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Full Length Research Paper

Shea waste slurry as an organic soil amendment of tropical soils in the Tamale Metropolis, Northern Ghana

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Infertile and less productive soil due to continuous cropping, poor soil management and other forms of land exploitation are mostly amended using inorganic fertiliser. Shea waste slurry (SWS) as an organic soil amendment material was applied to soils in two locations and its effect on plant primary and secondary nutrients evaluated. One-way diagonal method was employed in sampling soil from fields measuring 25 m×40 m at depths of 0-30 and 30-60 cm for SWS applied and non-applied soils. Results showed increased pH resulting from SWS application and EC increasing from 41.15±3.89 to 155.5±83.4 µS/cm in both locations. SWS application also increased %N levels at depth of 0-30 cm from 0.03±0.0 to 0.56±0.2%, concentration of P increased from 3.47±0.62 to 262.0±176 mg/kg and K from 21.9±2.39 to 231.6±98 mg/kg. Na levels increased from a low of 0.46±0.09 to a maximum of 2.81±1.0 meq/100 g in both study sites, Mg increased from 0.80±0.3 to 8.51±4.86 meq/100 g whilst Ca increased from 1.6±0.07 to 6.3±098 meq/100 g for the depth of 0-30 cm. Soil %OM and OC, respectively increased from 0.58±0.01 to 10.94±3.95 and 0.34±0.11 to 6.36 ±2.29% for the depth of 0 to 30 cm in both study locations. The study indicated a general increase in the levels of all the parameters analysed for the study at the SWS applied soils as compared to the non-applied soils. The use of SWS as a soil nutrient amendment in crop production as an organic material was observed to be very effective.

Key words: Shea waste slurry (SWS), organic soil amendment, tropical soil, plant nutrients.

INTRODUCTION

The success of soil management to maintain soil quality depends on the understanding of how soils respond to agricultural use and practices over time (Negassa and Gebrekidan, 2004). Ayoola (2006) reported improvement of environmental conditions and public health as well as the need to reduce costs of fertilising crops to also be important reasons for advocating increased use of organic materials. Excessive and inappropriate use of chemical fertilisers has been reported by different authors as a major cause of nutrient imbalance and degrading soils (Singh and Agarwal, 2001; Meena et al., 2003; Mahajan et al., 2008; Mukhtar et al., 2011).

According to Tran-Thi et al. (2004), among available means to achieve sustainability in agricultural production, organic manure and bio-fertiliser play an important and key role because they possess many desirable soil properties and exert beneficial effect on soil physical, chemical and biological characteristics. Crop yield increased from 30 to 50% resulting from application of commercial fertilisers as indicated by Vlek (1990) and

Stewart et al. (2005).

Shea butter is a product from the nuts of the Shea tree (*Vitellaria paradoxa*) mainly found in the savannah region of West Africa. The butter is used for domestic consumption (mainly as edible oil) and in some products of the cosmetic and pharmaceutical industries (Cof, 2016; Akparanta et al., 2017).

The Shea butter processing industry is an increasing economic venture which serves as the principal source of income, particularly for many women in northern Ghana (Jibreel et al., 2013).

According to Teketay et al. (2003), processing of the Shea butter from the Shea fruit is labour-intensive activity mainly carried out using traditional techniques by women. The basic processes for the butter extraction begin with the collection of nuts, de-pulping, drying of nuts, dehusking, drying and smoking of kernels and pounding and grinding into past. Next is mixing with water, treading, kneading and churning, floating and refining, solidifying and moulding (Teketay et al., 2003). The tradition processing method generates significant quantities of both liquid and solid waste which is described by Jibreel et al. (2013) as brown water and black sludge. The liquid fraction, according to Ofosu (2009), constitutes suspended and dissolved OM and oil, which might have a potential impact on the environment.

Shea waste-slurry (SWS) as used in this study refers to the concentration of the remnant liquid (brown water) and solid (black sludge) as well as the oil at the end of the Shea butter extraction processes (Abagale et al., 2012). It is generally disposed of into the surroundings in the production communities which accumulate onto receiving soils. A survey conducted by Jibreel et al. (2013) in the Tamale metropolis realised that the solid waste-slurry is dried into cake for further use while almost 46% of the Shea butter processors disposed of the liquid waste on bare land.

Production of Shea waste-slurry is thus expected to increase as small-scale Shea butter processing industries continues to gain much attention as a potential economic venture in the Tamale Metropolis.

