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Email: colplantjournal@funaab.edu.ng

Effect of Organic Amendments at Phosphorus Rate on Sulphur Fractions and Maize (*Zea Mays* L.) Performance in Soils of Southwest Nigeria

Bankole[1*], G. O., Aghorunse[1], A. C., Odelana[1], T. B., Sakariyawo[2], O. S., Adejuyigbe[1], C. O. and Azeez[1], J. O.
[1]*Department of Soil Science and Land Management, Federal University of Agriculture Abeokuta, Ogun State, Nigeria*
[2]*Department of Plant Physiology and Crop Production, Federal University of Agriculture Abeokuta, Ogun State, Nigeria*
*Corresponding author: Email: bankolego@funaab.edu.ng

Abstract
Sulphur (S) forms are important parameters in managing soil S status however; their importance on crops had not been fully elucidated. Incubation and screenhouse experiments were conducted to investigate the effects of cattle manure (CM), cattle manure and wood ash (CM+WA), poultry manure (PM), poultry manure and wood ash (PM+WA), and wood ash (WA) on S fractions and maize dry matter weight (DMW). Soils were collected from different agro-ecological zones. Animal manure and WA were applied at 90 kg P ha^{-1} and 5 t ha^{-1}, respectively. Samples were analyzed for available, adsorbed, organic and total S at an interval of 4 weeks. Maize DMW was estimated after harvest. Data were subjected to analysis of variance using DMRT at 5% level of probability. The application of amendments resulted to decrease in total and organic S and increase in available and adsorbed S contents. PM or CM resulted to higher available and lower adsorbed S contents than PM+WA, CM+WA and WA amended soils in incubation study while soils amended with PM+WA or CM+WA had higher available and lower adsorbed S than PM, CM and WA amended soils under screenhouse study. The combined application of organic amendments with WA recorded 30, 100 and 153% higher available S content than sole application of animal manure, WA and control, respectively, and also higher maize DMW than WA and control in screenhouse study. The study concluded that the incorporation of animal manure with wood ash enhanced the consistent supply of soil available S status above the critical limit.

Keywords: Maize, manure, nutrient release, soil S status, sulphur forms.

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Introduction

Sulphur (S) is an essential plant nutrient and plays a vital role in the synthesis of amino acids, chlorophyll and vitamins (Tiwari and Gupta, 2006). Plants absorb S mainly in the form of sulphate (SO_4^{2-}) ions through the roots, thus SO_4^{2-} ion must be present in soil solution in sufficient amount in order to meet crop S requirements (Brady and Weil, 2013). Extensive studies have been conducted on nitrogen (N) and phosphorus (P) as limiting nutrients for crop production in Nigeria (Ogunlela *et al.*, 1988), but not much on S nutrition. Fertilizer regime for cereal crops in Nigeria emphasizes continuous application of high rates of N, fairly high rate of P and K, with no attention given to S.

However, crop and soil deficiencies of S have been reported with increasing frequency in the last two decades in tropical soils (Scherer, 2001) resulting from soil organic matter depletion, leaching, erosion losses, continuous use of S-free fertilizers such as NPK, reduction of sulfur dioxide emission (Lehmann *et al.*, 2008), increasing cropping intensity with high yielding cultivars and highly weathered coarse soils (Sipai *et al.*, 2016) especially in high rainfall areas. Insufficient availability of sulphur to crop plants not only declines their growth and yield but can also deteriorate nutritional quality of the produce (Schonhof *et al.*, 2007).

Sulphur forms in soils varies widely depending on organic matter content, soil parent material, soil properties and the amount of S added via fertilizer amendments and atmospheric deposition (Scherer, 2009). The most important form of S uptake by plants is bioavailable sulphate ($SO_4^{2–}$) in the soil solution. This form represents usually only about 1% of total S (Knauff, 2000). Another form is adsorbed S which is weakly bonded on the surface of soil colloids (McLaren and Cameron, 1996). More than 95% of total S in soil exists in organic form (Bankole *et al.*, 2022) and becomes available through mineralization to sulphate in order to become available to plants.

Soil characteristics especially organic matter may influence S fractions, particularly available S by controlling the availability, mobility, retention and leaching characteristics of highly mobile SO_4^{2-}-S in soils (Biswas *et al.*, 2003). Animal manure is preferred amongst other organic manures because of it has high concentration of macro-nutrients (Duncan, 2005).

Previous studies (Adetunji, 1991; Ogunsola and Adetunji, 2016) have reported both synergistic and antagonistic relationship between S and P, depending on their rate of application and crop species. Synergistic effect was observed at 30 and 45 kg P ha^{-1} by Kumawat (2004). Antagonistic relationship was observed at 45 and 60 kg P ha^{-1} in mung and wheat (Islam *et al.*, 2006) and in maize (Muhammed *et al.*, 2015). Despite the general recognition of sulphate interactions in soils, little study on this aspect has been reported. Sulphate may be more available by the application of manure due to its high P contents. Limited information exists on the influence of organic source of P applied at higher concentration on S fractions. Therefore, this research was carried out to study the effect of organic amendments at 90 kg P ha^{-1} on soil S fractions and also its effect on maize performance.

Materials and Methods

Description of the Experimental Sites

The experiment was carried out at the Federal University of Agriculture, Abeokuta (FUNAAB), Ogun State, Southwest Nigeria with Latitude 7^0 12' 46.9"N to 7^0 20' 54.2"N and Longitude 3^0 20' 18.1"E to 3^0 42' 21"E, located in a tropical humid climate, characterized by distinct wet and dry seasons; having altitude of 108 meters above sea level. The research work consisted of incubation experiment carried out at Soils of Forest Island in Africa (SOFIIA) Laboratory and pot experiment conducted in the screenhouse of Centre for Agricultural Development and Sustainable Environment (CEADESE).

Soil samples collection and preparation

Soil samples were randomly collected at a depth of 0-15 cm in six different locations in the forest and savannah agro-ecological zones of Ogun State, Nigeria as shown in Table 1. Collected soil samples were air dried, pulverized, and sieved with 2 mm sieve and analyzed for soil properties.

