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ORIGINAL RESEARCH

Influence of *Tithonia diversifolia* and cattle manures on the growth and yield of sesame (*Sesamum indicum* L.).

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Abstract

Purpose Much cattle manure and *Tithonia* are in abundance in the Guinea savanna of Nigeria where sesame has been found to do well. The cost of inorganic fertilizer is going beyond the reach of the average sesame farmer; the need therefore arises to synthesize farming practices that incorporate the rich organic materials locally available as a substitute for inorganic fertilizer for sustainable food production.

Method A study was conducted at the Teaching and Research Farm, University of Ilorin, Nigeria during the 2018 and 2019 cropping seasons, to evaluate the performance of sesame using *T. diversifolia* and cattle manures. The following treatments; *T. diversifolia* (control, 0.9, 1.8 and 2.7 tha^{-1}) and cattle manure (7.5, 15 and 22.5 tha^{-1}) were used. Treatments were laid out in randomized complete block design, and replicated four times. Data on soil water content, growth and morphological characters and yield were collected.

Result Results showed that *T. diversifolia* and cattle manures application improved soil water and nutrient contents, growth and yield attributes of sesame. *Tithonia diversifolia* applied at 2.7 tha^{-1} and cattle manure applied at 22.5 tha^{-1} gave the highest growth attributes, *T. diversifolia* applied at the rate of 1.8 tha^{-1} gave a yield of 547.2 kgha^{-1} and 527.6 kgha^{-1} in the 1st and 2nd seasons respectively. Cattle manure at 15 tha^{-1} gave a yield of 517.3 and 517.2 kgha^{-1} in first and second season respectively.

Conclusion Farmers are advised to use *T. diversifolia* at the rate of 1.8tha^{-1} for high yield.

Keywords *Tithonia diversifolia*, Green manure, Cattle manure, Yield, Sesame

Introduction

A variety of crops such as Maize *(Zea mays* L.), Sorghum (*Sorghum bicolor*), Rice (*Oryza sativa*), roots and tubers such as Cassava (*Manihot spp*.), Yam (*Dioscorea spp.),* Sweet potato (*Ipomea batatas*); legumes such as cowpea (*Vigna unguiculata),* Soya beans (*Glycine max*), Groundnut (*Arachis hypogea*) and leafy vegetables are

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cultivated in the southern Guinea savannah zone of Nigeria. In addition to these crops, oil seed crops, such as sesame (*Sesamum indicum*), Sunflower (*Helianthus annuus* L.) and Groundnut can also be cultivated in the area. However, some of these crops cannot provide sufficient income for farmers due to fluctuating market prices. Surprisingly, the price of sesame has remained stable in the market in the past few years and, can be a crop for peasant farmers who want to break the endemic cycle of poverty.