Organic waste generally has a significant effect on soil properties (physical, chemical, and biological) which favours plant growth and development (Hossain et al., 2017). According to Jibreel et al. (2013), the intrinsic elements in waste-slurry might alter the structure and properties of receiving soils and affect crop development (Jibreel et al., 2013). A study by Abagale et al. (2012) highlighted the positive potentials of Shea waste-slurry on improving soil physical properties such as the bulk density, infiltration rate, porosity, gravimetric and volumetric moisture content for crop development in northern Ghana. However, the fertiliser potentials of SWS for the recycling of essential plant nutrients, has over the years receive little attention (Danikuu, 2016).

The study, therefore, examined the effect of SWS as an organic soil amendment material for enhancing soil nutrients for the small-scale subsistence farmer.

MATERIALS AND METHODS

Study area

The study was conducted in two communities: Kasaligu and Jisonayilli in the Tamale Metropolis (731 km^2) and located on latitude 9°24′30.10″N and longitude 0°50′25.63″W of northern Ghana.

The northern region of Ghana is characterised by a unimodal rainfall pattern with an average annual rainfall of 1,000 to 1,300 mm which begins from May to October with the peak occurring between August and September. A long dry period is experienced between the months of November and May. The region is one of the hottest in the country with an annual average temperature of 29 to 34°C. Reference evapotranspiration (ETo) is reported above 600 mm/year (Kranjac-Berisavljevic, 1999; Armah et al., 2010; Abdul-Ganiyu, 2011).

Soils in the study areas are mostly sandstone, mudstone and shale and these have weathered into different soil grades. Due to seasonal erosion, soils emanating from this phenomenon are sand, clay and laterite oxysols. The parent rock of the experimental field consists of sandstone and clay-shale and belongs to rock of the abosum bed of the lower voltaian formation. The soil belongs to Kpalsawgu series and consists of yellow-brown clay and silt which are developed mainly from local colluvium (SARI, 1993).

Soil sampling and analysis

The study was carried out on soils that are used for the disposal of Shea waste-slurry and cultivated for small-scale subsistence farming in the selected communities. These soils are manually tilled with simple farm tools (hoe and cutlass) at the onset of the raining season for the production of grains, cereals and vegetables. Typical crops include *Capsicum annuum* (pepper), *Zea mays* (maise) and *Pennisetum glaucum* (millet).

The study considered soils with SWS as the treatments while adjacent soils without the SWS were used for the control. One-way diagonal method was employed in soil sampling towards the ends of the 25 m × 40 m diagonal fields for both sites of application of SWS and non-application of SWS as control.

Soil samples were taken uphill of about 200 m away from the application site of SWS against gradient in each of the study areas to avoid interference from the application site. 200 g of soil samples were taken from 0-30 and 30-60 cm depths at both applied and non-applied sites of SWS. Sampling was carried out during the dry season before land cultivation. A total of 16 samples of soil were collected from the sampling sites for laboratory analysis. The GPS coordinates of the various sampling points and the standard methods of laboratory analysis are presented in Tables 1 and 2 respectively

Data analysis

The analysis was carried out to determine and compared the concentration of the selected parameters for the different sampling sites (treatment and control) with respect to the depth (0-30 and 30-60 cm). The variation in soil nutrients as influenced by SWS was analysed using Analysis of Variance (ANOVA) at probability (p) of <0.05. Means at the various sites were compared for significant difference using the Fisher Pairwise Comparisons (LSD) method at 95% confidence interval. Data were analysed using Minitab 17 and GraphPad prism 8.

Table 1. Geo-references of soil sampling points.

Site	Latitude (º)	Longitude (º)	Altitude (m)
KAD_1	N 09.40517	W 000.92334	169
KAD_2	N 09.40142	W 000.92448	166
KAN_1	N 09.40344	W 000.92555	163
KAN_2	N 09.40545	W 000.92452	167
JID_1	N 09.45208	W 000.85558	163
JID_2	N 09.45307	W 000.85557	165
JIN_1	N 09.45342	W 000.85529	168
JIN_2	N 09.45333	W 000.85629	167

KAD = Kasalgu Applied Site; KAN = Kasalgu Non-Applied Site; JID = Jisonayilli Applied Site, JIN = Jisonayilli Non-Applied Site.

Table 2. Laboratory methods of soil samples.

Soil parameter	Analysis method	Reference
Soil pH	Supernatant suspension of a 1:2.5 soil to water ratio using pH meter	Rhoades (1982)
Electrical conductivity (EC)	1:2.5 soil to water suspension was measured using Conductivity Meter	Motsara and Roy (2008)
Organic carbon (OC)	Walkley-Black method	Walkley and Black (1934)
Organic matter (OM)	Wet combustion with $K_2Cr_2O_7$	Nelson and Sommers (1982)
Total nitrogen (N)	Kjeldahl method	Bremner and Mulvaney (1982)
Available phosphorus (P)	Olsen's method	Olsen et al. (1954)
Potassium (K)	Flame Photometer at 766.5 nm	Toth and Prince (1949)
Calcium (Ca) and magnesium (Mg)	Ethylenediamine Tetraacetic Acid (EDTA) Titration and use of AAS	Cheng and Bray (1951)
Sodium (Na)	Flame Photometry at 589 nm	Robbins and Wiegand (1990) and Helmke and Sparks (1996)

