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Growth and Shoot Yield of *Worowo* [*Senecio biafrae* (Oliv. & Hiern.) S. Moore] Influenced by Neem-Enriched Cow Dung/Sawdust Compost

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ABSTRACT

Background and Objective: *Worowo* is a nutritious and medicinal vegetable, which has not been given cultivation attention, probably due to lack of knowledge on its fertilizer requirements. Utilizing inorganic fertilizers for its cultivation can be costly and harmful to the environment, whereas composts are eco-friendly but have low nitrogen levels, thus necessitating enrichment with nitrogen sources. Effects of neem-enriched cattle dung+sawdust compost (CDSNM) on the growth and shoot yield of *Worowo* were therefore investigated. **Materials and Methods:** Main/residual effects of CDSNM, applied at 0, 10, 20, 30, and 40 t/ha on growth and edible shoot yield (ESY) of *Worowo*, were compared with NPK 15-15-15 at 400 kg/ha, using randomized complete block design with four replicates. Vine length, the number of leaves and branches, leaf area index, vine girth, and edible shoot output were measured, and data were analyzed using ANOVA at $\alpha_{0.05}$. Means were separated using DMRT. **Results:** The ESY (180 DAP) from CDSNM at 40 t/ha (10.55±1.95) was highest in the main plots and was only comparable to CDSNM at 30 t/ha (7.30±1.35). The lowest ESY (1.41±0.26) was from NPK. The order of shoot outputs from both main and residual plots was: CDSNM-40>CDSNM-30>CDSNM-20>CDSNM-10>CONTROL>NPK. The best yield values were obtained from the organically treated plots, with the best yield value (18.80±3.10 t/ha) from CDSNM applied at 40 t/ha in the residual plots. **Conclusion:** The CDSNM applied at 30 t/ha is the most sustainable and efficient treatment for optimal production of *Worowo*, as it provided comparable growth and yield parameters to the 40 t/ha application.

KEYWORDS

Soil fertility management, compost enrichment, residual impact, *Worowo* production, neem-enriched cattle dung

INTRODUCTION

Green leafy vegetables, which are the tender parts of plants cultivated in gardens, are a crucial component of the African diet[1]. They are significant sources of essential nutrients such as protein, minerals, vitamins, and fiber, which are often deficient in typical diets, especially in rural areas[2]. These vegetables play an important role in human nutrition[3]. Adequate production and consumption of vegetables should therefore be emphasized in the nation's health program through output expansion, efficient marketing, and post-harvest handling (preservation, storage, processing, and utilization) which would ensure the availability of vegetables in large quantities and at affordable prices, at all times and places.

ISSN: 2618-0928 (Online)
ISSN: 2618-0936 (Print)
https://doi.org/10.17311/sd.2025.43.53

Received: 20 Nov. 2024
Accepted: 11 Jan. 2025
Published: 16 Jan. 2025

Vegetables contain good supplements of vegetable protein, fats, minerals (Calcium (Ca), Iron (Fe)), vitamins such as carotene, pro-vitamins, thiamine, carbohydrates, and some dietetical nutrients and supplements[4], which are necessary for appropriate growth, eyesight development and the formation of strong teeth and bones. They also contain vitamins A, C, and Foliate (folic acid), as well as Thiamine (B1), Riboflavin (B2), and some useful amounts of vitamin E[5]. Heart disease and diabetes, growth of certain cancer cells, kidney stones, and bone loss could all be combated through vegetable consumption. Phytochemicals in vegetables can inhibit oxidation reactions, and the growth of disease-causing organisms (bacteria, fungi, viruses) and carcinogenic materials[6,7].

Agulanna[8] gave a list of semi-wild under-utilized and neglected vegetables in Nigeria, but the agronomic information needed for their optimum production is lacking. Efforts are necessitated, therefore, to domesticate them and study their production techniques. *Worowo* is included in the list, as it has been confirmed to be indigenous to West Africa[9]. *Worowo* (*Senecio biafrae*) is an underutilized indigenous vegetable that grows spontaneously in wild or semi-wild conditions and has not received any significant cultivation attention. In Nigeria, it is known as *Worowo* in Yoruba, while in Sierra Leone, it is referred to as bologi. The fresh, tender leaves of *Worowo* are often cooked as a vegetable, seasoned with pepper, tomatoes, and onions. In Sierra Leone, *Worowo* leaves are usually steamed or boiled and served alongside okra and fish.

