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Influence of Biofertilizer-Fortified Organic and Inorganic Nitrogenous Fertilizers on Performance of Sesame (*Sesamum indicum Linn.*) and Soil Properties Under Savanna Ecoregion

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Abstract

Application of chemical fertilizers as supplement to the pre-existing soil nutrients has become inevitable for obtaining optimum crop performance in the tropics. However, persistent application of inorganic fertilizers affects soil physico-chemical conditions and reduces crop productivity. Integration of mycorrhizal inoculum as biofertilizer and organic manure with little inorganic fertilizer input could improve crop performance and soil quality. However, there is little information on response of crops particularly Sesame (Sesamum indicum L.) to such integrated nutrient management approach. Two greenhouse experiments were carried out at Ladoke Akintola University of Technology (LAUTECH), Ogbomoso, Nigeria and Institute of Agricultural Research and Training (I.A.R&T), Moor plantation, Ibadan, Nigeria to assess response of sesame to integrated nutrient management approach. Twelve factorial combinations each of integrated green tithonia biomass and urea, with and without Glomus clarum mycorrhizal inoculum were investigated. Trials were arranged in a completely randomized design with three replications. Data were collected on growth and yield parameters and analysed using ANOVA at $p < 0.05$. Mycorrhizal inoculation significantly enhanced sesame growth (except number of branches) and yield with or without applied N-source(s), compared to their non-inoculated counterparts. Sesame responded best to inoculation of 75% tithonia + 25 % Urea + Glomus clarum which significantly enhanced plant height, stem circumference, number of leaves, biomass yield and seed yield. Soil physical and chemical properties significantly improved with increasing application of green Tithonia-biomass. At above 50 % of urea integration, values of growth and yield parameters were statistically similar but significantly higher than the control. Thus, green Tithonia-biomass integration at 75 % level with urea at 25 % level to meet up N-requirement of sesame + mycorrhizal inoculum is suitable for optimum growth and yield of sesame and improved soil quality under savanna ecoregion.

Keywords; Biofertilizer, sesame, soil properties, savanna ecoregion, nitrogenous fertilizers

Introduction

Incorrect application of chemical fertilizers and lack of appropriate soil management / conservation strategies are the major causes of rapid depletion of soil nutrients and subsequently low crop productivity persisting in the tropics. Tropical farmers apply chemical fertilizers "anyhow" regardless of scientific recommendations for different crops as well as the importance of improving and maintaining organic matters in the soil system (Sobulo, 2000). Also, human activities (such as incessant yearly bush burning, continuous cropping, mono-cropping, overgrazing, mining, bulldozing, open-clean-clear cultivation, ridging-along-the-slope, excessive logging etc) and other climatic attributes (such as torrential rainfall and high solar radiation) are equally aggravating nutrient imbalances and rapidity of nutrient depletion in the tropics (Babajide *et al.,* 2008).

Sesame (*Sesamum indicum*) is a flowering annual plant in the genus *sesamum.* It belongs to the family Pedaliaceae. It is an erect plant which grows 50 to 250 cm tall, depending on the varieties and soil environmental conditions (Sharma, 2005). Sesame matures 70-150 days after sowing, depending on the varieties and its seed contains 25 % protein and about 50 % oil (Weiss, 2000). Utilization of sesame includes human consumption, health treatments, beautification, livestock feeding and industrial uses (Sharma, 2005; El-Habbasha *et al.,* 2007). It is now widely cultivated in the derived, northern and southern guinea, Sudan and Sahel savannas of Nigeria (Alegbejo *et al.,* 2003).

Biofertilizers are microsymbionts which improve the host-plant performance through enhanced water and nutrient uptakes (Boureima *et al.,* 2007). Arbuscular mycorrhizal fungus is a microsymbiont which improves water and nutrient uptakes in many crops found in both tropical and temperate regions of the world (Neveen *et al.,* 2008).