RESULTS AND DISCUSSION

Effect of Shea waste slurry on soil pH and EC

The use of cover crops, the application of high-quality compost, the return of crop residue and the application of other natural fertiliser have been reported to work together to neutralise soil pH (ASFG, 2010). Low soil pH stress is a major growth-limiting factor for crop production in many regions of the world and the optimum pH for crop growth can vary among crop cultivars and soils (Fageria et al., 2011). According to Liu and Hanlon (2015), soil pH is one of the most important soil chemical properties which influences the solubility and bioavailability of essential plant nutrients.

Slightly acidic soils with pH levels ranging from 5.18±0.13 to 5.42±0.33 for both depths at KAD and 5.49±0.08 to 5.97±0.3 at KAN was recorded indicating how SWS influences soil pH (Table 3). For the Jisonayili soils, average pH of 5.67±0.10 to 8.85±2.47 at JID were noted to be higher than that of JIN with pH of 7.62±0.49 to 7.56±0.62 (Table 3).

Though the effect of SWS application to soils in the two study locations did not statistically influence the level of pH by the ANOVA (Table 3), the mean for the upper depth (0-30 cm) of KAN was significantly higher than that of KAD.

Table 3. Mean pH levels in the study area soils.

Site	pH		ANOVA (α = 0.05)		EC (μS/cm)		ANOVA (α = 0.05)	
	0-30 cm	30-60 cm	F-stat	F-pr	0-30 cm	30-60 cm	F-stat	Fpr
KAD	5.18 ±0.13[b]	5.42 ±0.33[ab]	3.59	0.124	155.5±83.4[a]	75.8 ±40.7[a]	2.44	0.204
KAN	5.97 ±0.3[a]	5.49 ±0.08[ab]			41.15 ±3.89[a]	39.6 ±32.0[a]		
JID	8.85± 2.47[a]	5.67± 0.10[a]	2.04	0.251	52.8± 53.0[a]	47.4± 40.3[a]	0.76	0.574
JIN	7.62±0.49[a]	7.56±0.62[a]			110.2 ± 79.8[a]	40.65± 7.28[a]		

KAD = Kasalgu Applied Site; KAN = Kasalgu Non-Applied Site; JID = Jisonayilli Applied Site, JIN = Jisonayilli Non-Applied Site. F-stat = F-statistics; F-Pr = f-probability. Means that do not share a letter ([a] or [b]) are significantly different. Values after ± indicate Standard deviation.

Liu and Hanlon (2015) noted that pH range from 5.5 to 7.0 favours the solubility of essential nutrients thus indicating that the pH recorded for the two locations are suitable for the cultivation of crops. However, SWS application to soils in the Jisonayili resulted in increasing the pH from acidic to alkaline soils. A study by Adeli et al. (2008) reported that long-term treatments with anaerobic swine lagoon liquid reduced the soil pH by 0.97, 0.11, and 0.88. Sharpley et al. (2004) investigated soils with varying organic manure application histories and found that pH was significantly greater in manured soils than in untreated soils using poultry litter and swine slurry manure. Similar results were also reported by Oguike and Mbagwu (2001) for soil pH using organic manure for soil fertility amendments. Whalen et al. (2000) also observed a significantly higher pH for manure-amended than unamended soil. Another study by Carmo et al. (2015) highlighted the potentials of organic wastes on increase soil pH and to elevated levels that may not be favourable for plant development. According to Fageria et al. (2010), the most useful soil pH for acid soils, is the minimum pH above which liming will not increase crop yield.

Higher levels of EC of 155.5±83 and 41.15±3.89 μS/cm for the upper depth (0-30 cm) of KAD and KAN, respectively, reduced to 75.8±40.7 to 39.6±32.0 μS/cm at their respective lower depths (30-60 cm). Similarly, EC at the upper depths (0-30 cm) of JID and JIN, respectively decreased from 52.8±53.0 and 110.2±79.8 μS/cm to 47.4±40.3 and 40.65±7.28 μS/cm at their lower depths (30-60 cm). However, the observed variations for both sites were statistically insignificant.

The application of SWS as an organic soil amendment material thus increased the soil EC at Kasalgu. A study by Carmo et al. (2015), realised a slight increase in soil EC for medium-textured Oxisol by the addition of organic wastes. The increase of EC levels by application of organic waste on soil have earlier been reported by different authors (Tsadilas et al., 1995; Topper and Sabey, 1986; Hinesly et al., 1982).

