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SOIL NUTRITION AND PERFORMANCE OF SESAME (*SESAMUM INDICUM* LINN.) AS INFLUENCED BY DECOMPOSING PHYTO-RESIDUES AND MICROSYMBIONT INOCULA UNDER STERILE AND NON-STERILE SOIL CONDITIONS

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ABSTRACT

Integration of organic phyto-residues' application with inoculation of effective soil-borne microsymbiont strain(s) may be reasonably exploited as a suitable low-input technology, for ensuring enhanced tropical soil productivity and crop performance, under chemical-free and environment-friendly soil conditions. Research studies were carried out at the Ladoke Akintola University of Technology, Ogbomoso and the Institute of Agricultural Research and Training (IAR&T), Ibadan, between April and July, 2013, to assess the effects of combining different microsymbiont inocula with basal application of Tithonia divesifolia biomass on growth, yield and nutrient uptakes of sesame, under sterile and non-sterile soil conditions. Two (2) levels of soil treatment (i.e. Sterile and Non-sterile), and six (6) levels of application / inoculation (comprising five (5) levels of microsymbiont inocula (Azospirillum spp., Rhizobium spp., Mycorrhiza spp., Azotobacter spp. and the control, plus urea fertilizer application (which was consciously included as a reference, for better comparisons), were assayed, under similar rate of basal application of tithonia residues. The trial was arranged in a Completely Randomized Design (CRD), replicated three times. Data collected were analysed using Analysis of Variance (ANOVA), and the means were separated using Duncan

Multiple Range Test (DMRT). At the two locations, all the investigated microbial inocula significantly ($p < 0.05$) improved sesame performance, irrespective of the soil conditions, compared to the control. However, response of sesame was best with Azospirillum spp., which significantly increased nutrient uptakes and induced improved and prolonged leaf production in sesame, irrespective of the locations and soil conditions. Also, sesame growth increased by 160.6 % and 197.0 % (Ogbomoso), and 166.2 % and 185.8 % (Ibadan), under non-sterile and sterile soil conditions respectively. Thus, combining basal application of decaying Tithonia diversifolia residues with inoculation of effective microsymbiont, may be suitable for improved sesame production, which could also promote chemical-free organic farming in the study areas.

Keywords; Sesame, Microsymbiont, *Tithonia diversifolia*, Soil nutrition and Crop Performance.

I. INTRODUCTION

Environment friendly farming activities, which should discourage or alleviate the use of agro-chemicals should be encouraged nowadays, since the manifestation of the negative impacts of chemical use is currently a major concern, particularly in the tropics. However, abusive use of chemical fertilizers and lack of appropriate soil management strategies are the major causes of rapid essential nutrients' depletion and low crop productivity [1]. In addition, undesirable climatic attributes are rapidly aggravating nutrient imbalances and rates of nutrient losses [2]. Hence, an organic and environment-friendly strategy which could be easily adopted and afforded, particularly by the resource-poor farmers, are required for improving soil quality and crop performance.

Sesame (*Sesamum indicum*) is an erect, non-leguminous annual crop belonging to the family Pedaliaceae and the genus Sesamum. Sesame seed is rich in oil and protein of about 50 % and 25 % respectively [3]. It is useful for human and livestock consumptions, industrial raw materials, health treatments and beautification [4].

T*ithonia diversifolia* (also known as Mexican sunflower) belongs to the family Asteraceae and genus sesamum. It is a flowering annual weed which grows aggressively on abandoned waste-lands, beside highways, waterways and cultivated farmlands [5]. It is relatively high in nutrients, particularly nitrogen, and could be applied green, composted or dried, for improved crop performance [1].

