manure; Fplus= Fertiplus®. Values with the same letter(s) within the same column are not significantly different using DNMRT at 5% probability.

Table 8 shows the effect of fertilizer types and rates on yield parameters of sweet potato at Makurdi and Otobi in 2018. Although the application of soil amendment did not significantly affect the yield of sweet potato plants in Otobi, the application of 15t/ha produced the highest yield of 13.39t/ha followed by NPK 150kg/ha (13.11t/ha) and Fertiplus® applied at 3t/ha (13.00t/ha). The untreated control had the least yield of 4.66t/ha. Sweet potato yield in Makurdi was lower than yields recorded from Otobi. Sweet potato plots where poultry dung was applied at 15t/ha was significantly higher producing the highest yield of 7.50t/ha which was followed by the application of Fertiplus® at 3t/ha having a yield of 7.36t/ha. At Otobi, the application of NPK at the rate of 150kg/ha produced significantly higher ($P \leq 0.05$) number of marketable sweet potato tubers (65.33) which was comparable with the number of sweet potato tubers from all other plots except plots which received poultry manure at the rate of 10t/ha (30.33) and the control (28.00).

In Makurdi, sweet potato plants which received Fertiplus® at the rate of 1t/ha recorded the highest number of marketable sweet potato tubers (39.00) and this was comparable with the number of marketable tubers from all other soil amendment types and rates. The untreated control plots had the least number of marketable tubers of 20.67. The number of unmarketable sweet potato tubers recorded at Otobi was not significantly different ($P \geq 0.05$) among all the soil amendment types and rates. However, in Makurdi, the application of Fertiplus® at the rate of 1t/ha recorded the least number of unmarketable tubers (11.33) while the application of poultry manure to sweet potato plants at the rate of 15t/ha produced the highest number of unmarketable sweet potato tubers (45.33).

Table 8: Effect of fertilizer types and rates on yield parameters of sweet potato at Makurdi and Otobi in 2018 cropping season

Fertilizer type and rates	Yield (t/ha)		Number of marketable tubers		Number of unmarketable tubers	
	Otobi	Makurdi	Otobi	Makurdi	Otobi	Makurdi
Control	4.66a	3.19d	28.00b	20.67b	39.00a	26.33abc
NPK 100kg/ha	10.11a	4.45bcd	56.67a	25.67ab	74.67a	25.00bc
NPK 150kg/ha	13.11a	5.17abcd	65.33a	31.67ab	72.00a	25.67bc
NPK 200kg/ha	10.50a	7.14ab	55.33a	31.33ab	61.33a	23.00bc
PM 5t/ha	9.61a	5.44abcd	43.67ab	35.33ab	58.00a	30.67ab
PM 10t/ha	11.44a	6.67ab	30.33b	36.33ab	48.33a	14.67bc
PM 15t/ha	13.39a	7.50a	58.00a	31.00ab	69.00a	45.33a
Fertiplus® 1t/ha	10.67a	6.41abc	41.33ab	39.00a	49.33a	11.33c
Fertiplus® 2t/ha	9.00a	3.67cd	59.33a	24.33ab	71.33a	25.00bc
Fertiplus® 3t/ha	13.00a	7.36a	64.33a	35.33ab	62.67a	24.00bc

PM= Poultry manure; Fplus= Fertiplus®. Values with the same letter(s) within the same column are not significantly different using DNMRT at 5% probability.

Pearson correlation coefficient between disease, plant vigour and yield parameters of sweet potato plants in Otobi is presented in Table 9. Data presented in Table 9 shows there was moderate positive and significant relationship (P>0.01) between disease incidence and disease severity (0.620**), leaf spot severity and plant vigour (0.499**) in Otobi. There was however negative but significant relationship (P>0.01) between incidence of leaf spot disease and leaf area in Otobi (-0.469**). There was also negative significant relationship between leaf spot severity and number of marketable sweet potato tubers (-0.515**) while leaf area had moderate significant correlation with number of unmarketable sweet potato tubers (0.532**). Leaf area had moderate significant positive correlation with yield (0.426*) while leaf spot severity had a strong negative correlation with yield of sweet potato plants at Otobi (-0.702**).

Table 10 shows the Pearson correlation between disease incidence, disease severity, plant vigour and yield of Sweet potato in Makurdi. Data presented in Table 10 shows that in Makurdi, leaf spot severity had weak negative correlation with sweet potato yield (-0.012) while leaf spot incidence exhibited weak significant but negative correlation on number of marketable sweet potato tubers (-0.395*). Plant vigour had strong positive and significant correlation with yield (0.645**) and leaf area (0.667**).

Table 9: Pearson correlation coefficients between disease, plant growth and yield parameters of sweet potato plants in Otobi at 12 weeks after planting

	Number of leaves	Leaf spot Incidence	Leaf spot Severity	Leaf area	Plant vigour	Yield	Number of marketable tubers	Number of unmarketable tubers
Number of leaves	1	-0.098	-0.068	0.080	0.104	0.098	-0.022	0.008
Leaf spot Incidence		1	0.620**	-0.469**	-0.236	-0.556**	-0.498**	-0.309
Leaf spot Severity			1	-0.517**	0.499**	-0.702**	-0.515**	-0.186
Leaf area				1	0.687**	0.426*	0.447*	0.532**
Plant vigour					1	0.556**	0.386*	0.331
Yield						1	0.691**	0.023
No of marketable Tubers							1	0.448*
No of unmarketable tubers								1

**Correlation is significant at the 0.01 level 2-tailed

*Correlation is significant at the 0.05 level 2-tailed.