Plant primary nutrients in soils

Increasing the soil OM as well as pH increases soil P availability. The optimum pH for P availability is 6.0 to 6.5. If pH is outside this range, supplementary P may be needed even if soil tests show adequate P. K regulates osmotic balance, opening and closing of stomata and cell turgor pressure, while stimulating rooting, photosynthesis, chlorophyll formation, starch formation and translocation of sugars. Adequate K levels reduce plant susceptibility to insect and disease attack.

As an essential component of chlorophyll, proteins, enzymes and hormones, N is essential for plant growth. N does not exist as a mineral element in the soil. It must be taken from the atmosphere, which is composed of approximately 78% N. However, plants cannot use atmospheric N until it is fixed into an available form such as ammonium or nitrate by free bacteria, algae in the soil and through symbiotic bacteria in nodules contained in the roots of legumes such as alfalfa and beans. Artificial sources of N (chemical fertiliser) are fixed through the Haber-Bosch process of reacting hydrogen and atmospheric N under heat and pressure to form ammonium (ASFG, 2010).

Table 4 presents changes in soil %N content due to the influence of SWS. It can be observed from Table 4 that N levels increased from a low of 0.03±0.0% at KAN (0-30 cm) to 0.56±0.2% at KAD while at the 30-60 cm, 0.015±0.02 and 0.01±0.0% were recorded for the KAD and KAN soils, respectively. The results of the ANOVA at Kasalgu site were statistically significant with F-pr of 0.012. The significant difference was observed for the mean concentration at KAD (0-30 cm) over the other soil samples (Table 4).

N content increased from 0.04±0.01 at JIN (0-30 cm) to 0.14±0.13% at JID while the 30-60 cm depth did not record any increment between the applied and the non-applied soils. The variation among mean concentrations was statistically insignificant with f-probability values 0.274, respectively (Table 4).

At a depth of 0-30 cm, soil at KAN and JIN recorded lower than the 0.15% N-value recommended by Brady and Weil (1999) for cultivated soils resulting from the non-application of SWS. Comparison between both depths indicates that the level of concentration of %N was higher at the applied soils, thus presenting the

Table 4. Mean primary plant nutrients in experimental soils.

Site	%N		ANOVA (α = 0.05)		P (mg/kg)		ANOVA (α = 0.05)		K (mg/kg)		ANOVA (α = 0.05)	
	0 - 30 cm	30 - 60 cm	F-stat	Fpr	0 - 30 cm	30 - 60 cm	F-stat	Fpr	0 - 30 cm	30 - 60 cm	F-stat	Fpr
KAD	0.56 ± 0.2[a]	0.015 ± 0.02[b]	14.97	0.012	98.6 ± 21.9[a]	11.56 ± 12.29[b]	27.16	0.004	152.2 ± 14.3[a]	91.9 ±52.3[ab]	10.84	0.022
KAN	0.03 ± 0.0[b]	0.01 ± 0.01[b]			3.47 ± 0.62[b]	3.83 ± 1.35[b]			21.9 ± 2.39[b]	18.60±7.17[b]		
JID	0.14 ± 0.13[a]	0.01 ± 0.0[a]	1.88	0.274	262.0 ± 176[a]	8.10 ± 2.09[b]	3.83	0.114	231.6 ± 98.0[a]	52.4 ±21.5[b]	7.43	0.041
JIN	0.04 ± 0.01[a]	0.01 ± 0.0[a]			42.78 ± 1.52[ab]	11.00 ± 1.02[b]			43.96 ± 4.4[b]	21.98±7.17[b]		

KAD = Kasalgu Applied Site; KAN = Kasalgu Non-Applied Site; JID = Jisonayilli Applied Site, JIN = Jisonayilli Non-Applied Site. F-stat = F-statistics; F-Pr = f-probability. Means that do not share a letter ([a] or [b]) are significantly different. Values after ± indicate Standard deviation.

contribution of applied SWS to increased concentration of %N. An experiment by Kaniz and Khan (2013) to reclaim saline soil using gypsum, rice hull, and rice straw resulted to an increase N content in plant straw which increase by the application of rice hull and sawdust as these treatments added organic matter, in turn, N to the soil. Murmu et al. (2013) also found that organic manure increases crop productivity, N utilisation efficiency, and soil health compared to chemical fertiliser. A study by Elbl et al. (2013) realised a significant decrease of N leaching by the simultaneous applications of soluble humic substances and compost to soils. According to Li et al. (2014), the growth and development of plant may largely depend on the N supplying capacity of the soil.