Microsymbionts are soil-borne microbes which are known to be engaged in mutualism or symbiotic associations with their host-plants. In some cases, they are referred to as biofertilizers, which are living micro-organisms commonly inoculated or used as biological fertilizer materials, for improved water and nutrient uptake, and general soil nutrition improvement, so as to promote crop performance. Examples are Rhizobium, Mycorrhiza, Azospirillum etc. [6; 1; 7]. They are extremely beneficial in enhancing water and nutrient uptake and thereby assist in improving soil moisture, enriching the soil with organic nutrients and improving the general crop performance [8; 9]. Therefore, these duplicated research studies in two distinct two agro-ecological zones i.e. derived guinea savanna (Ibadan) and southern guinea savanna (Ogbomoso) were conducted to comparatively assess the responses of sesame to basal application of tithonia residues (representing usual farmers practice in the areas), and different microsymbiont inocula, under sterile and non-sterile soil conditions.

II. MATERIALS AND METHODS

2.1. *Experimental Location and Description*

Greenhouse studies were carried out between April and July, 2013, at the Ladoke Akintola University of Technology, Ogbomoso and the Institute of Agricultural Research and Training (I.A.R. & T), Ibadan, Nigeria. Ladoke Akintola University of Technology (LAUTECH), Ogbomoso (latitude 8^0 10’ N and longitude 4^0 10’ E) falls under southern guinea savanna vegetation zone of Nigeria, while the Institute of Agricultural Research and Training (I.A.R&T), Ibadan (latitude 7^0 30’ N and longitude 3^0 45’ E) falls under derived guinea savanna vegetation zone of Nigeria. These two vegetation zones are located in the south-west of Nigeria and are similarly characterized by bimodal rainfall distribution whereby the early rainy season starts in late March and ends in late July/early August, followed by a short dry spell in August and finally the late rainy season from August to November. The annual mean rainfall is between 1150 mm and 1250 mm**.**

2.2. *Soil Sampling and Analysis*

The soil samples used at Ibadan and Ogbomoso were both Alfisols belonging to Egbeda and Olorunda soil series respectively [10]. The samples were collected from the soil depths of between 0-15 cm. Pre-planting collection of soil samples was carried out, for laboratory analyses of the soil physical and chemical properties [11].

2.3. *Treatments and Experimental Design*

The experiment was a 2 x 6 factorial involving soil treatment at two (2) levels (i.e. S+ = Sterile soil and S- = Non-sterile soil), and six (6) levels of application / inoculation, comprising five (5) levels of microsymbiont inocula (*Azospirillum spp.*, *Rhizobium spp.*, *Mycorrhiza spp.*, *Azotobacter spp.* and the control, which received no microbial inoculation or fertilizer application), plus urea fertilizer application (which was consciously included and applied at the recommended rate of 80kg $Nha^{-1,}$ for referencing or representative of the commonly applied chemical fertilizers, for better comparisons). The trial was arranged in a completely randomized design (CRD), replicated three times.

2.4. *Soil Sterilization and Inoculation Microbes*

Soil was sterilized by autoclaving at 120 ^{0}C, for 1 hour for two consecutive days Chopped root fragments of maize plant (20g) containing mycorrhizal propagules were used as mycorrhizal inocula placed at 3 cm soil depth. Other inocula were applied according to [12]. 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 [9]. Also, Inocula for the *Rhizobia spp.* (R25B) were obtained from the International Institute of Tropical Agriculture (IITA), Ibadan. One ml each of inoculum containing approximately 10^8 cfu/ ml of R25B rhizobial strain was applied to the soil at one week after sowing, by using a sterile pipette [7]. Fresh liquid culture medium containing approximately 10^8 cfu/ ml of pure local strain *Azotobacter chroococcum* isolated from arable crop unit of the Teaching and Research Farms, of the Ladoke Akintola University of Technology (LAUTECH), Ogbomoso, purified and identified was also used as microsymbiont inoculum applied to the soil at sowing [13]. *Azospirillum lipoferum* strain was isolated from the rhizosphere of a millet (*Pennisetum typhoides*) experimental plot located at the Teaching and Research Farms, LAUTECH, Ogbomoso. Pure culture of the strain of *Azospirillum lipoferum* was grown in malate broth [14], supplemented with NH_4Cl [15]. The log phase culture was used for inoculation. The cells were harvested by centrifugation at 5,000g at 4^0C for 20 min. The supernatant was discarded and the pellet was washed two times with saline (5g NaCl and 0.12g $MgSO_4.7H_2O$ in distilled water) and re-suspended in saline at a concentration of 10^8 colony forming units (CFU) per ml. Each plant per pot was inoculated with 10ml of the material culture.