Soil laboratory analyses

The prepared soil samples were analysed for pH in a 1:2 soil to water ratio using a glass electrode pH meter (McLean, 1982). Soil electrical conductivity was measured in the suspension by the method of Jackson (1973). Particle size distribution was determined by the hydrometer method as described by Bouyoucous, (1951). Total organic carbon was determined using acid dichromate wet oxidation procedure by Nelson and Sommer (1996). nitrogen was determined by modified Micro-Kjeldahl digestion technique as described by Jackson (1964). Available P was extracted by Bray-1 procedure (Bray and Kurtz, 1945). The exchangeable sodium (Na), potassium (K), calcium (Ca) and magnesium (Mg) in the soils were extracted with normal ammonium acetate buffered at pH 7. The extracted Ca and Mg were determined by Atomic Absorption Spectrophotometer (AAS) while extracted Na and K were determined by flame photometer. Exchangeable acidity was determined titrimetrically according to Mclean (1982). The effective cation exchange capacity was calculated as the sum of exchangeable cations and exchangeable acidity. Total S was determined by digestion of the soil with diacid mixture of nitric acid (HNO_3) and perchloric acid ($HClO_4$) in the ratio 3:1 (Chapman and Pratt, 1961). Available S was determined in 0.01 M $CaCl_2$ extract (Williams and Steinbergs, 1959). Adsorbed S was determined from S extracted with 0.01M $Ca(H_2PO_4)_2.2H_2O$ solution (Chesnin and Yien, 1951). Organic S was calculated as the difference between total S and adsorbed S. Sulphur in all the extracts was determined by the turbidimetric procedure of Chesnin and Yien (1951).

Table 1: Geographical co-ordinates of the collected soil samples

Location	Parent Material	Soil Order	GPS coordinate	Agro-ecological zone	Vegetation (land use history)	Distance above sea level (meter)
Alabata	Basement Complex	Alfisol	N07° 14' 21" E03° 26' 49"	Forest/savannah	Mixture of cropped, fallow land with weeds	174
Ojere	Basement Complex	Alfisol	N07° 05' 57" E03° 20' 32"	Forest/savannah	Fallow land with tress	61
Owode	Basement Complex	Ultisol	N06° 53' 59" E03° 26' 38"	Forest/savannah	Fallow land with grasses	70
Ijale orile	Sedimentary	Ultisol	N07° 11' 20" E03° 11' 16"	Savannah	Grassland under fallow	140
Ikenne	Sedimentary	Alfisol	N06° 50' 53" E03° 42' 34"	Forest	Grassland and trees	67
Obada	Sedimentary	Alfisol	N07° 05' 48" E03° 18' 17"	Forest/savannah	Fallow land with few trees	64

Phosphorus sources

The treatments included the control (no amendment), poultry manure (90 kg P ha^{-1}); poultry manure (90 kg P ha^{-1}) + wood ash (5 t ha^{-1}); cattle manure (90 kg P ha^{-1}); cattle manure (90 kg P ha^{-1}) + wood ash (5 t ha^{-1}) and wood ash (5 t ha^{-1}).

Treatments collection and preparation

Poultry and cattle manures were collected from College of Animal Science and Livestock Production Farm (FUNAAB). The management practices of the poultry and cattle were intensive and semi-intensive, respectively, and both poultry and cattle manures were found stored as heap within the livestock building. Collected poultry and cattle manure were air-dried and sieved with 2 mm sieve. Wood ash was collected from a renowned sawmill company at Obantoko, Abeokuta.

Incubation study (Experiment 1)

A closed incubation experiment was arranged in a Completely Randomized Design (CRD) with six treatments and six soils (Alabata, Ojere, Owode, Ijale-orile, Ikenne and Obada) in three replications which consisted of a total of 108 experimental units. The experiment was carried out for 12 weeks. Two hundred grams of six air dried soils were passed through 2 mm sieve, was dispensed into incubation plastic containers. Treatments were applied appropriately into each plastic and mixed accordingly. The samples were moistened and incubated for 12 weeks. Temperature of the experiment was recorded daily with the aid of a Laboratory thermometer. Soil samples were collected at 4 weeks interval and analyzed for S-fractions (total, organic, adsorbed and available S).

Screenhouse experiment (Experiment 2)
The pot experiment was conducted in a Screenhouse and was arranged in a CRD with four soils (based on their performance in the incubation study) and six P sources in three replications. This experiment was conducted in two cycles; 8 weeks each. Five kilogram of soil sample was weighed into a perforated pot with treatments applied separately into each pot. The samples in the pots were moistened and hybrid maize seeds were sown at 3 seeds per pot. The plant was thinned to one stand per pot after two weeks. Soil samples from the treatments were collected at 0, 4 and 8 weeks of the experiment and analyzed for S-fractions.

Harvesting of maize was carried out at 8 weeks of each planting. Maize shoots were cut from the root level in the trial pots and kept in a labeled paper bags to avoid decomposition; the plant samples were cleaned to remove contaminants before air dried. The dry matter weight (DMW) was determined by drying plant materials in an oven at temperature of ≤65°C to constant weight. The second cycle experiment was carried out immediately after the first screenhouse experiment to determine the residual effect of applied treatments on S fractions and maize DMW. The experimental procedure was repeated as in the first cycle.

Statistical analysis
Data collected were subjected to Analysis of Variance (ANOVA) using the GENSTAT statistical package 9th edition (David *et al.*, 2017). Treatment means were separated for significant difference using Duncan's Multiple Range Test at 5% level of probability.

Results

Physical and chemical properties of the experimental soils
The properties of the experimental soils as presented in Table 2 showed that the soils ranged from sand to sandy loam in texture. The pH of the soils ranged from very strongly acid (5.0) in Ijale-orile soil to slightly acid (6.2) in Ojere. Organic carbon content of the soils ranged from low (0.46%) to moderate (1.37%). Exchangeable cations ranged from 0.08 to 4.94 cmol kg^{-1}. The available P status of the soils ranged from low 4.31 mg kg^{-1} to medium 18.39 mg kg^{-1} with Ojere

being the soil with the highest inherent P while available S ranged from 7.17 to 14.19 mg kg^{-1}. The total nitrogen of the soils ranged from 0.04-0.14%.

Characterization of organic amendments used

The characterization of the organic amendments as indicated in Table 3 showed that the pH of wood ash was the highest (11.06) among others with a corresponding electrical conductivity of 4.39 ds m^{-1}. Similarly, the values of the exchangeable bases were highest. The total organic carbon content of the amendments and C:N ration ranged from 0.16 to 1.69% and 4.78 to 14.15, respect-tively, with cattle manure being the highest. Poultry manure had the highest amount of total N, while the mixture of poultry manure and woodash has the highest amount of total P and S. Generally, the micro-nutrient composi-tions of the amendments were of variable proportions.