Sesame (*Sesamum indicum* L.) which is the third largest export commodity after oil and cocoa (*Theobroma cacao* L.), contributed significantly to the Gross Domestic Product of Nigeria during the 2012 cropping season (FAO 2012; Umar et al. 2013). There has been a slight decline in its production in the past few years (FAO 2020), Though, cultivation of the crop in Nigeria has gone through many stages of development, the yield is still below 450 kgha^{-1} compared to 1,960 kgha^{-1} in Venezuela and 1,083 kgha^{-1} in Saudi Arabia (Abubakar et al. 1998; Eifediyi et al. 2016). The low yield is attributed to poor cultural practices, use of unimproved seeds and low soil fertility. Unfortunately, the improved varieties produced by the National Cereal Research Institute, Badeggi, also produce low yields primarily due to inadequate use of recommended organic and inorganic fertilizers. In the tropics, because of the climatic conditions, there is accelerated organic matter decomposition and mineralization; hence the soil quality degrades faster under cultivation. To ameliorate these problems, the use of organic materials which will slow down the rate of fast soil degradation is recommended. On the other hand, the price of inorganic fertilizers are prohibitive and beyond the reach of peasant farmers (Basak 2019) and more importantly, farmers have no access to credit facilities, this have made their access to fertilizer difficult. The major limiting nutrient in soils of the southern Guinea savannah zone of Nigeria is nitrogen (Shehu et al. 2015) and this can be sourced from a variety of organic materials such as the leaves of *Tithonia diversifolia and* cattle manure. These organic materials are cheap, environmentally friendly (Omenda et al. 2021), and abound in areas of sesame cultivation. *T. diversifolia* (Mexico sunflower) is a fast growing roadside plant which belongs to the Asteraceae family, has aggressive growth pattern and often constitutes environmental nuisance to roadside scenery, thus creating an extra financial burden to the Nigerian Government for its control. Fortunately, the plant can produce high biomass within a short period of time for the production of green and compost manure (Drechsel and Reck 1998). *T. diversifolia* when applied as green manure has the potential of supplying 3.5% nitrogen, 0.37% phosphorus and 4.1% potassium on dry weight basis at minimal cost to the farmer (Mwangi and Mathenge 2014), improve the organic matter content of the soil and also ensure nutrient availability (León Castro and Whalen 2019) and can enrich the soil (Balachandar et al. 2020). *Tithonia diversifolia* has been used for the improvement of soil nutrient composition for arable crops such as rice and maize (Dayo-Olagbende et al. 2020; Kang et al. 2020).Cattle dung is faecal remains or waste product from cattle, is found in the savannah zones of Nigeria where animals are reared because of the abundance of grasses and the absence of tsetse fly (*Glossina* species). This manure which is environmental friendly, contains total nitrogen of 0.3 – 0.45%, total phosphorus 0.15 – 0.25% and total potassium 0.05 – 0.15% (NACA 1989) and is often not harnessed for soil fertility restoration due to cultural limitation, thus causing environmental pollution (Pongracz and Pohjola 2004). These materials can be sourced and transported to the farmers' field at affordable cost compared to the cost of fertilizer. The use of these materials for soil amendment has become important due to increasing demand for organic food, prevention of environmental pollution and high cost posed by the use of inorganic fertiliser. The soil of the study area has little potentials for water retention, but the use of these materials may help to improve the water holding capacity of the soil and hence the yield of crops. Eifediyi et al. (2022) has stated that the use of poultry manure which is a form of organic manure improved the water holding capacity of soil in the study area using kenaf as a test crop.The objective of this study was to investigate the effect of *T. diversifolia* as green manure and cattle manure as nitrogen sources on the growth and yield of sesame.

Materials and methods

Description of experimental site

The experiment was carried out at the Teaching and Research Farm of the University of Ilorin, Nigeria during the season 2018 referred to as season 1 and 2019 as season 2. The site is located in the southern Guinea Savannah zone of Nigeria (latitude $8^0 49^1$ North and longitude $4^0 58^1$ East and 308 m above the sea level). The rainfall in the study area is bimodal and usually begins around April with a peak in September to early October; with an average annual rainfall of between 1000 mm and 1500 mm, and the mean monthly temperature of between 25 – 30^{0}C throughout the year (Olubanjo et al. 2019). But due to the effects of climate change, this rainfall pattern has become increasingly erratic in the last decade (Ayanshola et al. 2018).

Experimental design and treatment application

The experiment was laid out as a randomized complete block design (RCBD) replicated four times, the treatments imposed consists of *T. diversifolia* (control, 0.9, 1.8, 2.7 tha^{-1}) and cattle manure (7.5, 15 and 22.5 tha^{-1}) to supply 0, 30, 60 and 90 kg Nha^{-1} respectively. The *T. diversifolia* were harvested at the Teaching and Research farm chopped into pieces and applied as green manure while the cattle manure was collected from the kraal of the Teaching and Research farm, University of Ilorin, Nigeria, and cured for ninety days. Both were evenly spread within the appropriate experimental plots and incorporated into soil at a depth of 15 cm two weeks before sowing using a hoe.

Soil sampling

Soil samples (0 – 15 cm depth) were collected within the experimental site using a soil auger and the grid method prior to sowing. The soil samples collected were bulked and thoroughly mixed to constitute a composite sample. The soil samples after cropping were taken from each plot separately using a soil auger. Soil pH was measured (soil: water ratio 1:2) using a glass electrode pH meter, total N was determined by micro Kjeldahl method (Bremner 1996), available phosphorus was determined by following Bray No I (IN NH_4F + 0.5 N) HCL extractant by vanadomolybdophodphoric acid method (Kuo 1996), organic carbon was determined using the modified Walkley and Black method (Nelson and Sommers 1996) and exchangeable acidity done by using 1M KCL, exchangeable bases extraction was done using 1 N ammonium acetate, while calcium and magnesium were analysed by atomic absorption Spectrophotometer, particle size was determined by using soil hydrometer method.