2.5. *Pot filling, Manuring, Propagation and Agronomic Practices*

Basal application of organic manure was done by incorporating the pre-existing Tithonia residues on the farmland into the soil at four weeks (at a similar rate), before sowing of seeds. Four seeds of sesame (variety E8), were sown in 10 kg soil-filled pots and later thinned to one seedling per pot at three (3) weeks after sowing. All plants were regularly watered. Pots were manually weeded by careful hand-pulling of all the emerging weed seedlings from the pots on weekly basis.

2.6. ***Data Collection and Statistical Analysis***

Data were collected on growth and yield parameters. Plant height was determined by using measuring tape placed at the base of the main stem of the plant to the tip. Fully matured capsules were carefully and cumulatively harvested (before shattering), and weighed per treatment, followed by total seed yield converted from the seed yield obtained (from 2.5 by 2.0 m^2) at spacing of 50 cm by 25cm [16]. Data collected were subjected to analysis of variance (ANOVA). The means were separated using Duncan's Multiple Range Test (DMRT) at 5% probability level [17].

2.7. ***Plant Sampling and Analysis***

The experiments were terminated at the two experimental sites at fourteen (14) weeks after sowing. After harvesting, all shoots and roots were oven dried at a temperature of 80 ^{0}C to a constant weight for five days, for dry weight determination of the total biomass yield and to determine the nutrient concentrations. The nutrients accumulated in plant parts were calculated as; Nutrient uptake = % Nutrient content x sample dry weight according to [18] and [19].

III. RESULTS AND DISCUSSION

As indicated in the results obtained from the pre-cropping physical and chemical soil analyses, the soils used were both texturally sandy-loam and mildly-acidic (with pH 6.0 and 6.2 at Ogbomoso and Ibadan respectively). Also, the soils were grossly low in essential nutrients particularly N (total N = 0.04 % and 0.08 % and available P (4.78 / 5.10 mg kg^{-1}), at Ogbomoso and Ibadan respectively. These results agreed with [20] and [7], who reported that the soils at the study areas were slightly acidic and also that they were grossly low in nutrient concentrations made them inadequate to support most arable crops, without boosting the soil fertility status through application of any available / affordable fertilizer materials.

Application of microbial inocula significantly improved sesame performance under different soil conditions investigated, at the two experimental locations (Table1 and Figure 1). However, sesame responded best (in terms of growth and yield parameters) to inoculation of *Azospirillum spp.,* under both sterile and non-sterile soil conditions, irrespective of the location, compared to urea application and other microbial inocula, and the control (Table1 and Figure 1). Azospirillum inoculation significantly ($p < 0.05$) increased sesame growth by 160.6 % and 197.0 % at Ogbomoso, under non-sterile and sterile soil conditions respectively. At Ibadan, Azospirillum inoculation significantly increased plant height of sesame by 166.2 % and 185.8 % under non-sterile and sterile soil conditions respectively. Also, at Ibadan, it was observed that, mycorrhizal and rhizobial inoculations resulted in similar plant height of sesame but were significantly ($p < 0.05$) higher than those obtained from Azotobacter inoculum and the control under sterile and non-sterile soil conditions at the two experimental locations (Table 1). Azotobacter inoculation had the least values of plant height under sterile and non-sterile soil conditions at both locations but, the values were significantly higher than the control (Table1). These agreed with earlier reports on bio-fertilizers, particularly Azospirillum which had been reported to be good alternative sources to chemical fertilizers in order to increase soil fertility and crop production in sustainable farming [21; 22].