Table 2: Physico-chemical properties of the soils used

Location			Particle size			Exch. Bases											Micro-nutrients			
	pH	EC	Sand	Silt	Clay	Ca	Mg	K	Na	Al+H	ECEC	Base Sat.	Total N	TOC	Av. P	Av S	Mn	Fe	Cu	Zn
	(H$_2$O)	(ds m^{-1})	……%……			……………cmol kg^{-1}……………						……%……			……………………mg kg^{-1}……………………					
Alabata	5.9	0.16	78.6	9.4	12	3.07	2.46	0.52	0.36	0.11	10.52	98.95	0.14	1.37	12.47	13.71	71.06	43.97	5.29	2.84
Ojere	6.2	0.12	90.4	5.2	4.5	4.94	2.54	0.18	0.2	0.1	7.97	98.74	0.06	0.46	18.39	12.17	61.4	50.64	1.95	4.19
Owode	5.8	0.02	89	3.6	7.4	3.84	2.27	0.24	0.51	0.13	6.98	98.14	0.04	0.49	10.48	14.19	56.9	30.49	2.79	3.75
Ijale orile	5.0	0.13	91	4.2	4.8	2.63	1.09	0.08	0.13	0.15	4.09	96.33	0.09	1.08	8.61	7.36	30.08	25.38	5.02	2.36
Ikenne	5.6	0.05	88.6	6	5.4	3.68	1.82	0.09	0.17	0.13	4.89	97.34	0.11	0.82	4.31	11.56	70.94	33.68	4.11	1.45
Obada	5.5	0.08	89.2	6.8	4	3.2	2	0.32	0.26	0.09	6.47	98.61	0.12	0.94	9.71	3.93	71.7	36.66	1.36	1.39

EC: Electrical conductivity, ECEC: Effective cation exchange capacity, Base Sat: Base saturation, TOC: Total organic carbon, Av P: available P., Av S: available S

Table 3: Characterization of the amendments used

Treatments	pH	EC	Ca	Mg	K	Na	Total Org C	Total N	C/N	Total P	Total S	Mn	Fe	Cu	Zn
	(H_2O)	(ds/m)		……………%……………………					Ratio		………………………g kg^{-1}……………………				
Cattle manure	7.99	1.43	0.35	0.26	0.17	0.11	1.69	0.12	14.15	2.97	1.73	0.11	1.03	0.14	0.16
Cattle manure + Wood ash	10.59	2.78	7.1	2.17	1.85	0.53	0.49	0.05	11.97	4.61	2.22	0.31	6.33	0.43	0.26
Poultry manure	8.43	1.87	3.2	1.84	0.28	0.18	1.58	0.14	11.51	5.18	2.98	0.24	2.75	0.28	0.19
Poultry manure + Wood ash	10.79	3.03	7.23	2.44	2.12	0.84	1.34	0.1	13.46	5.83	3.12	0.39	6.44	0.49	0.24
Wood ash	11.06	4.39	13.85	2.68	3.75	1.07	0.16	0.03	4.78	1.28	0.53	0.38	7.34	0.73	0.3

Incubation study (Experiment 1)

Available S

The effects of the amendments on available S (Av. S) in during incubation study are presented in Tables 4 to 6. Soil amended with animal manure and combined application of animal manure with WA recorded significantly higher Av. S content all through the periods of the experiment compared with control and WA treated soil. However, PM amended soil recorded the highest amount of Av. S among treated soils all through the incubation study. The highest amount of Av. S in all soils was recorded at 12 WAI except in Alabata (had highest Av. S at 8 WAI) while the least amount of Av. S was recorded in the control at 12 WAI in most locations except in Ijale-orile and Obada soils (where Av. S was lowest at 8 WAI). The mean Av. S content in soils amended with CM, PM and WA was 49, 88 and 46% higher and a further 353, 400 and 132% higher than the control at 4 and 8 WAI, respectively. Available S content in all treated soils followed this trend; PM > CM > PM+WA = CM+WA > WA > control except Ojere. At 12 WAI, the mean Av. S content in soils amended with PM and CM was 30 and 29% higher than PM+WA and CM+WA while at 0 WAI, Av. S was comparably higher by 7 and 8% in soil amended with PM and CM.

Adsorbed S

Soil treated with PM had the highest adsorbed S values except in soils from Alabata and Ikenne (from 0 to 4 WAI), and was significantly higher than the control and WA amended soil as shown in Tables 4 to 6. Manure treated soils (CM, CM+WA, PM and PM+WA) were observed to be significantly higher than control at 4 WAI, control and WA treated soil at both 8 and 12 WAI. As period of incubation increased, adsorbed S content in soils amended with CM+WA and PM+WA increased over CM and PM. The adsorbed S content in soils amended with CM+WA and PM+WA was 12.9 and 13.3% higher than CM and PM amended soil, respectively. At 12 WAI the adsorbed S contents in soils treated with CM, PM and WA was 62, 64 and 37% higher while at 0 WAI adsorbed S was comparably higher by 34, 40 and 18% than the control, respectively.

Table 4: Effect of amendments on sulphur fractionation in incubated soils of Alabata and Ijale-Orile