Tithonia diversifolia (Hemsl.) A. Gray commonly known as Wild flower or Mexican sunflower is an annual shrub and a highly aggressive weed which grows usually to a height of about 2.5m and adaptable to most soils (Olabode *et al.,* 2007). It belongs to the family Asteraceae. It was reported to be originated from Mexico and now widely distributed all over the humid and sub-humid tropics of the Central and South America, Asia and Africa (Babajide *et al.,* 2008). Although, it is a common weed which is relatively high in nutrient concentrations (particularly nitrogen) but, little is known about its potentials as a dependable nutrient source for improved soil fertility and crop yields (Chukwuka and Omotayo, 2009). Moreso, in modern crop production, nitrogen is one of the most critical elements needed to be carefully managed simply because of its significant roles and attributed high levels of volatilization and leaching losses (Akanbi, 2002). Unfortunately, nitrogen applied by the resource-poor local farmers is mostly sourced from highly-priced chemical fertilizers which had been reported to induce harmful effects (e.g. soil acidity, toxic nitrate pollution of underground waters, eutrophication and undesirable soil properties (Tejada *et al.,* 2005).

Integrated Nutrient Management Approach (INMA) is an environment friendly technology which involves proportionate combination of multiple fertilizer materials of different origins or sources (e.g. organic, inorganic and biological), may be economical and even more suitable for enhanced crop productivity and soil quality than using any other fertilizer from a single source. Therefore, since there is little information on response of crops, particularly *Sesamum indicum L.*, to such INMA, these experiments investigated the effects of Integrated Nutrient Management Approach (INMA) on performance of sesame and soil physico-chemical properties, under low fertile soil conditions located in the savanna ecoregion of Nigeria.

Materials and Methods

Two greenhouse experiments were conducted between April and July, 2011 at the Teaching and Research Farms, Ladoke Akintola University of Technology (LAUTECH), Ogbomoso and Institute of Agricultural Research and Training (I.A.R&T), Moor plantation, Ibadan, both in Oyo state, Nigeria, to assess response of sesame and soil physico-chemical properties to Integrated Nutrient Management Approach (INMA). Ogbomoso (latitude 8^0 10′ N and longitude 4^0 10′ E) and Ibadan (latitude 7^0 30′ N and longitude 3^0 45′ E) fall under southern guinea and derived guinea savanna ecoregions of the south-west Nigeria respectively. These experimental locations are similarly characterized by bimodal rainfall distribution with two peaks (between 1150 mm and 1250 mm) in late July / early August and October / November. Soil samples were collected (using soil auger at a depth of 0-15cm), from each experimental location and bulked into separate composite samples accordingly for physico-chemical analyses according to IITA (1982) and Akanbi (2002). The samples at Ogbomoso and Ibadan were Alfisols belonging to Egbeda and Olorunda series respectively (Smyth and Montgomery, 1962; Bridges, 1997). Plant residues found on the farm sites were applied as basal manure. Urea (46% N), was used as the only inorganic nitrogen (N) source, obtained from the Oyo State Agricultural Development Programme (OYSADEP), Ogbomoso. Urea was applied in two splits at 4 and 7 WAS. Green Tithonia biomass was used as the organic source of nitrogen cut at eight weeks after emergence and shredded (into smaller fragments of less than 5 cm in length with stem girths ranging from 2.8 cm to 4.2 cm), before incorporating into 10 kg soil-filled pots, at two weeks before sowing. Proportionate combinations of green Tithonia biomass and urea were done to meet up 100% level of the recommended N rate of 80 Kg Nha^{-1}. Twelve (12) treatments introduced were; To = Zero Application (Control), T_1 = 100% Urea (at the recommended rate), T_2 = 75% Urea + 25% Tithonia, T_3 = 50% Urea + 50% Tithonia, T_4 = 25% Urea + 75% Tithonia, T_5 = 100% Tithonia, T_6 = 100% Urea + Mycorrhiza, T_7 = 100% Tithonia + Mycorrhiza, T_8 = 75% Tithonia + 25% Urea + Mycorrhiza, T_9 = 50% Tithonia + 50% Urea + Mycorrhiza, T_{10} = 25% Tithonia + 75% Urea + Mycorrhiza and T_{11} = Mycorrhiza alone. Three pots per treatment were used at the two experimental locations. The trials were arranged in CRD, replicated three (3) times. The total number of pots used for each experiment was 12×3×3= 108.