Inoculation of sterile soil with Azospirillum significantly enhanced nutrient uptakes at both locations (Table 2). Highest uptakes of all nutrients determined was obtained in sesame plants grown on Azospirillum inoculated sterile soil at Ibadan. Significantly ($p < 0.05$) lower uptakes of P, K, Na, Fe, Mn and Zn were observed in Ogbomoso, although the values were significantly higher than the control. Azospirillum inoculation significantly ($p < 0.05$) enhanced nutrient uptakes particularly nitrogen (N) at both locations under sterile and non-sterile soil conditions (Table 2). This is in agreement with [23], who reported that Azospirillum strains improved nutrient uptake in sesame. Azospirillum strains were also reported to produce phytohormones like indole acetic acid, gibberellins and cytokinnins under in vitro conditions [24]. These hormones in turn have been reported to enhance nitrogen fixing capacity of the diazotrophs [25].

Mycorrhizal inoculation significantly ($p < 0.05$) improved nutrient uptake of Sesame particularly N, P, K, Ca, Mg, Na, Fe, Cu, Mn and Zn under both sterile and non-sterile soil conditions at Ibadan, compared to the control (Table 2). At the two locations, microbial inoculations generally enhanced nutrient uptakes significantly under both soil conditions, compared to the control (Table 2). This is in line with some research findings that mycorrhizal improves water and nutrient uptake of both the macro and micro elements [26;27].

Table 1: Plant height of sesame *(sesamum indicum)* as influenced by basal manuring and microsymbiont inocula under sterile and non-sterile soil conditions

Treatments	Ogbomoso	Ibadan
S-T0	43.4d	39.6e
S-T1	92.0bc	83.3bc
S-T2	113.1a	105.4a
S-T3	90.3bc	86.4b
S-T4	82.2c	86.0b
S-T5	81.4c	75.5d
S+T0	39.9d	38.0e
S+T1	95.8b	85.4b
S+T2	118.5a	108.6a
S+T3	89.9bc	87.3b
S+T4	83.0c	88.6b
S+T5	81.9c	77.9cd

Means followed by the same letters within the same column are not significantly different at $p<0.05$, using DMRT. S+= Sterile soil, S- = Non-sterile soil), T0 = No inoculation of biofertilizer / No application of fertilizer, T1= application of urea, T2 = inoculation with *Azospirillum spp.*, T3 = inoculation with *Rhizobium spp.*, T4 = inoculation with *Mycorrhiza spp*., T5 = *inoculation with Azotobacter spp.*