Tithonia diversifolia and cattle manure analyses

Samples of *T. diversifolia* and cattle manures were collected and oven dried. Nitrogen was determined using micro Kjeldal method. Phosphorus was determined by Bray1 method while K, Ca and Mg were determined using EDTA titration method, whereas, Zn was analysed by using extractable 0.1 M KCl. The details of treatment allocation in terms of nitrogen source from the *T. diversifolia* and cattle manures is presented in Table 1.

Table 1 Treatment details

Treatments	Rates (tha^{-1})	To give Nitrogen (kg)
Control	0	0
Tithoniadiversifolia	0.9	30
Tithoniadiversifolia	1.8	60
Tithoniadiversifolia	2.7	90
Cattle manure	7.5	30
Cattle manure	15	60
Cattle manure	22.5	90

The allocation showed that using the leaves of *T. diversifolia* as green manure at the rates of 0.9, 1.8 and 2.7tha^{-1} to give 30, 60 and 90 kg nitrogen ha^{-1} respectively while the cattle manure at the rates of 7.5, 15 and 22.7 tha^{-1} to give 30, 60 and 90kg nitrogen ha^{-1}. Nitrogen is the most limiting nutrient in this area and this was calculated thus; Quantity = Recommended rate x area of land x 100/Guaranteed analysis (Anon 2011)

Agronomic management practices

The land was ploughed, harrowed, and marked into plots measuring 4 x 4 m with 0.5 m alleyway between the plots. The marked plots were later made into seed beds and the seeds (cv. Ex Sudan) were sown by drilling in shallow furrows and then covered lightly with soil and thinned three weeks later at a spacing of 25 x 75 cm between and within rows giving a plant population density of 53,333 per hectare. The seeds were sown on August 27, 2018 referred as the first season and repeated on the 28th August, 2019 referred to as the second season. Manual weeding was done at 4 and 7 weeks after sowing (WAS). Harvesting was done manually by hand picking of the capsules from the net plot which were put in polythene bags to minimize seed loss when capsule dehisces and later sun dried.

Data collection

Data was collected on soil water content, growth parameters (plant height, number of leaves and leaf area index) and yield components (number of capsules per plant, seed weight per net plot and yield per hectare). Data on soil water content was collected using the Gravimetric method at 5, 7 and 9 weeks after sowing. The plant height of five tagged plants from the net plot were measured using a measuring tape from the base of the plant to the terminal bud at 5, 7, and 9 weeks after sowing (WAS) while the number of leaves of the five tagged plants in the net plot were visually assessed at 5, 7, and 9 WAS. The leaf area of the five tagged plants in the net plot was calculated based on the work of Silva et al. (2002) and the leaf area index was calculated as leaf/ground area covered. The data on yield and yield components; the number of capsules from the five tagged plants within the net plot were counted; the seed weight per net plot after threshing were weighed by using a sensitive balance while the yield per hectare was extrapolated from the net plot.

Data analysis

Data were subjected to analysis of variance (ANOVA) using Genstat software package 17th Edition. The new Duncan Multiple range test was used to separate significant means at 5% level of probability ($p<0.05$).

Results and discussion

Physical and chemical properties of soil

The physical and chemical properties of soil before cropping in 2018 (season 1) is presented in Table 2. The pH of the soil was slightly acidic, the organic matter content and the nitrogen content was low; the P, Ca and Mg were low but the K content was moderate.

Table 2 Physical and chemical properties of soil before sowing.