Sesame seeds of variety E8 (an early maturing type) were obtained from the National Cereal Research Institute

(NCRI) at Badeggi, Niger State, Nigeria. The seeds were surface sterilized by using 95% ethanol for 10 seconds and were later rinsed six (6) times with sterile water after shaking for three to five minutes in 3% hydrogen peroxide (H_2O_2). Four seeds were sown per pot on April 10th and 13th, 2011 at Ogbomoso and Ibadan respectively and were thinned to one seedling per pot at one week after sowing. Chopped root fragments of maize plant containing mycorrhizal propagules of *Glomus clarum* were used as mycorrhizal inocula. Each inoculum of a root-soil-fungal spore mixture weighing 20g obtained from the Microbiological Laboratory of Agronomy Department, University of Ibadan, Nigeria, was placed at about 3cm depth of the soil (Dare, 2008). After harvesting, root samples were cut into 1cm length and stored in 50% ethanol for mycorrhizal root staining and percentage mycorrhizal root colonization (Dare, 2008). Data were collected on growth and yield parameters; plant height, stem circumference, number of branches, number of leaves, number of capsules per plant, weight of 1000 seeds per treatment, oil content, mycorrhizal root colonization, total biomass production, total seed yield and nutrient uptakes of N, P and K according to AOAC (1980); Ombo (1994); Gungunla (1999); Akanbi (2002) and Fathy *et al.,* (2009). The experiments were terminated at 14 WAS (i.e. July 17th and 20th, 2011) at Ogbomoso and Ibadan sites respectively. Soil temperature was determined (using soil thermometer placed at 5cm soil depth at 1500 Hour). At the end of the trials, two core soil samples collected from each pot, at a soil depth range of between 5 and 10cm were composited for gravimetric determination of the soil moisture content and bulk density. Also, post-cropping pH determination only was done as described by I.I.T.A., (1982). All data collected were analyzed following the procedures of analysis of variance (ANOVA) at $p < 0.05$. Significant means were separated using Duncan Multiple Range Test (SAS, 2011).

Results and Discussion

The results from the pre-cropping soil analyses revealed that the soils were mildly-acidic (Table 4). Also, the soils were texturally sandy-loam; (sand; 80.00 % and 83.60 %, silt; 11.08 % and 8.82 %, clay; 8.92% and 7. 58 %) and grossly low in fertility particularly in essential nutrients (total N; 0.22 g kg^{-1} and 0.26 g kg^{-1}, available P; 4.08 mg kg^{-1} and 4.81 mg kg^{-1}; organic carbon; 3.88 and 4.56 g kg^{-1}) and exchangeable bases (cmol.kg^{-1}); K; 0.28 and 0.30, Ca; 15.25 and 15.24, Mg; 2.94 and 3.06; Na; 0.28 and 0.26 at Ogbomoso and Ibadan respectively. These showed that the soil samples used were inadequate in nutrients and therefore required artificial supply of nutrients to meet sesame nutritional requirements. These results were in agreement with other earlier researchers (Babajide *et al.,* 2008; Olabode *et al.,* 2007; Akanbi, 2002), who reported that the soils at the study areas were slightly acidic and grossly inadequate in nutrients. Therefore, application of high dosage of chemical fertilizer may not favour successful crop production in the locations simply because of the high risk of soil acidity which is possible under intensive and continuous application. Growth and yield parameters significantly increased with increasing level of integration of both organic and inorganic fertilizers with or without mycorrhizal inoculation at both locations (Tables 1 and 2). Integration of biofertilizer with 75% Tithonia biomass + 25% urea had the significantly highest growth and yield parameters (Tables 1 and 2). These results supported Palaniappan *et al* (1999) who reported improvement in general crop performance when inoculated with biofertilizer / microsymbiont solely or in combination with other fertilizer materials. Mycorrhizal root infection or colonization significantly increased with mycorrhizal inoculation compared to the non-inoculated counterparts at both experimental locations (Table 3). Moreso, mycorrhizal infectivity of sesame plant roots significantly reduced when urea integration level was greater than 50%. This revealed that application of chemical fertilizer may be toxic to soil microbes thereby affecting their proliferation and effective competition with other soil microbes as earlier reported by Dare (2008). Moreso, combined inoculation of mycorrhiza and green Tithonia biomass significantly regulated soil temperature (Table 4). Application of Tithonia significantly regulated soil temperature particularly at 50% integration and above (Table 4). Bulk density followed similar trend (Table 4). Also, soil moisture, N-uptake and post-cropping soil pH significantly improved with Tithonia integration at 75% level + 25% urea + mycorrhizal inoculation (Tables 3 and 4) at both locations but, 100 % integration of Tithonia + mycorrhizal inoculation significantly enhanced phosphorus (P) and potassium (K) uptakes (Table 3). These results corroborated the findings of Palaniappan *et al* (1999), Akanbi, 2002 and Babajide *et al.* (2008), who reported improved crop performance and (or) soil quality as resulted from either sole application of manure or integration of different nutrient sources.