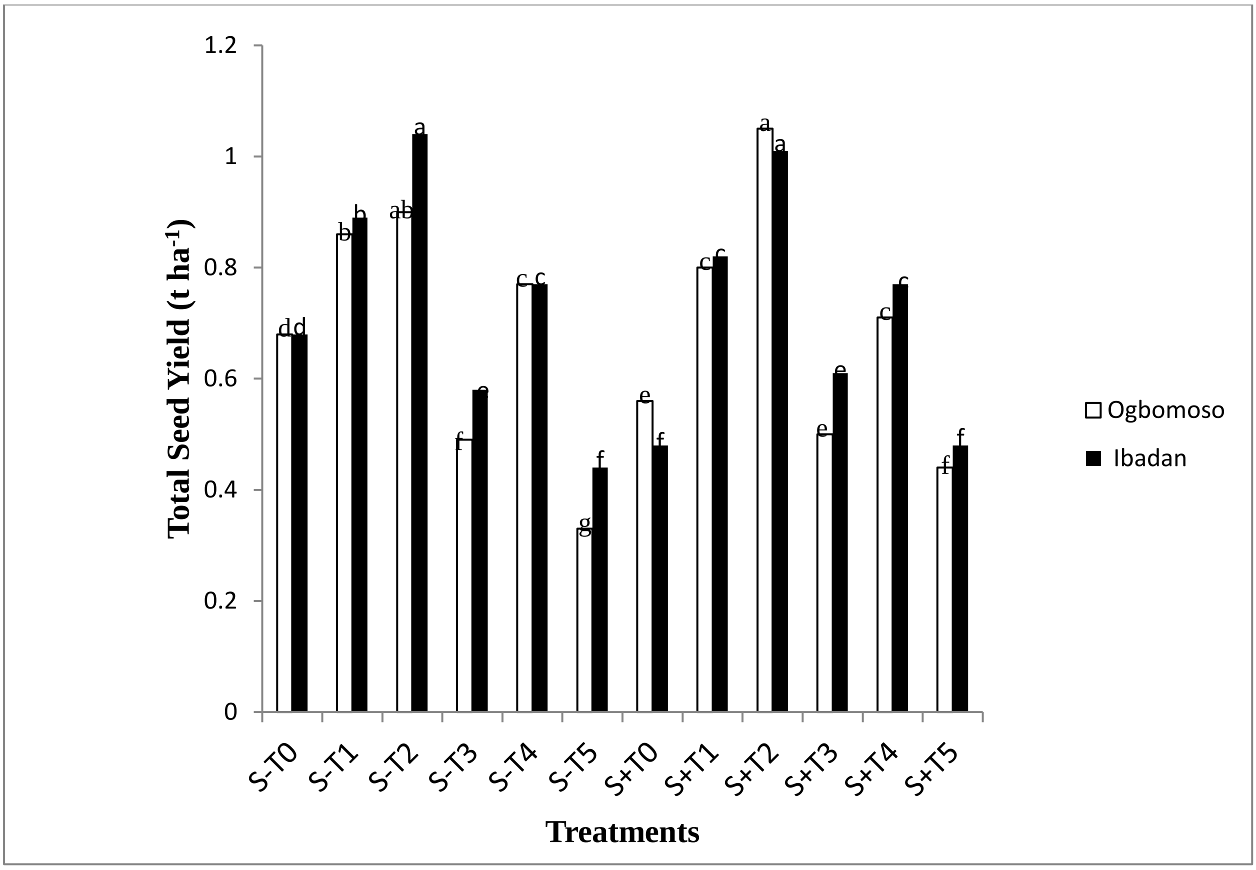

Fig. 1: Effect of inoculation of different microsymbionts on total seed yield of sesame under sterile and non-sterile soil conditions at Ogbomoso and Ibadan.

Means followed by the same letters are not significantly different at $p<0.05$, using DMRT. S+= Sterile soil, S- = Non-sterile soil), T0 = No inoculation of biofertilizer / No application of fertilizer, T1= application of urea, T2 = inoculation with *Azospirillum spp.*, T3 = inoculation with *Rhizobium spp.*, T4 = inoculation with *Mycorrhiza spp.*, T5 = *inoculation with Azotobacter spp.*

Table 2: Effect of microsymbiont inoculations on nutrient uptakes of sesame under sterile and non-sterile soil conditions at Ogbomoso and Ibadan

Treatments	Ogbomoso										Ibadan									
	N	P	K	Ca	Mg	Na	Fe	Cu	Mn	Zn	N	P	K	Ca	Mg	Na	Fe	Cu	Mn	Zn
	(g kg-^{1}dw)						(mgkg-^{1}dw)				(g kg-^{1}dw)						(mgkg-^{1}dw)			
S¯T0	3.27g	1.60e	0.47e	0.47f	0.57f	0.33d	83.87c	0.90d	28.03e	12.43e	3.80f	1..90c	0.50c	0.45d	0.55d	0.40d	85.50c	0.80c.	29.00c	13.25b
S¯T1	23.30c	4.77a	12.70a	1.10a	1.37b	0.93ab	166.73a	4.60ab	53.30b	19.93a	17.03bcdef	3.70b	9.00ab	0.93abc	1.23abc	0.97a	144.90a	3.60ab	43.90abc	17.80ab
S¯T2	27.53b	4.23b	10.57bc	0.87b	1.40b	0.70bc	116.87b	4.10b	48.70c	14.60c	28.00abc	4.90a	12.00a	1.07ab	1.37abc	0.80ab	127.30abc	4.37a	52.30abc	17.70ab
S¯T3	20.33d	4.23b	9.60c	0.60ed	1.03de	1.03c	88.80c	2.20c	40.97d	15.30c	23.73abcd	4.57a	10.20a	0.73bcd	1.37abc	0.77abc	99.23bc	2.63bc	45.17abc	15.13ab