A higher P concentration of 98.6±21.9 mg/kg at 0-30 cm depth was recorded in soils of KAD as compared to a low level of 3.47±0.62 mg/kg at KAN. ANOVA at 5% resulted in a statistically significant difference between the soils which received SWS (specifically for KAD at 0-30 cm) and soils which did not, with F-pr of 0.004 (Table 4). According to Hossain et al. (2018), the application of organic amendments at variable rates individually or in combinations showed a significant (*p*<0.05) positive influence on the P contents of rice plants grown under both Field Moist Condition and Standing Water Conditions.

A higher P concentration of 262.0±176 mg/kg was recorded at JID (0-30 cm) while a relatively lower concentration of 42.78±1.52 mg/kg was noted for soils at JIN (0-30 cm) resulting from the non-application of SWS. However, P levels at JID (30 - 60 cm) was slightly lower (8.10±2.09 mg/kg) than that of JIN (11.00±1.02 mg/kg). The variation was not statically significant by ANOVA with F-pr of 0.114 (Table 4). Available P contents in the soil in Tamale area ranges from deficient to marginal (5.0-7.0 mg/kg) in the top soil (Agyare, 2004). The effect of SWS in increasing the levels of P in tropical soils was evident from the results of the study and based on the recommended value of 20 ppm for crop cultivation (ASFG, 2010), the addition of SWS as an organic soil amendment material to increase P concentration in tropical soils has been realised. The higher level of P in SWS applied soils could also be attributed to the findings of Hinsinger (2001) which indicates that the distribution of P species (organic and inorganic) in soil is determined primarily by the pH of the soil solution. The study revealed that the pH of the soils at the SWS applied site increased, leading to P availability. Mokolobate and Haynes (2002) and Pypers et al. (2005) also reported that incorporation of organic residues can improve soil conditions making an increase in P availability possible.

From Table 4, soils from the sampling points of Kasalgu recorded 152.2±14.3 and 21.9±2.39 mg/kg of K at 0-30 cm depth for KAD and KAN, respectively. Concentration at the lower depth (30-60 cm) reduced to91.9±52.3 and 18.60±7.17 mg/kg for KAD and KAN, respectively. ANOVA at 5% resulted in f-probability of 0.022, indicating a significant difference. K concentration at the upper depth (0-30 cm) of KAD was significantly higher than the soils at KAN (Table 4).

Soils sampled from the Jisonayilli community at 0-30 cm recorded an average of 231.6±98 and 43.96±4.4 mg/kg of K for JID and JIN soils, respectively with a decrease to 52.4±21.5 and 21.98±7.17 mg/kg at their respective lower depths (30-60 cm). Comparatively, results of the ANOVA revealed that the mean concentration of K at the upper depth (0-30 cm) was significantly higher than the other samples at F-pr of 0.041 (Table 4). According to Hossner and Juo (1999), most tropical soils are highly weathered, infertile, acidic and have deficient levels of K. However, the

Table 5. Mean levels of secondary plant nutrients in soil.

Site	Na (meq/100 g)		ANOVA (α = 0.05)		Mg (meq/100 g)		ANOVA (α = 0.05)		Ca (meq/100 g)		ANOVA (α = 0.05)	
	0 - 30 cm	30 - 60 cm	F-stat	Fpr	0 - 30 cm	30 - 60 cm	F-stat	Fpr	0 - 30 cm	30 - 60 cm	F-stat	Fpr
KAD	1.76 ± 0.39[a]	1.07 ± 0.46[ab]	8.80	0.031	8.51 ± 4.86[a]	1.47 ± 0.57[b]	4.34	0.095	6.3 ± 0.98[a]	1.87 ± 0.38[b]	36.82	0.002
KAN	0.46 ± 0.09[b]	0.37 ± 0.03[b]			1.19 ± 0.96[b]	0.80 ± 0.38[b]			1.6 ± 0.07[b]	1.74 ± 0.19[b]		
JID	2.81 ± 1.0[a]	0.57 ± 0.18[b]	9.19	0.029	3.21 ± 1.14[a]	0.80 ± 0.38[b]	5.74	0.062	6.14 ± 4.16[a]	2.41 ± 0.38[a]	1.58	0.327
JIN	0.72 ± 0.09[b]	0.53 ± 0.12[b]			0.80 ± 0.3[b]	0.81 ± 0.76[b]			4.68 ± 0.19[a]	2.27 ± 0.57[a]		

KAD = Kasalgu Applied Site; KAN = Kasalgu Non-Applied Site; JID = Jisonayilli Applied Site, JIN = Jisonayilli Non-Applied Site. F-stat = F-statistics; F-Pr = f-probability. Means that do not share a letter ([a] or [b]) are significantly different. Values after ± indicate Standard deviation.

addition of SWS to soils in the tropical lands have been noted to influence significantly, the amounts of K but this was noted for this study to have decreased with increasing soil depth. ASFG (2010) reported that, at a depth of 0-30 cm, K is high in applied soils but low in non-applied soils while at 30-60 cm it was generally low in all the soils.