Conclusion

Biomass from *Tithonia diversifolia* is a potential fertilizer material (organic manure) that could be integrated as green manure at 75 % with 25 % urea plus mycorrhizal inoculation, for improved sesame performance and soil physicochemical properties. Therefore, crop production efforts should be streamlined towards alleviating (or possibly eliminating) the amount of chemical fertilizer inputs applied per unit area of farmland. Adoption of Integrated nutrient management approach is a reliable technology for improved crop production and for safeguarding the environment for future generations.

Table 1: Growth parameters and oil content of sesame as influenced by biofertilizer and different nitrogen sources at Ibadan and Ogbomoso.

Treatments	Plant Height (cm)		Stem Circumference(cm)		No. of Branches		No. of Leaves		Oil Content (%)	
	Ogbomoso	Ibadan	Ogbomoso	Ibadan	Ogbomoso	Ibadan	Ogbomoso	Ibadan	Ogbomoso	Ibadan
T0	76.0^{f}	70.7^{d}	4.4^{bc}	4.4^{c}	4.4^{b}	4.5^{b}	47.2^{d}	46.6^{d}	40.0^{c}	41.1^{c}
T1	114.2^{c}	123.1^{ab}	4.6^{b}	4.8^{bc}	7.7^{a}	8.0^{a}	88.2^{b}	84.2^{b}	42.1^{bc}	42.4^{c}
T2	104.2^{c}	119.2^{ab}	3.8^{c}	4.2^{c}	7.6^{a}	8.0^{a}	88.1^{b}	86.4^{b}	43.0^{bc}	43.4^{c}
T3	114.1^{c}	123.1^{ab}	3.9^{c}	4.2^{c}	7.6^{a}	8.0^{a}	84.2^{b}	84.0^{b}	44.1^{b}	44.4^{ab}
T4	118.3^{c}	122.6^{ab}	3.8^{c}	4.3^{c}	7.6^{a}	8.0^{a}	80.6^{b}	81.5^{b}	46.2^{b}	46.0^{ab}
T5	129.4^{ab}	133.2^{a}	4.7^{b}	4.6^{c}	7.8^{a}	7.9^{a}	84.6^{b}	83.7^{b}	46.0^{b}	45.0^{ab}
T6	114.3^{c}	122.4^{ab}	5.1^{b}	5.0bc	7.9^{a}	7.7^{a}	81.0^{b}	81.5^{b}	52.1^{a}	51.4^{a}
T7	134.6^{a}	141.2^{a}	6.6^{a}	5.1^{bc}	8.0^{a}	8.0^{a}	82.4^{b}	84.5^{b}	52.3^{a}	52.3^{a}
T8	146.4^{a}	140.1^{a}	7.6^{a}	7.8^{a}	8.0^{a}	8.0^{a}	105.0^{a}	107.7^{a}	58.4^{a}	57.3^{a}
T9	129.4^{ab}	134.6^{a}	6.2^{ab}	6.3^{b}	8.0^{a}	8.0^{a}	85.6^{b}	86.7^{b}	56.5^{a}	57.0^{a}
T10	130.2^{ab}	138.1^{a}	5.6^{b}	5.7^{b}	8.0^{a}	8.0^{a}	83.6^{b}	84.5^{b}	44.0^{b}	44.2^{ab}
T11	88.4^{e}	91.2^{c}	4.6^{b}	4.5^{c}	4.8^{b}	4.9^{b}	71.2^{c}	69.4^{c}	46.5^{b}	46.0^{ab}