Parameters	Before planting
pH in H_20	6.4
Organic carbon (%)	0.67
Organic matter (%)	1.17
Nitrogen (%)	0.086
Phosphorus ($mgkg^{-1}$)	6.93
Calcium ($cmolkg^{-1}$)	4.50
Magnesium ($cmolkg^{-1}$)	0.37
Potassium ($cmolkg^{-1}$)	0.47
Sand (%)	87.52
Silt (%)	6.00
Clay (%)	6.48
Textural class	sandy loam
Soil classification	Alfisol

The properties of *T. diversifolia* and cattle dung manure are presented in Table 3. The result showed that the nutrients vary from low to high. The physical and chemical properties of the soil after cropping in the first season are presented in Table 4. The data showed that the application of *T. diversifolia* and cattle manure reduced the pH though the result was not significant. The cattle manure applied at 22.5tha^{-1} and *T. diversifolia* at the rate of 2.7 tha^{-1}, produced organic carbon, phosphorus, and calcium contents which were significantly different from the other treatments and the control gave the lowest values; but no significant K content was observed. The cattle manure applied at the rates of 22.5 and 15 tha^{-1} gave the highest magnesium contents which was significantly different ($p<0.05$) from the control. The low fertility status of the experimental site before cropping is an indication of increased cropping intensity, and reduction in the fallow period from ten years to three years and this necessitated the use external inputs in the form of *T. diversifolia* and cattle manures.

Table 3 Properties of *Tithonia diversifolia* and cattle manure

Parameters	*T. diversifolia*	Cattle manure
Nitrogen (%)	3.47	0.43
Phosphorus (%)	0.32	0.24
Potassium (cmol/kg)	3.55	0.11
Calcium (cmol/kg)	1.23	9.19
Magnesium (cmol/kg)	0.38	1.46
Sodium (cmol/kg)	0.24	0.67
Zinc (mg/kg)	1.32	Not determined

Own analysis

Eifediyi et al. (2013, 2022) reported that soil of the study area are deficient in plant nutrients especially N. There was an increase in soil organic carbon (C), nitrogen (N), phosphorous (P), and potassium (K) and other nutrients after the first cropping season in plots treated with *T. diversifolia* and cattle manure. The nutrients status of the soil after the second cropping in the plots where *T. diversifolia* and cattle manures were applied could be adduced to the residual effects of organic manures which releases its nutrients slowly and their long lasting effect on the soil (Ajay 2017). Chukwuka and Omotayo (2008), and Crespo et al.(2011) reported the positive effects of *T. diversifolia* on the improvement of physical and chemical properties of soil. Ikpe and Powell (2002) also reported that cattle manure has organic matter in adequate amount which in turn improves the soil physical and chemical properties. Olowoake and Adeoye (2013) reported that the application of cattle manure and compost to the soil increased the soil pH, organic carbon, nitrogen, phosphorus, calcium, potassium, magnesium contents. The effect of *T. diversifolia* and cattle manure on the soil water content is presented in Table 5.The data showed that the cattle manure applied at 22.5tha^{-1}consistently produced the highest soil water content throughout the period of assessment at 5, 7 and 9 WAS, which was closely followed by the *T. diversifolia* applied at 2.7tha^{-1} with the control producing the least moisture content. The higher water contents of the soil applied with the 22.5 tha^{-1} of cattle and 2.7tha^{-1}*T. diversifolia* manures could be attributed to higher organic matter content, which has the tendency to absorb and retain water. Soils high in organic matter content will promote good vegetative growth which will culminate in improved yield. With the available water in the soil, the nutrients present in the soil were readily available for roots absorption. This synergistic effect between water and nutrients led to an increase in assimilate production which resulted in higher leaf area and dry matter production (Ali 1999; Vengadaramana and Jashothan 2012). This study also corroborates the reports of Mustikawati et al. (2019) who reported that organic materials contains nutrients which has the tendency to hold water due to high organic matter content which will have a positive effect on the physical, biological and chemical properties such as aeration, water retention and the proliferation of microorganisms.

Table 4 Physical and chemical properties of soil after cropping in the second year

Treat t/ha	pH H_2O	OC %	P mg/kg	N %	Ca cmol/ kg	K cmol/kg	Mg cmol/kg
Control	6.63	0.20f	4.02c	0.06d	3.45d	0.40	0.29e
Ti 0.9	6.63	0.86d	5.28b	0.16bc	3.98cd	0.43	1.49d
Ti 1.8	6.63	0.89c	5.41ab	0.19ab	4.47c	0.44	1.75c
Ti 2.7	6.56	0.95a	5.74a	0.21a	5.44ab	0.44	1.80c
CD 7.5	6.56	0.75c	5.20b	0.12c	4.66bc	0.40	1.85bc
CD 15	6.70	0.93b	5.30b	0.16bc	5.77a	0.42	2.02ab
CD22.5	6.54	0.97a	5.71a	0.20ab	5.90a	0.43	2.05a
SE.(p<0.05)	Ns	0.0089	0.162	0.0203	0.388	Ns	0.0835