Secondary plant nutrients in soils

A number of secondary nutrients such as iron, manganese, zinc, copper, boron, chlorine and molybdenum are known to influence plant growth and are usually required in small amounts for proper functioning of plant metabolism. The absolute or relative absence of any of these nutrients can hamper plant growth; alternatively, too high a concentration can be toxic to the plant or to humans (Gruhn et al., 2000).

As an organic soil amendment material, the study evaluated the effect of the application of SWS on availability of Mg, Ca and Na and results presented in Table 5.

Na levels in soils of KAD recorded higher levels of 1.07±0.46 to 1.76±0.39 meq/100 g while KAN soils recorded levels ranges from 0.37±0.03 to 0.46±0.09 meq/100 g. A statistically significant difference of Na concentration (Table 5 and Figure 1) was realised with F- pr of 0.031. Na concentration of the upper depth (0-30) of KAD was significantly different from soils at KAN (Table 5).

Na concentration in soils of JID ranged from 0.57±0.18 to 2.81±1.0 meq/100 g while JIN soils recorded 0.53±0.12 to 0.71±0.09 meq/100 g concentration levels. ANOVA at 5% resulted in statistical difference with F-pr of 0.029. The maximum mean concentration of Na at the upper depth (0-30 cm) of JID was significantly different over all the samples of the study site (Table 5).

Mg levels of 8.51±4.86 and 1.19±0.96 meq/100 g reduced with depth to 1.47±0.57 and 0.80±0.38 meq/100 g for KAD and KAN, respectively (Figure 2). ANOVA at 5% significant level indicates that the difference in Mg concentration is insignificant with F-pr of 0.095. However, the maximum Mg concentration of KAD at 0-30 cm was significantly higher than all the soil samples (Table 5).

Soil Mg concentration at JID reduced from 3.21±1.14 to 0.80±0.38 meq/100 g for 0-30 and 30-60 cm, respectively. At JIN, Mg concentration was virtually the same for both depths (Figure 2). Once more, the highest Mg concentration recorded for SWS at 0-30 cm was significantly different from all the soil samples though the results of ANOVA was statistically significant with F-Pr of 0.062 (Table 5). The concentration of Mg in soils applied with SWS was noted to be influenced by high levels of soil pH. According to Maathuis et al. (2011), concentration of Mg is dependent on soil OM content, pH and the presence of other cations. The availability of Mg for plants is thus ultimately reduces by soil acidity (Maathuis et al., 2011).

The maximum soil Ca of 6.30±0.98 meq/100 g recorded at the upper depth (0-30 cm) of KAD showed a highly significant difference with all the other samples at the study site by ANOVA with F-pr of 0.002. Despite the reduction in Ca concentration at Jisonayilli site, for the various depths, there was no significant difference among mean concentrations with F-pr of 0.327 by ANOVA (Table 5 and Figure 3). An experiment by Mubarak et al. (2009), found a significant increase (P 0.02) in Ca and Mg with the application of wool and hoof powder for amendment of sandy soils. However, residues of pigeon pea (dried or fresh) and baggase had no significant effects on soil pH

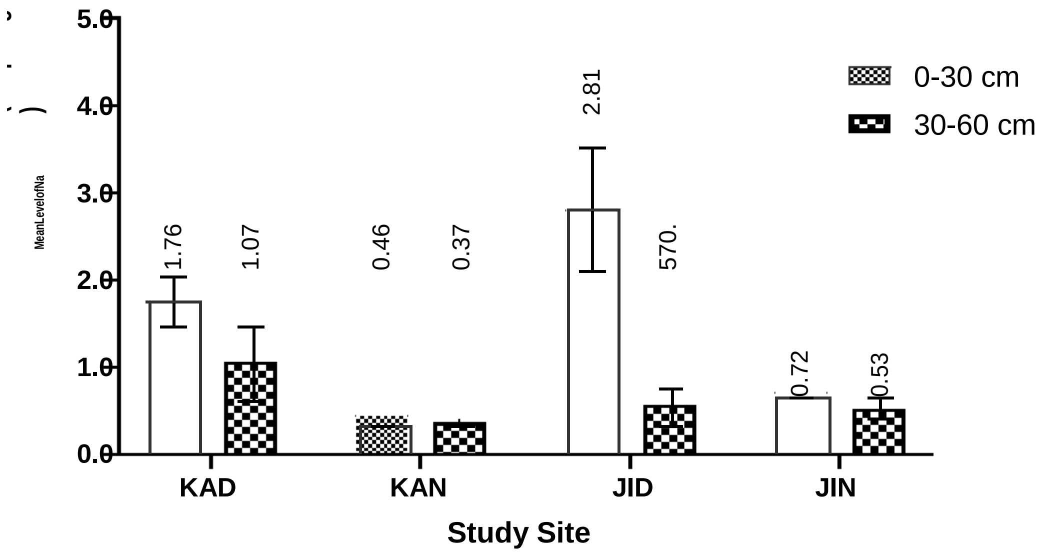

Figure 1. Mean Na level at the study areas.