Means followed by the same letters within the same column are not significantly different at $p \leq 0.05$, using DMRT. T0 = Zero Application (Control), T1 = 100% Urea (Recommended rate), T2 = 75% Urea + 25% Tithonia, T3 = 50% Urea + 50% Tithonia, T4 = 25% Urea + 75% Tithonia, T5 = 100% Tithonia (Recommended rate), T6 = 100% Urea + Mycorrhiza, T7 = 100% Tithonia + Mycorrhiza, T8 = 75% Tithonia + 25% Urea + Mycorrhiza, T9 = 50% Tithonia + 50% Urea + Mycorrhiza, T10 = 25% Tithonia + 75% Urea + Mycorrhiza, T11 = Mycorrhiza alone

Table 2: Yield parameters of sesame as influenced by biofertilizer and different nitrogen sources at Ibadan and Ogbomoso.

Treatments	No. of Capsules plant^{-1}		Weight of1000 seeds (g)		Total Seed Yield (t ha^{-1})		Total biomass production (t ha^{-1})	
	Ogbomoso	Ibadan	Ogbomoso	Ibadan	Ogbomoso	Ibadan	Ogbomoso	Ibadan
T0	20.3^{e}	21.5^{e}	2.2^{c}	2.3^{c}	0.5^{e}	0.6^{g}	2.7^{h}	2.6^{h}
T1	67.5^{c}	70.1^{bc}	2.4^{b}	2.4^{b}	1.4^{c}	1.4^{de}	6.4^{d}	6.5^{d}
T2	70.2^{b}	71.2^{b}	2.4^{b}	2.4^{b}	1.4^{c}	1.5^{d}	6.5^{d}	6.5^{d}
T3	74.3^{b}	73.1^{b}	2.4^{b}	2.4^{b}	1.5^{c}	1.6^{d}	7.0^{c}	6.9^{c}
T4	77.5^{b}	72.1^{b}	2.4^{b}	2.5^{b}	2.6^{b}	2.6^{b}	7.0^{c}	6.9^{c}
T5	74.8^{b}	76.8^{b}	2.4^{b}	2.4^{b}	2.5^{b}	2.6^{b}	7.1^{c}	7.1^{c}
T6	73.5^{b}	78.4^{b}	2.4^{b}	2.4^{b}	2.5^{b}	2.4^{bc}	5.7^{e}	5.8^{e}
T7	74.0^{b}	77.9^{b}	2.5^{ab}	2.4^{ab}	2.4^{b}	2.4^{bc}	8.6^{b}	8.6^{b}
T8	97.6a	96.9^{a}	2.8^{a}	2.7^{a}	3.2^{a}	3.1^{a}	9.0^{a}	9.1^{a}
T9	70.2^{b}	71.0^{b}	2.5^{ab}	2.5^{ab}	2.6^{b}	2.6^{b}	7.0^{c}	6.9^{c}
T10	66.5^{c}	69.1^{bc}	2.4^{b}	2.3^{c}	2.5^{b}	2.5^{b}	5.9^{e}	5.8^{e}
T11	35.0^{d}	33.0^{d}	2.4^{b}	2.4^{ab}	0.9^{d}	0.9^{f}	4.7^{g}	4.5^{g}