OC = Organic Carbon, Ti = Tithonia and CD = Cattle manure.*Values followed by the same letter do not differ significantly

Physiological growth of sesame

The plant height of sesame at 5, 7 and 9 WAS is presented (Table 6). At 5 WAS, in the first season (2018), the *T. diversifolia* at 2.7 tha^{-1} produced the tallest plants which were about 45% different from the control. In 2019 (second season), *T. diversifolia* produced the tallest plants which had similar values with the cattle manure at 15 and 22.5 tha^{-1} but about 35% different from the control. At 7WAS, in the first season, the *T. diversifolia* at 2.7 tha^{-1} produced the tallest plants which were significantly different from the other treatments, while the control produced the shortest plants. In the second season, the *T. diversifolia* at 2.7 tha^{-1}, produced the tallest plants which was at par with *T. diversifolia* at 1.8 tha^{-1}, 0.9 tha^{-1}, the cattle manure at 15 and 22.5 tha^{-1} but significantly different from the other treatments while the control produced the shortest plants. At 9 WAS, in the first season, the *T. diversifolia* at 2.7 tha^{-1}, 1.8 tha^{-1}, the cattle manure at 15 and 22.5 tha^{-1} produced plants with similar height but significantly different from the control. In the second season, the *T. diversifolia* at 2.7 tha^{-1}, produced plants which were similar with the manures applied plots but significantly different from the control.

Table 5 Effect of *Tithonia diversifolia* and cattle manures on the soil water content (%) of the soil at 5, 7 and 9 weeks after sowing (WAS) in the two seasons

Treatments	Rates tha^{-1}	5 WAS		7 WAS		9 WAS	
		Season					
		1	2	1	2	1	2
Control	0	32.85e	30.80d	27.92e	26.73e	26.16e	26.69
Tithonia	0.9	35.19e	34.17c	31.36d	31.07d	30.78d	32.12
Tithonia	1.8	38.05d	37.69b	34.87b	33.53bc	34.01c	32.55
Tithonia	2.7	44.07b	41.97a	35.85a	35.40a	35.49b	33.33
Cattle manure	7.5	41.07c	38.86b	33.70c	32.24cd	35.45b	34.68
Cattle manure	15	44.07b	41.33a	35.66ab	34.88ab	36.77a	35.33
Cattle manure	22.5	48.52a	43.00a	36.41a	34.54a	37.62a	36.30
SE.(p<0.05)		1.183	0.819	0.831	0.776	0.440	Ns

*Values followed by the same letter do not differ significantly

The superior growth exhibited by the cattle manures at 22.5 tha^{-1} and *T. diversifolia* at 2.7tha^{-1} amended treatments over the control is due to the role nitrogen plays in the promotion of vegetative growth and P in metabolic process, better nutrient retention capacity of nitrogen, phosphorus, potassium, magnesium and calcium in the soil compared to the control (Jeptoo et al. 2013), the mineralization and slow release of nutrients resulting in the enhancement of growth and improved assimilate production (Iqtidar et al. 2006). Thus the high organic matter content of the amended soil resulted in the formation of optimum plant height and better display of leaves for light interception for photosynthesis (Saeed et al. 2001; Liasu et al. 2008). In addition, Gachengo et al. (1998) reported that *T. diversifolia* accumulate large amount of nitrogen and phosphorus from the soil and when cut and incorporated into the soil releases these nutrients to the soil slowly. The increase in plant height with increasing levels of cattle and *T. diversifolia* manures could be adduced to the presence of nutrients in adequate amount for crop growth and development especially at critical stages of the plants growth cycle. This agrees with the findings of Jeptoo et al. (2013) who opined that *T. diversifolia* manure improves the vegetative growth, fresh root yield and quality of crops. The effects of *T. diversifolia* and cattle manures on the number of leaves of sesame presented in (Table 7). At 5WAS, the number of leaves ranged from 17.80 - 39.33 in the first season (2018), the *T. diversifolia* at 2.7 tha^{-1} produced the highest number of leaves which were at par with the other manure treated plots but significantly different from the control. In the second season, the *T. diversifolia* at the rate of 2.7 tha^{-1} produced the highest number of leaves (41) which was significantly different from the other treatments. At 7WAS, in the first season, the *T. diversifolia* applied at the rate of 2.7 tha^{-1} produced the highest number of leaves which was similar with the cattle manure at 22.5 tha^{-1} but significantly ($p<0.05$) different from the other treatments. At 9 WAS, in the first season, the T. diversifolia applied at the rate of 2.7 tha^{-1} produced the highest number of leaves which was statistically similar to cattle manure applied at the rate of 22.5 tha^{-1} but significantly different ($p<0.05$)from the other treatments. In the second season, the *T. diversifolia* applied at the rate of 2.7 tha^{-1} produced the highest number of leaves which was significantly different from the other treatments. An increase in the number of leaves implies higher light interception for photosynthesis which will promote plant growth; thus an increase in light interception will result in more dry matter production, accumulation and partitioning into different parts of the plant.