	Available S (mg kg^{-1})				Adsorbed S (mg kg^{-1})				Organic S (mg kg^{-1})				Total S (mg kg^{-1})			
Alabata	0WAI	4WAI	8WAI	12WAI	0WAI	4WAI	8WAI	12WAI	0WAI	4WAI	8WAI	12WAI	0WAI	4WAI	8WAI	12WAI
Control	15.15d	21.3c	13.65e	12.09e	33.78c	40.65c	31.9d	22.05e	194.23c	172.45e	170.29d	136.47e	228.01d	230.96d	202.19c	189.34c
CM	18.17cd	24.63bc	41.43a	35.31b	49.67a	50.2ab	55.9b	44.5c	385.2a	349.88b	325.61b	309.05b	430.87a	396.08b	338.51b	315.45b
CM + WA	21.2abc	24.34bc	28.77c	21.63c	39.81bc	47.78b	56.4b	64.35a	257.21c	226.31d	203.61c	180.94cd	287.03c	260.23d	247.34c	200.82c
PM	22.65ab	29.49a	45.72a	41.02a	48.4a	51.14ab	59.11a	50.95b	409.21a	385.5a	377.99a	357.23a	447.61a	433.64a	407.11a	388.18a
PM + WA	23.88a	25.66b	32.8b	22.49c	45.36ab	56.4a	60.23a	66.24a	294.64b	278.32c	221.13c	203.85c	330b	304.72c	244.7c	210.1c
WA	18.92bcd	21.27c	22.1d	17.43cd	43.61ab	44.6bc	46.3c	36.99d	228.75c	210d	177.29d	154.84de	252.36cd	238.6d	201.15c	190.6c
SE(±)	1.31	1.25	4.88	4.49	2.41	2.23	4.43	6.87	35.19	34.07	34.94	36.37	37.54	34.90	33.62	33.96
Ijale-orile																
Control	14.55b	21.95c	5.73e	5.59d	28.62d	36.15d	25.15d	18.43e	220.52c	197.83d	177.19d	171.95d	249.14c	213.97e	202.34e	190.38c
CM	18.06b	23.23bc	37.45ab	32.23b	41.03ab	53.41a	50.61b	47.45c	407.38a	390.92a	374.12a	322.13a	458.41a	454.33a	414.74a	339.58a
CM + WA	16.96b	23.18bc	28.28c	21.86c	37.42bc	44.24c	48.84b	56.47b	317.64b	267.46c	258.34c	210.9c	345.06b	291.69d	267.18d	237.37bc
PM	15.63b	30.14a	40.76a	42.89a	45.04a	49.46b	56.87a	48.02c	403a	366.7a	328.58b	318.78a	438.04a	386.16b	355.45b	346.81a
PM + WA	22.68a	27.71a	32.34bc	23.04c	39.26bc	46.2bc	59.15a	63.71a	339.02b	318.34b	297.05b	260.34b	368.28b	344.53c	306.21c	284.06b
WA	17.11b	21.63c	12.34d	10.27d	35.96c	43.12c	33.57c	28.08d	185.8c	170.77d	169.68d	156.65d	221.76c	213.88e	205.25e	204.73c
SE(±)	1.15	1.42	5.75	5.62	2.26	2.40	5.50	7.02	37.61	36.50	33.56	29.32	39.34	39.28	34.39	27.42

Means with the same letter(s) within the same column are not significantly different at $p \leq 0.05$; SE – standard error. WAI – weeks after incorporation; CM- Cattle manure (90 kg P ha^{-1}); PM – Poultry manure (90 kg P ha^{-1}); WA- Wood ash (5 t ha^{-1})

Table 5: Effect of amendments on sulphur fractionation in incubated soils of Ikenne and Obada

	Available S (mg kg^{-1})				Adsorbed S (mg kg^{-1})				Organic S (mg kg^{-1})				Total S (mg kg^{-1})			
Ikenne	**0WAI**	**4WAI**	**8WAI**	**12WAI**	**0WAI**	**4WAI**	**8WAI**	**12WAI**	**0WAI**	**4WAI**	**8WAI**	**12WAI**	**0WAI**	**4WAI**	**8WAI**	**12WAI**
Control	13.47c	14.53c	6.99e	5.77e	27.65d	35.3d	35.15c	28.71e	260.7d	172.32d	149.16d	129.87d	288.35d	197.62e	184.31e	138.59d
CM	18.09b	23.66b	31.31b	35.17a	41.09b	51.68c	57.61b	54c	389.4b	295.25b	288.89b	233.5b	410.49b	346.93b	316.5b	257.5b
CM + WA	19.27ab	24.55b	25.29c	24.99c	42.07b	61.37b	60.42b	58.77b	286.01d	253.18c	244.83b	203.44c	298.07cd	274.54cd	265.25c	222.21c
PM	24.38a	30.47a	37.37a	38.54a	48.13a	60.21b	59.37b	58.54b	441.23a	420.71a	364.59a	347.57a	469.36a	420.92a	383.85a	356.11a
PM + WA	23a	25.49b	35.99ab	30.79b	48.89a	67.5a	64.89a	64.86a	302.13c	286.92b	265.37b	225.27b	331.02c	304.52bc	290.26bc	260.14b
WA	15.77b	23.09b	15.87d	7.12e	37.48c	36.05d	38.63c	35.97d	275.4d	225.65c	180.74d	176.76c	292.87cd	261.7d	239.37d	224.73c
SE(±)	1.70	2.11	4.90	5.77	3.19	5.56	5.11	5.88	29.60	34.27	31.55	29.86	30.56	31.32	27.84	28.85
Obada																
Control	14.77c	16.77c	4.91c	6.31d	29.27d	23.8d	16.44d	8.2d	287.47c	268.68c	246.14c	202.54c	316.74d	302.48c	292.59c	260.73c
CM	20.71a	24.52b	33.86a	35.68ab	49.3b	50.86b	56.37b	47.97b	469.03b	431.1a	409.46a	362.96a	508.33b	461.97a	445.82a	390.92a
CM + WA	20.9a	26.98b	27.34b	31.31b	48.87b	53.75b	58.52b	57.51a	380.35c	358.45b	310.13bc	280.2bc	409.22c	382.2b	358.65b	327.71b
PM	16.31b	30.87a	35.28a	40.19a	55.92a	62.79a	67.51a	55.61a	544.01a	462.76a	424.75a	368.54a	579.92a	495.55a	452.26a	404.15a
PM + WA	16.16b	26.6b	30.51a	33.58b	44.55b	51.21b	56.42b	59.12a	381.34c	359.12b	318.19b	298.6b	415.89c	385.33b	374.6b	347.72b
WA	18.31abc	24.39b	19.78b	15.39c	38.88c	40.48c	36.67c	25.67c	301.56d	236.79c	209.05d	195.26d	340.44d	287.26c	265.72c	240.93c
SE(±)	1.04	1.91	4.66	5.40	3.81	5.50	7.65	8.49	40.16	35.98	35.04	30.61	40.86	33.92	31.29	27.23

Means with the same letter(s) within the same column are not significantly different at $p \leq 0.05$; SE – standard error WAI – weeks after incorporation; CM – Cattle manure (90 kg P ha^{-1}); PM – Poultry manure (90 kg P ha^{-1}); WA – Wood ash (5 t ha^{-1})

Table 6: Effect of amendments on sulphur fractionation in incubated soils of Ojere and Owode