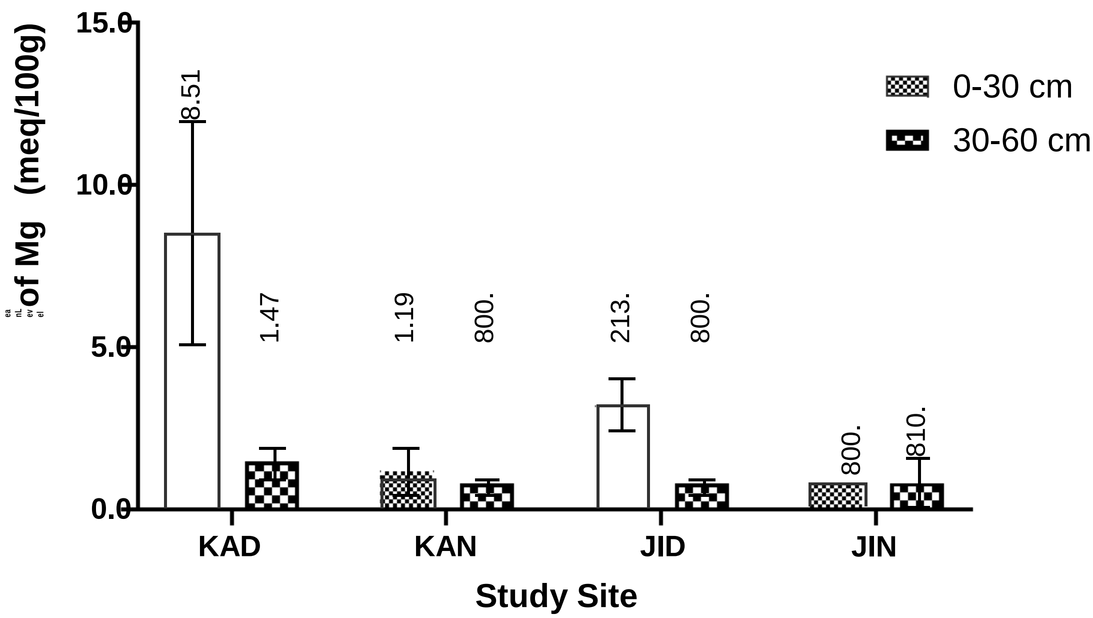

Figure 2. Mean Mg level at the study areas.

and the soluble cations (Ca, Mg and Na).

Shea waste slurry effect on soil OM and OC content

Use of cover crops, return of crop residue, addition of compost and/or composted manure and practices that maintain OM on the surface of the soil all increase OM levels (ASFG, 2010).

High levels of soil %OM (0.35±0.09 to 10.9±3.95%) were recorded at KAD while the KAN fields recorded 0.29±0.02 and 0.58±0.01% (Table 6). The variation among mean concentrations was statistically significant (F -pr 0.013) with %MO of KAD at 0 - 30 cm being significantly higher than the other samples at the site. Also, at JID, 0.29±0.03 to 2.45±2.15% of %OM was recorded while 0.23±0.08 to 0.88±0.10% was measured for JIN. The results of ANOVA indicated no significant

Table 6. Mean percentage OM content in the soil.

Site	%OM		ANOVA (α = 0.05)		%OC		ANOVA (α = 0.05)	
	0 - 30 cm	30 - 60 cm	F-stat	Fpr	0 - 30 cm	30 - 60 cm	F-stat	Fpr
KAD	10.94±3.95[a]	0.35±0.09[b]	14.25	0.013	6.36±2.29[a]	0.21±0.05[b]	14.28	0.013
KAN	0.58±0.01[b]	0.29±0.02[b]			0.34± 0.11[b]	0.17±0.0[b]		
JID	2.45 ±2.15[a]	0.29±0.03[a]	1.85	0.279	1.43 ± 1.25[a]	0.17±0.03[a]	1.84	0.280
JIN	0.88 ± 0.10[a]	0.23±0.08[a]			0.51±0.10[a]	0.14±0.05[a]		

KAD = Kasalgu Applied Site; KAN = Kasalgu Non-Applied Site; JID = Jisonayilli Applied Site, JIN = Jisonayilli Non-Applied Site. F-stat = F-statistics; F-Pr = f-probability. Means that do not share a letter ([a] or [b]) are significantly different. Values after ± indicate Standard deviation.