Table 6 Effect of *Tithonia diversifolia* and cattle manures on the plant height (cm) of sesame at 5, 7 and 9 weeks after sowing (WAS) in the two seasons

Treatments	Rates tha^{-1}	5 WAS		7 WAS		9 WAS	
		Season					
		1	2	1	2	1	2
Control	0	24.67e	29.76e	69.50g	61.45c	77.70d	80c
Tithonia	0.9	40.48d	39.64d	82.77c	85.10b	95.04bc	98.33b
Tithonia	1.8	42.84c	41.24c	83.87b	85.21b	96.61bc	99.67b
Tithonia	2.7	44.67a	45.81a	85.57a	86.49a	100.40a	102.00a
Cattle manure	7.5	40.93d	39.72d	79.82f	84.49b	94.38c	99.33b
Cattle manure	15	42.83c	44.83b	80.93e	85.12b	99.00ab	100.67a
Cattle manure	22.5	43.83b	45.77a	81.50d	85.60b	100.05ab	100.00b
SE.($p<0.05$)		0.353	0.759	0.23	0.644	1.923	1.853

*Values followed by the same letter do not differ significantly

Table 7 Effect of *Tithonia diversifolia* and cattle manures on the number of leaves of sesame at 5, 7 and 9 weeks after sowing (WAS) in the two seasons

Treatments	Rates tha^{-1}	5 WAS		7 WAS		9 WAS	
		Season					
		1	2	1	2	1	2
Control	0	17.80c	17.00f	39.67e	34.64d	39.00d	47.33f
Tithonia	0.9	22.23c	24.67e	69.77b	57.67c	59.33c	72.23d
Tithonia	1.8	37.10a	39.00b	73.67a	62.67b	61.67b	90.77b
Tithonia	2.7	39.33a	41.00a	74.10a	68.33a	65.00a	93.60a
Cattle manure	7.5	31.70b	33.00d	57.47d	59.00c	59.00c	60.47e
Cattle manure	15	36.23a	37.00c	65.57c	62.33b	61.00b	74.23d
Cattle manure	22.5	38.33a	39.00b	69.10b	67.33a	65.00a	87.00c
SE.($p<0.05$)		5.13	0.471	1.536	1.327	0.752	2.082

*Values followed by the same letter do not differ significantly

Mbatha (2008) reported an increase in the number of leaves of a crop subjected to higher rates of organic manure was attributed to enhanced nutrients availability, moisture retention and uptake as a result of manure application. But in this study, the number of leaves produced by the cattle manure at 22.5 tha^{-1} and *Tithonia* at 2.7tha^{-1} amended plots could not be translated into higher yield. This could be attributed to partitioning of assimilates into uneconomic parts of the plants rather than on the reproductive parts.