	Available S (mg kg^{-1})				Adsorbed S (mg kg^{-1})				Organic S (mg kg^{-1})				Total S (mg kg^{-1})			
Ojere	**0WAI**	**4WAI**	**8WAI**	**12WAI**	**0WAI**	**4WAI**	**8WAI**	**12WAI**	**0WAI**	**4WAI**	**8WAI**	**12WAI**	**0WAI**	**4WAI**	**8WAI**	**12WAI**
Control	15.58c	13.2c	12.55d	10.74e	23.6b	33.21d	27.05e	21.41d	276.89d	248d	220.24d	201.03d	310.49d	281.2d	260.29d	242.44c
CM	19.74abc	25.15b	34.83ab	46.23a	42.12a	55.5ab	54c	59.98b	416.98b	383.87b	357.09b	322.23b	459.1b	419.38b	391.09b	352.2b
CM + WA	22.28ab	27.25b	32.39b	30.65c	43.36a	51.81b	53.95c	62.1b	345.44c	308.39c	289.62c	258.27c	388.8c	360.2c	343.57c	310.3b
PM	23.57a	31.25a	37.16a	39.4b	46.77a	57.52a	70.51a	63.48b	494.83a	460.53a	437.2a	417.23a	521.6a	508.05a	487.71a	450.7a
PM + WA	21.35ab	27.63ab	33.5b	31.2c	43.67a	56.6a	65.49b	70.21a	379.97bc	345.34bc	313.07bc	290.74bc	413.65c	391.95bc	368.56bc	330.9b
WA	18.12bc	27.32b	23.18c	15.81d	29.42b	40.23c	39.96d	30.9c	239.49d	223.13d	207.93d	194.28d	278.91e	263.36d	247.89d	225.1c
SE(±)	1.19	2.55	3.82	5.54	3.81	4.11	6.58	8.18	38.06	35.95	35.16	34.05	37.03	37.12	36.29	33.33
Owode																
Control	17.66b	13.72c	10.3e	7.3e	39.71c	40.65c	35.57c	23.54d	285.88d	242.3e	226.58e	200.95d	325.6c	282.94d	262.14d	224.5d
CM	16.09b	23.45b	35.62b	52.29b	52.6b	61.22b	64.58b	64.52b	438.92a	390.7b	346.24bc	316.89b	471.52a	421.92b	390.72a	351.4b
CM + WA	18.79b	22.69b	26.2c	37.03c	47.83b	67.71a	68.19ab	66.41ab	337.75bc	296.6cd	262.31de	232.12cd	365.58bc	324.31c	310.5bc	278.5c
PM	20.28ab	30.6a	41.43a	58.12a	59.33a	70.68a	71.58a	67.85ab	484.15a	447.2a	401.04a	371.83a	503.47a	477.88a	422.62a	399.6a
PM + WA	23.29a	26.28b	36.32b	39.13c	49.94b	70.3a	72.72a	72.62a	358.68b	330.36c	297.03cd	267.05c	398.61b	360.66c	339.76b	309.6c
WA	18.09b	23.06b	20.45d	16.63e	37.06c	40.46c	35.31c	32.68c	306.73cd	288.95de	242.11e	205.84d	333.79c	319.41cd	287.41cd	268.5cd
SE(±)	1.02	2.27	4.76	8.08	3.37	5.84	7.23	8.53	31.63	30.48	27.34	27.56	29.96	29.70	25.15	25.58

WAI – weeks after incorporation; CM – Cattle manure (90 kg P ha^{-1}); PM – Poultry manure (90 kg P ha^{-1}); WA – Wood ash (5 t ha^{-1})

Organic S

The highest value of organic S content was 544.01 followed by 494.83 mg kg^{-1} (Tables 4 to 6) in PM amended soils of Obada and Ojere, respectively at 0 WAI while the lowest value was 129.87 followed by 170.29 mg kg^{-1} in the control soils of Ikenne and Alabata, respectively at 12 WAI. Organic S was the dominant fraction of the total S in all treatments, the highest mean contribution of organic S to total S was 93.4% in PM amended soil followed by soils amended with CM (91.3%) and PM+WA (90.4%), while the lowest was 84.5 % in WA amended soil followed by 86% in the control.

In the incubation study, soil amended with PM recorded significantly higher organic S than other amendments except CM amended soil of Ijale-Orile and Obada. All manure amended soils had significantly higher organic S than the control. Significant differences were not observed between the control and WA amended soil, and soils treated with CM+WA and PM+WA though the formers had higher amount of organic S.

Total S

The highest total S content was recorded in PM amended soil except in Ijale-orile where CM amended soil had the highest S value (Table 4 to 6). The amount total S was not significantly different between soils treated with CM+WA and PM+WA, however, manure amended soils recorded significantly higher total S than the control and wood ash amended soil. Soil amended with WA, CM+WA, PM+WA, CM and PM had total S mean values of 3.9, 25.1, 36.4, 62.4 and 119.3% higher than the control. Total S content in treatments declined all through the 12 weeks of the incubation study, though it was observed to be more pronounced in the control (10.2%) compared to PM (7.4%).

Screenhouse (Experiment 2)

Available S

Soil treated with PM+WA recorded the highest amount of available S as presented in Tables 7 to 10, though, not significantly higher than CM+WA amended soils. Available S in manure amended soils was observed to be significantly higher than the control and WA, though, soil amended with WA was observed to record significantly higher amount of available S over the control only at 16 WAI in all soils except in Alabata where it was significantly higher from 8 to 16 WAI. Soil amended with PM+WA had significantly higher available S content compared to PM by 24.2%, likewise soil treated with CM+WA was 26.7% higher than CM amended soil and soil amended with WA had 27% higher available S than the control.

Adsorbed S

Soils amended with PM recorded the highest adsorbed S content (Table 7 to 10) and was significantly higher than other treatments while the control had significantly the lowest. Adsorbed S content in soils amended with CM and PM was 64% and 141% higher than the control at 8 WAI (end of first cycle) while a further increase of 160% and 238% over the control at 16 WAI (end of the second cycle), respectively. Soils amended with CM+WA and PM+WA had 49% and 58% higher adsorbed S than WA amended soil at 8 WAI, while at 16 WAI, 34% and 55% was recorded, respectively.

Organic S

The highest value of organic S content was 513.13 mg kg^{-1} followed by 503.51 mg kg^{-1} in PM amended soils of Obada and Ijale-orile, respectively, at 0 WAI while the lowest value was 121.17 mg kg^{-1} in WA amended soil of Owode at 16 WAI (Table 7 to 10). However, the highest and lowest mean organic S was 366.7 and 203.5 mg kg^{-1} in PM and control, respectively. The highest mean contribution of organic S to the total S was 89.7% in PM amended soil followed by soil amended with CM (88.9%) while the lowest was 85.5% in WA amended soil.

Organic S content in soils treated with CM+WA and PM+WA were observed to be significantly higher than WA amended soil and control. Organic S content in treated soils and the control decreased gradually as the periods of study increased, however, the highest and lowest decrease in organic S content was in CM+WA and PM amended soils by 13.3 and 7.8%, respectively, though highest and lowest rate of decrease of organic S in treated soils and control was recorded at 4 and 12 WAI by 19.4 and 6%, respectively.