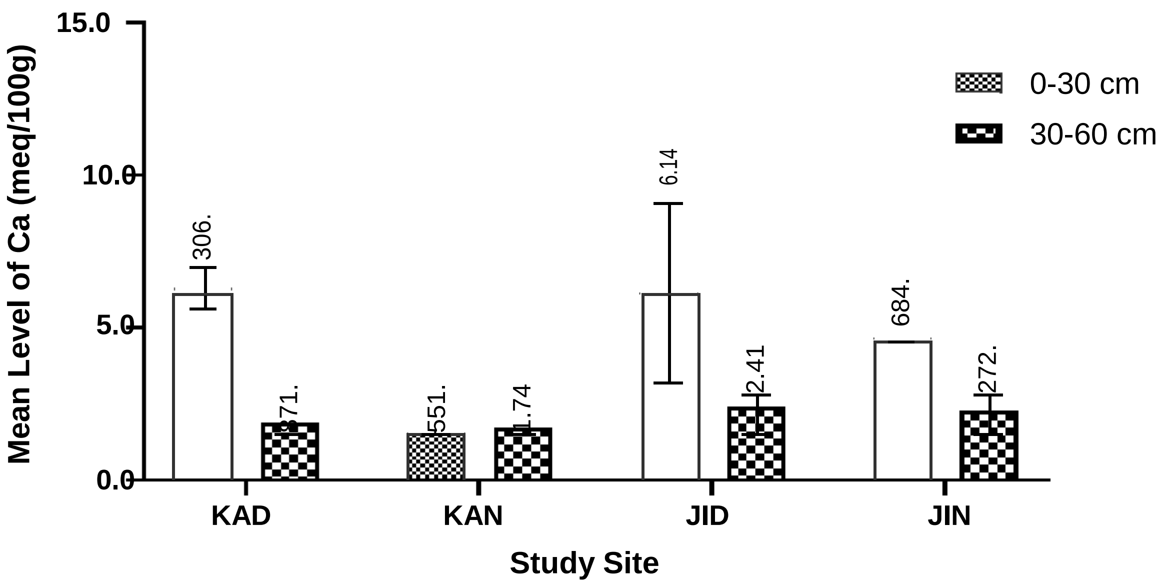

Figure 3. Mean Ca level at the study areas.

differences (F-pr 0.279) among the mean %OM at the study site (Table 6). Comparison between both depths clearly indicates that the level of %OM accumulation in the soils decreases with increasing depth in both soils. It is observed from the findings of the study that the OM content is a clear improvement over the findings of Fening et al. (2005) with the indication that soils in the interior savanna zone have low organic matter contents (1.0 ±0.4%) and low levels of the major plant nutrients. Seçer et al. (2016), similarly recorded a significant increase in soil OM with the application of organic waste products of oily oregano and cumin.

Soil organic amendments such as manures and plant residues are a significant source of OC to the soil. Plants also promote microbial populations and subsequent turnover by exuding OC from their roots (Merckx et al., 1985). The application of SWS was observed to also influence the percentage levels of OC content of the study soils. High levels of %OC (Table 6) were recorded in the two sites to which SWS were applied. However, the difference in mean concentration of %OC was statistically significant at Kpsalgu site only with a significantly higher concentration at the upper depth (0-30 cm) of KAD (Table 6). In a similar study, Chen et al. (2019) observed an increase in soil OC when different organic waste was applied. Landon (1991) reported an average of 0.5% of OC content as a requirement for tropical crops, whilst Young (1976) also reported that tropical crops require an average range of 0.6 to 1.2% of carbon content for proper growth and development. The increased percentage OC content of soils was noted to have been influenced by the application of SWS thus indicating it as a good source of organic manure for soil fertility amendments especially in degraded tropical soils. Mekki et al. (2017), after observing a significant increase in soil OM and OC from application of biowaste compost noted That soil OC content is critical for the maintenance of soil quality and balance of the terrestrial carbon cycling.

Conclusions

The results of the study indicated that the application of

SWS as an organic soil amendment material resulted in increased concentration levels of plant primary nutrients (N, P and K) and also secondary nutrients such as Na, Ca and Mg. The application of SWS also influenced soil pH, percentage OM and carbon content percentage and soil EC by increasing their levels. The application of SWS as an organic soil amendment material thus affected soil chemical properties positively and thus will translate to the availability of the necessary plant nutrients for plant growth and yield. Comparison between both depths indicates that the level of %OM accumulation in the soils decreases with increasing depth in both soils. The application of SWS also influenced the percentage levels of OC content of the study soils. The study noted and concluded that SWS has a nutrient influencing effect and therefore could be used as an organic soil amendment material for plant growth as well as soil physical properties improvement.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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