Table 8 Effect of *Tithonia diversifolia* and cattle manures on the leaf area index (m^2) of sesame at 5, 7 and 9 weeks after sowing (WAS) in the two seasons

Treatments	Rates tha^{-1}	5 WAS		7 WAS		9 WAS	
		Season					
		1	2	1	2	1	2
Control	0	0.20g	0.13d	0.26e	0.31d	0.46d	0.41d
Tithonia	0.9	0.29f	0.18c	0.32d	0.37	0.74c	0.61c
Tithonia	1.8	0.36b	0.32b	0.38b	0.45b	0.90b	0.89b
Tithonia	2.7	0.41a	0.37a	0.43a	0.49a	1.00a	1.01a
Cattle manure	7.5	0.32e	0.16cd	0.35c	0.44b	0.74c	0.62c
Cattle manure	15	0.33d	0.28b	0.37b	0.45b	0.91b	0.85b
Cattle manure	22.5	0.34c	0.32b	0.37b	0.49a	0.97a	1.00a
SE(p<0.05)		0.0023	0.0138	0.00509	0.00756	0.0454	0.079

*Values followed by the same letter do not differ significantly

Leaf area index

At 5 WAS, in both seasons, the *T. diversifolia* at the rate of 2.7 tha^{-1} produced the highest leaf area index (Table 8) which was significantly different from other treatments. While at 7WAS, in the first season, the *T. diversifolia* at the rate of 2.7 tha^{-1} produced the highest leaf area index which was significantly different from the other treatments while in the second season, the *T. diversifolia* at the rate of 2.7tha^{-1} and cattle manure at 22.5 tha^{-1} produced the highest leaf area index which was significantly different from the other treatments. At 9 WAS, in both seasons, the *T. diversifolia* at the rate of 2.7 tha^{-1} and cattle manure at the rate of 22.5 tha^{-1} produced the highest leaf area index which was significantly different from the other treatments. The higher leaf area index experienced in the *T. diversifolia* and cattle manures amended plots resulted in better light interception for photosynthesis, thus more biomass production due to more photosynthetic capacity of the crop; hence more assimilate production for crop growth. This is in agreement with the findings of Ahmad et al. (2005) who reported positive effect of farm yard manure on leaf area and leaf area index with higher levels of *T. diversifolia* manure. An increase in the leaf area index increased the light interception and thus more source and sink. The higher LAI resulted in higher photosynthesis as more assimilates were produced hence higher growth and yield (Addai and Alimiyawo 2015).This response of sesame to higher rates of application of the amendment to leaf area is an indication that nutrients absorbed by the crops were used for cell division, protein synthesis and energy formation and other essential components in photosynthesis (Ng'etich et al. 2013).