Total S

The highest mean value of total S (Tables 7 to 10) in each location was observed in PM amended soil. Total S content in both PM and CM amended soils was observed to be significantly higher than PM+WA and CM+WA, respectively, while significant difference was not observed between CM+WA and PM+WA amended soils though soil treated with PM+WA had higher total S content. Manure amended soils had significantly higher total S content than the control and WA treated soil, however, soil treated with WA, CM+WA, PM+WA, CM and PM had 4, 25, 26, 38 and 44% higher total S than the control, respectively. Total S content in treated soils declined all through the study, though it was observed to be more pronounced in soil amended with WA that decreased by 12% compared to PM amended soil (7.5%), however, total S rate of decrease was highest at 4 WAI (12.7%) followed by 16 WAI (11.2%), while the least was at 8 WAI by 7.8%.

Effects of amendments on maize plant
Dry matter weights

Maize dry matter weights (DMW) produced by CM, CM+WA, PM and PM+WA were significantly superior to the control (Table 11). Soils treated with CM and CM+WA resulted to significantly higher DMW than WA amended soil except Alabata. Comparing the general effect of amendments on maize plant DMW, the highest DMW per plant was obtained in soil amended with CM followed by CM+WA, both observed in Ijale-orile soil while the lowest was noticed in Ijale-orile soil followed by Obada, both were control treatments.

The residual effect of CM, CM+WA and PM amended soils on maize plant DMW were significantly higher than the control. In the same pattern, manure amended soils were found to be significantly higher than the WA amended soil except Alabata soil treated with CM+WA. Comparing the residual effect of amendments, the highest maize plant DMW was recorded in Ijale-orile soil followed by Obada soil treated with CM respectively while the lowest was recorded in Ijale-orile soil followed Owode soil, treated with WA.

Discussion

The application of poultry manure resulted to high amount of soil available S during incubation study, this could be attributed to the fact that the applications PM contributed high available S content than other amendments. In incubation study, CM or PM amended soil recorded higher available S content than CM+WA or PM+WA, because higher amount of Ca^{2+} and Mg^{2+} in wood ash enhance the adsorption of SO_4^{2-} therefore reducing the amount of available S in an undisturbed system. Contrary to the incubation study soil amended with PM+WA under screenhouse condition had the highest available S content followed by CM+WA.

In the screenhouse, the highest available S content was at 8 WAI and gradually decreased as the period of study continued thus the second cycle of the screenhouse trial was characterized with continual decrease in available S content. According to Solomon *et al.* (2005), available S decrease could be as a result of soil floral utilization, plant up-take or leach to a greater soil depth by percolating water. The experimental control recorded the sulphate content (4.6 mg kg^{-1}) which was below the requirement of S for maize in Nigeria soil as reported by Kang and Osiname (1976) and Adetunji (1991). The study found that soil treated with PM+WA had the highest adsorbed S content, possibly due to poultry manure application, indicating WA's influence on organic S mineralization and $SO^4{}_{2-}$ adsorption. These results is in agreement with Srinivasarao *et al.* (2004) and Bankole *et al.* (2024) who reported that available S react with $CaCO_3$ when limed to get converted into insoluble and nonbio- available form to plant when not utilized by plant or soil organisms.

Adsorbed S content in CM+WA treated soil was 15% and soil amended with PM+WA was 16% higher than CM and PM amended soils, respectively, these results explained the influence of wood ash on the increase of adsorbed S content, several investigators also observed that SO_4^{2-} adsorption in soils increased in the presence of lime (Barrow 1972; Chao *et al.*, 1963; Marsh *et al.*, 1987; Marco-Martinez and McBride 1989). The mechanism of "cooperative adsorption" has been proposed by Marcano-Martinez and McBride (1989) as the possible mechanism in which Ca^{2+} and SO_4^{2-} form an ion pair which displaces the neighboring water molecule, so Ca^{2+} and SO_4^{2-} adsorption increased.

Table 7: Effect of amendments on sulphur fractionation in soils Alabata and Ijale-orile under Screenhouse study

	Available S (mg kg^{-1})			Adsorbed S (mg kg^{-1})			Organic S (mg kg^{-1})			Total S (mg kg^{-1})		
Alabata	**0WAI**	**4WAI**	**8WAI**	**0WAI**	**4WAI**	**8WAI**	**0WAI**	**4WAI**	**8WAI**	**0WAI**	**4WAI**	**8WAI**
Control	22.63c	10.92e	8.44d	25.55b	33.67e	29.52d	224.71d	190.69c	190.02c	250.26c	224.36c	219.54d
CM	27.13ab	33.45c	37.3b	35.57a	55.09b	54.5b	427.4a	378.72a	299.61a	462.97a	433.81a	354.11b
CM + WA	23.7bc	44.64a	42.52a	29.91b	47.32c	45.77c	352.66b	255.14b	234.22b	382.57b	302.46b	279.99c
PM	22.71c	29.2d	31.67b	34.21a	73.19a	71.13a	422.2a	354.14a	313.19a	456.4a	427.33a	384.32a
PM + WA	28.83a	39.31b	39.41a	33.43a	51.77bc	48.62bc	323.87b	251.15b	234.75b	357.29b	302.91b	283.37c
WA	18.21d	13.7e	21.27c	27.22b	38.97d	30.69d	268.53c	205.65c	200.81bc	295.75c	244.62c	238.5d
SE(±)	1.53	5.57	5.30	1.66	5.66	6.36	33.24	31.55	20.68	34.76	36.45	26.27
Ijale-orile												
Control	14.97c	26.54c	20.62d	17.07d	24.78d	27.21b	217.22d	194.74d	176.25d	234.29d	219.51d	213.47d
CM	33.02b	36.8b	39.26c	40.79b	59.96b	54.88a	426.77b	316.75b	298.83b	467.56b	376.7b	353.71b
CM + WA	37.48a	47.52a	49.3a	30.28c	55.84b	51.4a	336.02c	280.67bc	235.21c	366.3c	336.51c	286.61c
PM	31.07b	36.28b	44.28b	46.94a	75.37a	58.35a	503.51a	399.64a	391.66a	550.45a	475a	450.01a
PM + WA	35.57a	47.67a	50.29a	33.39c	57.29b	53.68a	337.44c	274.8c	266.79b	370.83c	332.09c	310.47c
WA	14.36c	19.89d	23.19e	16.93d	29.8c	31.11b	238.73d	216.12d	210.35c	255.66d	245.92d	241.47d
SE(±)	4.23	4.54	5.29	4.99	7.90	5.46	44.55	30.02	31.05	49.49	37.65	34.68