Means followed by the same letters within the same column are not significantly different at $p \leq 0.05$, using DMRT. T0 = Zero Application (Control), T1 = 100% Urea (Recommended rate), T2 = 75% Urea + 25% Tithonia, T3 = 50% Urea + 50% Tithonia, T4 = 25% Urea + 75% Tithonia, T5 = 100% Tithonia (Recommended rate), T6 = 100% Urea + Mycorrhiza, T7 = 100% Tithonia + Mycorrhiza, T8 = 75% Tithonia + 25% Urea + Mycorrhiza, T9 = 50% Tithonia + 50% Urea + Mycorrhiza, T10 = 25% Tithonia + 75% Urea + Mycorrhiza, T11 = Mycorrhiza alone

Table 3: Effect of Integration of Biofertilizer and Different Nitrogen Sources on mycorrhizal root infection and nutrient uptakes of sesame

Treatments	Mycorrhizal root infection (%)		Nutrient uptakes (g kg^{-1})					
			Ogbomoso			Ibadan		
	Ogbomoso	Ibadan	N	P	K	N	P	K
T0	8.2^{d}	7.0^{d}	3.6^{h}	1.3^{f}	0.5^{g}	3.7^{f}	1.4^{e}	0.6^{f}
T1	2.3^{d}	2.0^{d}	24.9^{f}	3.8^{e}	14.3^{e}	25.7^{d}	4.4^{d}	15.0^{d}
T2	2.0^{d}	2.2^{d}	28.9^{e}	5.5^{d}	16.9^{d}	31.4^{c}	5.6^{c}	17.3^{c}
T3	4.2^{d}	4.7^{d}	30.4^{e}	8.1^{bc}	19.5^{c}	31.8^{c}	8.2^{b}	20.5^{b}
T4	3.0^{d}	3.6^{d}	34.2^{bc}	7.8^{c}	20.4^{bc}	35.2^{b}	8.0^{b}	20.7^{b}
T5	8.0^{d}	6.0^{d}	36.7^{b}	9.0^{a}	21.1^{b}	37.5^{b}	9.2^{a}	20.7^{b}
T6	8.0^{d}	8.8^{d}	24.6^{f}	4.0^{e}	16.0^{d}	25.0^{d}	4.1^{d}	16.7^{c}
T7	67.2^{a}	63.6^{a}	31.7^{d}	8.9^{ab}	24.1^{a}	32.3^{c}	9.0^{a}	24.1^{a}
T8	67.6^{a}	67.0^{a}	44.5^{a}	7.9^{c}	21.7^{b}	46.0^{a}	8.0^{b}	21.8^{b}
T9	46.3^{b}	47.8^{b}	31.8^{cd}	8.7^{abc}	21.8^{b}	32.6^{c}	9.1^{a}	22.0^{b}
T10	23.2^{c}	22.0^{c}	27.8^{e}	5.7^{d}	15.6^{de}	27.3^{d}	5.8^{c}	16.4^{c}
T11	55.2^{ab}	51,3^{ab}	18.8^{g}	3.8^{e}	11.5^{f}	19.8^{e}	4.0^{d}	12.0^{e}

Means followed by the same letters within the same column are not significantly different at $p \leq 0.05$, using DMRT. T0 = Zero Application (Control); T1 = 100% Urea (Recommended rate);T2 = 75% Urea + 25% Tithonia; T3 = 50% Urea + 50% Tithonia; T4 = 25% Urea + 75% Tithonia; T5 = 100% Tithonia (Recommended rate); T6 = 100% Urea + Mycorrhiza; T7 = 100% Tithonia + Mycorrhiza;T8 = 75% Tithonia + 25% Urea + Mycorrhiza; T9 = 50% Tithonia + 50% Urea + Mycorrhiza; T10 = 25% Tithonia + 75% Urea + Mycorrhiza; T11 = Mycorrhiza alone

Table 4: Effect of Biofertilizer and different nitrogen sources on soil physical and chemical properties.