Yield components of sesame

The number of capsules per plant is presented in Table 9. In the first season, the *T. diversifolia* applied at the rate of 1.8tha^{-1} produced the highest number of capsules which was statistically at par with the *T. diversifolia* applied at the rate of 2.7 tha^{-1}, cattle manures at 22.5 tha^{-1}, and 15 tha^{-1}, and T. *diversifolia* at 0.9 tha^{-1} but the control produced the lowest number of capsules which was at par with the cattle manure treated plot at 7.5 tha^{-1}. But in the second year, the *T. diversifolia* applied at the rate of 1.8 tha^{-1} produced the highest number of capsules while the least number of capsules was produced by the control. The increase in the number of capsules per plant with increasing rates of organic amendment and declining at the highest rates of *Tithonia diversifolia* and cattle manure could be attributed to the nutrient availability for photosynthesis and subsequent translocation and partitioning into the uneconomic parts of the plant, thus reducing the reproductive capacity and yield potentials of the plant. The yield of the net plot presented in Table 9. It was observed that in the first season, the net plot yield ranged from 13.21 – 51.3g. The *T. diversifolia* applied at the rate of 1.8 tha^{-1} produced the highest yield while the control treatment produced the lowest yield. In the second year, the *T. diversifolia* applied at the rate of 1.8 tha^{-1} produced the highest yield which was at par with the cattle manure at the rate of 15 tha^{-1} while the control produced the lowest yield. The yield of sesame was higher in the first season than those of the second season (Table 9). In the first season, the yield ranged from 140.9 – 547.2 kgha^{-1} while in the second season, the yield ranged 134.5 – 527 kgha^{-1}. The control consistently gave lowest yield in both seasons. This was more pronounced in the second season when the *T. diversifolia* applied at the rate of 1.8tha^{-1} (60 N source) outperformed the control with about 75%. In both seasons, the *T. diversifolia* applied at the rate of 1.8 tha^{-1} (60 N source) gave overall highest yield in the first year but in the second year the *T. diversifolia* applied at the rate of 1.8 tha^{-1} (60 N source) produced yield which was at par with the cattle manure at 15 tha^{-1} (60 N source). The first season yield was in the order of *T. diversifolia* applied at 1.8 tha^{-1}> cattle manure at 15 tha^{-1} > cattle manure at 22.5 tha^{-1} ≥ *T. diversifolia* at 2.7 tha^{-1}>*T. diversifolia* at 0.9 tha^{-1}> control while in the second year the order was *T. diversifolia* at 1.8tha^{-1} ≥ cattle manure at 15tha^{-1} > cattle manure at 22.5tha^{-1} ≥ *T. diversifolia* at 2.7 tha^{-1} >*T. diversifolia at* 0.9 tha^{-1}> control. The higher yield experienced in the *Tithonia diversifolia* at 1.8 tha^{-1} and cattle manures at 15 tha^{-1} compared to *Tithonia diversifolia applied at the* rate of 2.7 tha^{-1} and cattle manure at 22.5tha^{-1} could be adduced to luxury consumption of the nutrients by the crop and the partitioning of the assimilates into vegetative parts rather than on seed formation. However, the *T. diversifolia* and cattle manure applied at 1.8tha^{-1} and 15 tha^{-1} out yielded the higher rates of application due to the presence of nutrients in moderate quantities, thus influencing the growth and yield of the crop. The soil was able to give good yield (although lower than the first season) in the next cropping season due to the slow release of nutrients by the *T. diversifolia* and cattle manures and stored for a long time in the soil and this characteristic of the manure improved the yield of sesame in the second season (Abou El-Magd et al. 2005). *Tithoniadiversifolia*used as green manure has been reported to increase yield of crops such as maize in eastern and southern Africa, rice as well as vegetables in Asia (Jama et al. 2000; Gachengo et al. 1998). Aguayon et al. (2010) stated that there was an increase in total yield of crop with increasing application rates of *T. diversifolia* manure. The increase in growth and yield parameters of treated plots with organic inputs can be ascribed to the attributes of organic manure`s ability to improve soil fertility and yield of crops (Adeniyan and Oyeniyi 2003; Ojeniyi and Adeyboyega 2003). Although the yield of sesame was higher than what was reported by FAO (2009) in Ivory Coast and Ethiopia but lower than the report of Abubakar et al. (1998) in Venezuela and Saudi Arabia.

Table 9 Effect of *T. diversifolia* and cattle manure on the yield components of sesame in the two seasons

Treatments	Rates tha-1	No of capsules plant^{-1}		Yield per net plot (g)		Yield per hectare (kg)	
		Season					
		1	2	1	2	1	2
Control	0	30f	28f	13.21e	12.76e	140.9e	134.5e
Tithonia	0.9	38e	37e	32.90d	30.45d	350.9d	324.8d
Tithonia	1.8	55a	50a	51.30a	48.50a	547.2a	527.6a
Tithonia	2.7	49b	45c	45.18c	39.80c	481.9c	424.5b
Cattle manure	7.5	42d	26g	31.49d	32.82d	335.9d	350.1c
Cattle manure	15	50b	48b	48.48b	46.16ab	517.3b	517.2a
Cattle manure	22.5	46c	44d	43.58c	41.88b	464.9c	446.8b
SE.($p<0.05$)		0.873	0.793	0.793	2.246	8.46	11.08

*Values followed by the same letter do not differ significantly

Conclusion

The study revealed the nutrient composition of *Tithonia diversifolia* as green manure and cattle manure in soil fertility restoration in a Guinea savannah zone of Nigeria. Taking into cognizance the quantity of *T. diversifolia* and the higher quantity of cattle manure required to supply the different nitrogen rates. These materials should therefore be used in the management of soils bearing in mind that the soils of the study area readily dries out due to the vagaries of weather was improved by the addition of these organic materials and, hence were able to improve the water retention capacity of the soil. The use of *T. diversifolia* at the rate of 1.8tha^{-1} and cattle manure at 15 tha^{-1}gave the highest growth and yield attributes of sesame. These organic manures can therefore be used in areas where inorganic fertilizer is inaccessible or too expensive for peasant farmers in the cultivation of sesame. However, economic analyses on the manures have to be determined to ascertain the profitability of its use for up scaling for farmers.

Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interest associated with this study.

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