Means with the same letter(s) within the same column are not significantly different at $p \leq 0.05$; SE- standard error

WAI – weeks after incorporation; CM – Cattle manure (90 kg P ha^{-1}); PM – Poultry manure (90 kg P ha^{-1}); WA – Wood ash (5 t ha^{-1})

Table 8: Effect of amendments on sulphur fractionation in soils Obada and Owode under Screenhouse study

	Available S (mg kg^{-1})			Adsorbed S (mg kg^{-1})			Organic S (mg kg^{-1})			Total S (mg kg-^{1})		
Obada	**0WAI**	**4WAI**	**8WAI**	**0WAI**	**4WAI**	**8WAI**	**0WAI**	**4WAI**	**8WAI**	**0WAI**	**4WAI**	**8WAI**
Control	26.66c	21.37d	25.1d	32.46b	33.4d	34.87c	308.36c	290.81c	275.76c	340.81c	332.21c	310.63c
CM	34.13b	39.02c	40.38c	42.33a	62.99b	59.57b	473.85a	431.79a	398.69a	516.17a	494.79a	458.26a
CM + WA	39.97a	50.2a	50.44a	41.7a	55.12c	52.41b	398.44b	357.72b	303.6bc	440.14b	412.84b	356.02b
PM	34.83b	41.92bc	45.63b	45.07a	70.7a	67.76a	513.47a	469.76a	425.19a	558.54a	510.47a	482.96a
PM + WA	40.68a	44.07b	51.3a	43.41a	65.62b	55.79b	385.94b	334.94b	315.8b	429.35b	400.57b	371.59b
WA	20.8d	24.7d	26d	31.84b	37.77d	32.64c	279.69c	263.77c	248.9c	311.54c	310.53c	301.54c
SE(±)	3.17	4.65	4.78	2.36	6.28	5.70	37.03	32.59	28.39	39.15	33.33	30.73
Owode												
Control	19d	19.11d	18.46d	24.32c	26.68e	24.53c	228.14d	191.15c	160.24c	252.46c	217.83c	184.67c
CM	31.44b	30.16b	30.35c	32.8b	54.13b	52.13a	331.81ab	280.74a	271.14a	364.61ab	334.87a	323.27a
CM + WA	33.9ab	38.92a	39.85b	31b	43.14c	43.53b	298.8bc	248.02b	215.6b	329.8b	281.16b	259.13b
PM	23.5c	32.09c	39.33b	39.12a	59.68a	58.26a	364.58a	295.02a	280.7a	403.61a	335.7a	328.96a
PM + WA	37.26a	49.2b	40.6a	30.43b	52.63b	44.65b	252.96c	219.7b	215.66b	283.4c	272.33b	270.31b
WA	16.43d	19.72d	18.25d	23.79c	32.92cd	22.51c	185.47d	182.83c	165.5c	209.26d	205.75c	200.01c
SE(±)	3.47	4.70	4.32	2.33	5.30	5.93	27.38	18.92	20.70	29.58	22.64	24.58

Means with the same letter(s) within the same column are not significantly different at $p \leq 0.05$; SE- standard error
WAI – weeks after incorporation; CM – Cattle manure (90 kg P ha^{-1}); PM – Poultry manure (90 kg P ha^{-1}); WA – Wood ash (5 t ha^{-1})

Table 9: Residual effect of amendments on sulphur fractionation in soils of Alabata and Ijale-Orile under Screenhouse study

	Available S (mg kg^{-1})			Adsorbed S (mg kg^{-1})			Organic S (mg kg^{-1})			Total S (mg kg^{-1})		
Alabata	**8WAI**	**12WAI**	**16WAI**	**8WAI**	**12WAI**	**16WAI**	**8WAI**	**12WAI**	**16WAI**	**8WAI**	**12WAI**	**16WAI**
Control	8.44d	2.52d	1.89d	29.52d	18.44e	15.38d	190.02c	166.56d	154.19c	219.54d	185d	169.58c
CM	37.3b	34.89b	25.91b	54.5b	47.92b	40.62b	299.61a	290.91a	280.11a	354.11b	333.83a	304.73a
CM + WA	42.52a	38.01b	27.86b	45.77c	37.68c	30.33c	234.22b	205.5bc	194.83b	279.99c	253.18b	229.16b
PM	35.67b	32.29b	28.59b	71.13a	57.34a	52.05a	313.19a	308.65a	301.77a	384.32a	355.99a	333.83a
PM + WA	39.41a	47.41a	37.98a	48.62bc	43.52b	35.26c	234.75b	234.93b	198.57b	283.37c	278.45b	233.83b
WA	21.27c	15.66c	14.12c	30.69d	28.95d	22.62d	200.81bc	186.85cd	152.84c	238.5d	215.81c	175.47c
SE(±)	5.38	6.69	5.20	6.36	5.66	5.33	20.68	23.36	18.34	26.27	27.07	27.24
Ijale-orile												
Control	20.62d	15.58c	3.68e	27.21b	25.76d	16.33d	176.25d	166.35d	160.13d	213.47d	202.11e	194.56d
CM	39.26c	30.28b	22.73c	54.88a	43.2c	42.81b	298.83b	271.71b	248.31b	353.71b	284.91b	251.12b
CM + WA	49.3a	46.33a	38.65b	51.4a	48.42b	40.38b	235.21c	220.29cd	218.42c	286.61c	258.71c	238.8bc
PM	44.28b	36b	29.82c	58.35a	54.53a	50.77a	391.66a	376.05a	356.63a	450.01a	410.58a	350.4a
PM +	50.29a	46.68a	40.07a	53.68a	48.62b	43.66b	266.79b	249.39bc	233.08bc	310.47c	298.01b	253.74b

WA												
WA	23.19e	14.86c	10.21d	31.11b	25.87d	23.48c	210.35c	199.22d	185.41d	241.47d	235.09d	228.89c
SE(±)	5.29	5.78	6.09	5.46	5.04	5.43	31.05	29.87	27.87	34.68	29.39	21.36

WAI – weeks after incorporation; CM- Cattle manure (90 kg P ha^{-1}); PM – Poultry manure (90 kg P ha^{-1}); WA – Wood ash (5 t ha^{-1})

Table 10: Residual effect of amendments on sulphur fractionation in soils of Obada and Owode under Screenhouse study