Treatments	Temperature (^{o}C)		Bulk density (cm^{-3})		Moisture content (%)		pH (pre-cropping)		pH (post-cropping)	
	Ogbomoso	Ibadan	Ogbomoso	Ibadan	Ogbomoso	Ibadan	Ogbomoso	Ibadan	Ogbomoso	Ibadan
T0	28.7^{a}	28.2^{a}	1.48^{a}	1.50^{a}	19.10^{c}	19.00^{c}	6.0^{NS}	6.1^{NS}	5.8^{bc}	5.8^{bc}
T1	28.3^{a}	28.2^{a}	1.45^{a}	1.49^{a}	19.00^{c}	19.12^{c}	6.0^{NS}	6.1^{NS}	5.7^{bc}	5.8^{bc}
T2	28.0^{a}	28.1^{a}	1.46^{a}	1.46^{a}	19.00^{c}	19.10^{c}	6.0^{NS}	6.1^{NS}	5.8^{bc}	5.9^{bc}
T3	24.3^{b}	25.1^{b}	1.10^{b}	1.15^{b}	26.70^{b}	26.40^{b}	6.0^{NS}	6.1^{NS}	6.1^{a}	6.2^{a}
T4	23.8^{b}	23.7^{c}	0.94^{bc}	0.96^{b}	28.00^{ab}	28.14^{ab}	6.0^{NS}	6.1^{NS}	6.1^{a}	6.2^{a}
T5	22.2^{c}	23.0^{c}	0.88^{c}	0.90^{b}	30.60^{a}	30.30^{a}	6.0^{NS}	6.1^{NS}	6.2^{a}	6.2^{a}
T6	28.3^{a}	28.0^{a}	0.89^{c}	0.90^{b}	25.8^{b}	26.00^{ab}	6.0^{NS}	6.1^{NS}	5.7^{bc}	5.7^{bc}
T7	22.0^{c}	22.4^{d}	0.88^{c}	0.89^{b}	30.90^{a}	30.85^{a}	6.0^{NS}	6.1^{NS}	6.2^{a}	6.3^{a}
T8	22.2^{c}	22.0^{d}	0.94^{bc}	0.95^{b}	30.40^{a}	30.6^{a}	6.0^{NS}	6.1^{NS}	6.1^{a}	6.2^{a}
T9	24.0^{b}	24.1^{bc}	1.00^{bc}	1.00^{b}	28.61^{ab}	29.00^{a}	6.0^{NS}	6.1^{NS}	6.1^{a}	6.2^{a}
T10	28.5^{a}	28.3^{a}	1.43^{a}	1.43^{a}	20.10^{c}	21.10^{c}	6.0^{NS}	6.1^{NS}	5.7^{bc}	5.8^{bc}
T11	24.2^{b}	24.3^{bc}	1.36^{b}	1.40^{a}	22.20^{bc}	21.90^{c}	6.0^{NS}	6.1^{NS}	6.0^{b}	6.1^{b}

NS= Not Significant. Means followed by the same letters within the same column are not significantly different at $p \leq 0.05$, using DMRT. T0 = Zero Application (Control), T1 = 100% Urea (Recommended rate), T2 = 75% Urea + 25% Tithonia, T3 = 50% Urea + 50% Tithonia, T4 = 25% Urea + 75% Tithonia, T5 = 100% Tithonia (Recommended rate), T6 = 100% Urea + Mycorrhiza, T7 = 100% Tithonia + Mycorrhiza, T8 = 75% Tithonia + 25% Urea + Mycorrhiza, T9 = 50% Tithonia + 50% Urea + Mycorrhiza, T10 = 25% Tithonia + 75% Urea + Mycorrhiza, T11 = Mycorrhiza alone

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