Table10: Pearson correlation coefficients between disease, plant growth and yield parameters of sweet potato plants in Makurdi at 12 weeks after planting

	Number of leaves	Leaf spot Incidence	Leaf spot Severity	Leaf area	Plant vigour	Yield	Number of marketable tubers	Number of unmarketable tubers
Number of leaves	1	0.035	0.108	0.055	0.228	0.077	0.057	0.271
Leaf spot Incidence		1	-0.040	-0.023	-0.205	-0.334	-0.395*	-0.114
Leaf spot Severity			1	-0.122	-0.211	-0.012	0.137	-0.306
Leaf area				1	0.667**	0.392*	0.162	0.303
Plant vigour					1	0.645**	0.531*	0.202
Yield						1	0.729**	0.025
No. of marketable tubers							1	0.010
No. of unmarketable tubers								1

**Correlation is significant at the 0.01 level 2-tailed

*Correlation is significant at the 0.05 level 2-tailed.

DISCUSSION

The soils of the experimental sites were classified as sandy loam and has a soil pH of 6.59 which is reported to be required for sweet potato production. Brandenberger *et al*. (2014) noted that sweet potato thrives in a sandy loam soil with rich soils producing high yield with an optimum pH of between 5.5 and 6.8. The soil analysis in the study indicated an acidic soil with reduced soil

nutrients at Otobi in Otukpo LGA. This result is in line with the report of Abah (2014) who noted that soils in Otukpo LGA are deeply weathered red and yellowish-brown soils developed essentially on sedimentary rock and hence lacking nutrients. Similarly, Ojo *et al*. (2014) reported that tropical soils were plagued with acidity, soil erosion and low nutrient content. This deficiency in soil nutrient is corroborated by the report of Aduayi *et al*. (2002) which reported that Nigerian soils are deficient in nitrogen, phosphorus and potassium. Marti and Mills (2002) also noted that Nitrogen availability increases sweet potato leaf area and tuber yield while excess Nitrogen reduces tuber yield

Although the Phosphorus content of the soil in the experimental site, Fertiplus® and poultry manure used for soil amendment was lower than the recommended soil phosphorus of 6.80mg/kg, as recommended by Kareem (2013a), the sweet potato plants in this study were able to produce moderate yield of sweet potato despite the low nutrient content. This result is in line with the report of Hartemink (2000) which reported low phosphorus demand in sweet potato plants. Kareem (2013b) observed that Phosphorus absorption was positively correlated with the number of leaves produced by sweet potato plants.

Leaf spot disease of sweet potato is an important disease of sweet potato occurring in areas with high humidity throughout the stages of its production and its occurrence could result in crop failure (Alabi and Waliyar, 2004; Amienyo and Ataga, 2008; Ilondu, 2013). Ekhuemelo and Nsobundu (2020) identified *Aspergillus flavus, Macrophomina phaseolina, Aspergillus tamarii* and *Fusarium verticillioides* as fungi inciting leaf spot disease on sweet potato plants in Makurdi. Waliyar *et al.* (2000) also noted that leaf spot resulting in leaf defoliation and leaf loss of between 25% and 43% could disrupt the photosynthetic process resulting in lower yield.

The result of this present study revealed that fertilizer types and rates had significant effect on the leaf spot incidence and severity of leaf spot disease on sweet potato at 12 WAP. This is in line with the report of Ekhuemelo and Olatunji (2015) which observed that NPK fertilizer and poultry application significantly increased the incidence and severity of leaf spot on pepper plants in Makurdi.

Although soil amendment in the form of fertilizer types affected leaf spot incidence of potatoes in the locations, the yield of sweet potatoes was moderate. This is in contrast with the report of (Ilondu, 2013) which reported reduced yield in sweet potato plants with leaf spot. Onunwa *et al*. (2021) reported nutrients were more readily released by poultry manure hence achieving an increase in yield compared with other soil amendments.

The increase in sweet potato yield could be attributed to tolerance of the sweet potato variety used in the study to leaf spot disease. Echezona and Nganwuchu (2006) observed that organic nitrogen sources may allow greater tolerance of vegetative damage due to the slow release of nitrogen. Ekhuemelo and Olatunji (2015) also reported increased yield of pepper when poultry manure was applied. The significant increase in growth and yield of sweet potato plants treated with poultry manure in the present study could be attributed to the ability of organic fertilizers to be retained in the soil compared with the chemical fertilizer (Ojo *et al*., 2014).

In conclusion, the study has shown that sweet potato plants treated with poultry manure at the rate of 15tons/ha had significantly lower incidence of leaf spots disease compared with other treatments. The application of poultry manure at 15tons/ha, and Fertiplus® at 1tons/ha to sweet potato plants recorded least severity of leaf spots disease with higher number of leaves and plant vigour. Highest yield was also recorded from the plot treated with poultry manure at 15tons/ha while highest number of marketable tubers was recorded from sweet potato plants treated with NPK 150kg/ha. The use of poultry manure at 15tons/ha and NPK 15:15:15 150kg/ha is recommended for the reduction of the leaf spot incidence and severity on sweet potato in the study area.

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