	Available S (mg kg^{-1})			Adsorbed S (mg kg^{-1})			Organic S (mg kg^{-1})			Total S (mg kg-^{1})		
Obada	**8WAI**	**12WAI**	**16WAI**	**8WAI**	**12WAI**	**16WAI**	**8WAI**	**12WAI**	**16WAI**	**8WAI**	**12WAI**	**16WAI**
Control	25.1d	14.39c	6.59d	34.87c	26.15c	17.44e	275.76c	243.14c	225.07c	310.63c	259.28c	242.51c
CM	40.38c	34.77b	29.04b	59.57b	52.86b	44.58b	398.69a	351.08a	330.49a	458.26a	403.95a	355.07a
CM + WA	50.44a	45.48a	33.2b	52.41b	49.76b	34.56c	303.6b	284.5b	272.21b	356.02b	334.26b	326.76b
PM	45.63b	38.44b	32.59b	67.76a	64.54a	60.87a	415.19a	382.8a	364.32a	482.96a	427.34a	361.2a
PM + WA	51.3a	46.41a	40.86a	55.79b	50.61b	42.93b	315.8b	287.88b	274.93b	371.59b	338.49b	327.86b
WA	26d	18.44c	15.99c	32.64c	25.13c	22.97d	248.9d	225.22c	213.14c	301.54c	290.35c	266.12c
SE(±)	4.78	5.56	5.17	5.70	6.45	6.45	27.27	24.88	23.97	30.73	26.27	19.72
Owode												
Control	18.46e	13.93e	6.34e	24.53c	17.25c	15.9c	160.24c	154.32d	151.17d	184.67c	171.57d	167.07c
CM	30.35b	35.48c	26.63c	52.13a	46.71a	40.09b	271.14a	256.03a	240.9a	323.27a	292.74a	265a
CM + WA	39.85b	41.73b	37.53b	43.53b	35.9b	30.15b	215.6b	188.24c	174.54c	259.13b	221.14c	203.59b
PM	29.33c	36.6c	34.29b	58.26a	50.39a	47.88a	280.7a	262.29a	247.57a	328.96a	299.68a	274.56a
PM + WA	40.6a	46.89a	44.29a	44.65b	39.53b	33.82b	215.66b	210.85b	205.63b	270.31b	259.38b	219.46b
WA	18.25d	20.1d	13.19d	22.51c	20.36c	18.14c	165.5c	140.51d	121.17e	200.01c	172.87d	139.31c
SE(±)	4.00	5.22	6.00	5.93	5.55	5.07	20.70	20.72	20.52	24.58	23.22	21.72

WAI – weeks after incorporation; CM – Cattle manure (90 kg P ha^{-1}); PM – Poultry manure (90 kg P ha^{-1}); WA – Wood ash (5 t ha^{-1})

Table 11: Effect of amendments on maize plant DMW

First cycle	**DMW (g pot^{-1})**			
Treatments	**Alabata**	**Ijale-orile**	**Obada**	**Owode**
Control	13.31b	2.9c	3.93d	9.00c
Cattle manure	22.12a	22.77a	17.49a	19.87a
Cattle manure + Wood ash	21.75a	22.6a	15.06ab	14.15b
Poultry manure	21.72a	15.39b	10.76c	15.23ab
Poultry manure + Wood ash	20.62a	12.29b	11.26bc	14.82b
Wood ash	19.36a	5.47c	8.34cd	9.09c
SE(±)	1.36	3.42	1.96	1.69

Second cycle				
Control	3.81d	2.56e	4.13d	2.11d
Cattle manure	13.09a	14.79a	13.14a	9.82a
Cattle manure + Wood ash	7.36bc	10.04b	12.8a	9.38a
Poultry manure	8.44b	7.32c	8.72b	6.17b
Poultry manure + Wood ash	8.32b	4d	6.28bc	3.74c
Wood ash	5.3cd	1.57e	3.85d	1.71d
SE(±)	1.30	2.06	1.68	1.45

Means with the same letter(s) within the same column are not significantly different at $p \leq 0.05$
SE: standard error; DMW: Dry matter weight

Adsorbed S content in the screenhouse unlike in the incubation study, was higher in manure amended soil, this could be attributed to the fact that the presence of organic anions especially PO_4^{3-} in manure may compete with SO_4^{2-} for colloidal site thus SO_4^{2-} was repelled from the site and lost to lower depth of the soil. Mehlich (1964) found out that the increased absorbed SO_4^{2-} in soil solution was in relation to the addition of successive increment of $Ca(OH)_2$, therefore little SO_4^{2-}adsorption was expected in pot amended with PM+WA at the final week of the study.

Organic S was the major fraction of S and further increased with the application of amendment, in the incubation study the mean contribution of organic S to total S was highest in poultry manure amended soil (94%). The proportion of organic S to total S slightly decreased in all soils, though, decrease was more prominent in soil amended with WA. This showed the influence of wood ash on the mineralisation of organic S. Jat and Yadas (2006) reported that the distribution of organic S in soils could be influenced by lime. The decrease of organic S in pots with combined application of manure with wood ash was higher than manure amended pots alone. This could be that the presence of wood ash enhanced greater rate of decomposition and mineralization of organic S. The proportion of organic to total S decreased in all amended treatments when compared with the initial, this dynamic change of organic S in the fraction of total S showed that organic S in the treatment is not static but changed from one form of S to another through mineralisation, similar findings was reported by Kertesz and Mirleau (2004).

The total S content of treatments decreased throughout the studies, with the maximum decrease observed at 4 and 12 WAI, possibly due to higher mineralisation rates, this finding is in agreement with Maynard *et al.* (1983) who reported that immobilization, mobilization and mineralisation occur simultaneously but at different time. Soil amended with manure and wood ash showed a higher decrease in total S, likely due to increased microbial activities. However, wood ash co-precipitated SO_4^{2-}, causing a more pronounced decrease in total S and increased adsorbed S.

Maize DMW produced by organic amendments were significantly superior to the control and wood ash amended pot, this shows the application of manure with wood ash was beneficial to the growth and development of maize plant and also maintaining soil fertility, similar result was reported by Poonia (2000) and Olatunji and Ayuba (2011).

Conclusion

The study reveals that the combination of animal manure and wood ash in cultivated soils leads to higher available and lower adsorbed sulfur content compared to animal manure alone. This is compared to the sole application of animal manure in undisturbed systems. The study also found that while sulfur was deficient in cultivated soils, the combined application of animal manure with or without wood ash was effective in achieving high maize DMW.

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