S¯T4	17.40e	4.17b	10.00c	0.53ef	1.30bc	0.53cd	110.60b	4.17ab	45.03cd	17.43b	20.57abcd	4.50a	11.00a	0.73bcd	1.20abc	0.70abcd	100.60abc	3.93ab	42.90abc	17.10ab
S¯T5	9.43f	3.70c	7.50d	0.37f	0.80f	0.67bc	94.27c	2.53c	43.43d	14.67c	12.97def	4.33ab	9.70a	0.60cd	1.03bcd	0.80ab	103.30abc	3.00abc	43.27abc	15.13ab
S+T0	3.17g	2.27d	0.90e	0.47ef	0.67f	0.60cd	65.73d	0.63d	28.70e	12.70e	5.80ef	2.77bc	2.97bc	0.67bcd	0.83cd	0.57bcd	75.13c	1.43c	33.20bc	13.80ab
S+T1	23.70c	4.83a	12.90a	1.16a	1.40b	1.00a	167.30a	4.73a	73.53a	20.23a	17.63bcde	4.17ab	9.47ab	0.87abcd	1.27abc	0.97a	136.43ab	3.47ab	60.50a	18.70a
S+T2	32.97a	4.07bc	11.47b	1.20a	1.73a	0.93ab	124.93b	4.60ab	48.57c	15.47c	34.30a	4.50a	12.20a	1.30a	1.77a	1.00a	144.43a	4.50a	57.30a	15.30ab
S+T3	22.43c	4.27b	9.80c	0.67cd	1.23cd	0.77abc	89.60c	2.37c	41.30d	17.53b	30.73ab	4.70a	10.70a	0.93abc	1.53ab	0.93a	100.70abc	3.23abc	44.83abc	17.43a

																				b
S+T4	20.23d	4.27b	9.93c	0.70c	1.30bc	0.50cd	111.57b	4.23ab	45.07cd	14.83c	23.30abcd	4.43a	10.87a	0.77bcd	1.37abc	0.73abc	104.23abc	3.83ab	45.17abc	15.63ab
S+T5	10.50f	3.93c	6.73d	0.43f	0.97e	0.50cd	91.60c	2.23c	44.13d	14.00cd	16.20cdef	3.93ab	7.93ab	0.47d	1.06bcd	0.47cd	110.27abc	2.97abc	45.27abc	14.23ab

Means followed by the same letters within the same column are not significantly different at $p<0.05$, using DMRT. dw = Dry weight , S+= Sterile soil, S- = Non-sterile soil), T0 = No inoculation of biofertilizer / No application of fertilizer, T1= application of urea, T2 = inoculation with *Azospirillum spp.*, T3 = inoculation with *Rhizobium spp.*, T4 = inoculation with *Mycorrhiza spp*., T5 = *inoculation with Azotobacter spp.*

IV. CONCLUSION

At the two locations, microbial inoculations significantly enhanced sesame performance under both soil conditions, compared to the control. Sesame responded best to Azospirillum inoculation under sterile and non-sterile soil conditions amongst other inocula tested. Also, Azospirillum inoculation significantly ($p < 0.05$) improved sesame yield. Thus, under organic farming system, combination of basal manure application with microsymbiont inoculation, may be beneficial to improved performance of sesame in the study areas. This is an environment friendly, low input and highly economical technology, which may also favour proliferation of soil beneficial microbes and general improvement of soil health and productivity via improved soil physical and chemical properties / conditions. Also, the results from these research studies could therefore be regarded as very good clues or platforms, for further studies in the area of organic crop production, which may promote sustainable tropical crop production and reasonably reduce chemical inputs on tropical soils, which are known to be severely depleted in essential nutrients.

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