There is a growing awareness of *Worowo's* potential in terms of its yield, nutrient composition, and nutritional health benefits, which compare favorably to or even exceed, those of commonly cultivated leafy vegetables. This has led to an increasing interest in the domestication of *Worowo* for regular cultivation. To ensure optimal production and improve the availability of this indigenous vegetable in the market at reasonable prices, it is essential to develop effective management practices that farmers can be encouraged to adopt. *Worowo* occurs as a weed in cocoa plantations in South-Western Nigeria and so protected during weeding even as the cocoa trees provide shade, support and stakes. *Worowo* can be cultivated in home gardens and occasionally in fields where adequate moisture, enough shade and wooden pole stakes are provided. When directly exposed to sunlight, the characteristic growth of the vegetable is limited. The plant is grown in nutrient-dense soils; particularly, organic matter, and is moist, well-drained, and fertile. It is frequently grown under cocoa trees where the moist conditions ensure that growth continues in the dry season[9]. The harvest remains fresh for 3 days under humid conditions. *Worowo* is locally marketed for domestic consumption, as there are no records of inter-regional trade[9]. *Worowo* has medicinal properties and its juice is applied to sore eyes[10]. It can also be used as a replacement for spinach in soups and stew preparation.

Badmus and Yekinni[11] noted that the production of foreign and new vegetables is a thriving business that has been an encouraging source of income for the growers, and that; government participation in rural extension programs and services, the introduction of better, new, and uncommon variety of vegetable seeds and issuing suitable incentives to growers, could stimulate profit maximization. An increase in output would significantly impinge household food security, particularly those of urban areas. More still, these indigenous vegetables are simpler to grow, pest-resistant, and acceptable to local tastes[12]. These reasons automatically qualify the use of our native vegetables as befitting as cash crops in peri-urban systems, as vegetables for subsistence farming in homestead farms or gardens, as new crops, and as a tool for variation in production systems and diets' diversification. They can provide both subsistence and income to rural, peri-urban, and urban populations without requiring substantial capital inputs. However, these traditional and orthodox varieties are being phased out in favor of high-yielding commercial cultivars, which are perceived to be more profitable and hence favored by most farmers[13].

Soil fertility is based on the environment's physical, biological, and chemical features but it is also greatly influenced by human management practices. Conventional practices associated with mechanized large open farms, continuous deep tillage, excessive utilization of synthetic amendments, including agrochemicals, and luxury watering have been indicted for soil degradation. Soil nutrient depletion is primarily caused by the continuous extraction of nutrients from the soil through crop removal without adequate restoration[14], soil formation processes, geographical location, climate, irrigation water applied, cropping history, and tillage practices (including continuous cultivation). Thus, in turn, external inputs must be used to rectify the negative nutrient budgets and therefore preserve soil productivity.

To introduce additional nutrients into the negative nutrient budget of the crop output system, the utilization of inorganic amendments as a form of fertilizer has become imperative in Nigeria[15]. Inorganic fertilizers are however often too expensive for subsistence farmers or may be uneconomical and difficult to obtain[16]. The scarcity and high cost of fertilizers in most African countries have prompted research focus on the promotion of cheap, locally available organic fertilizers[17]. Continuous inorganic fertilizer application to tropical soils has resulted in lower yields, reduced soil pH value (acidity), and the resultant nutrient imbalance, antagonism, and toxicity[18,19]. However, several studies had reported the capability of organic wastes to positively impact soil/crop performance[20-22]. This study therefore evaluates the main and residual impacts of the enriched organic nutrient source (CDSNM), on the edible shoot yield, or shoot output of *Worowo* (*Senecio biafrae*).

MATERIALS AND METHODS

Study site: This research was undertaken from March to October, 2020, at Ekiti State University's farms, Iworoko Ekiti Road, Ado-Ekiti, Nigeria. The Teaching and Research Farm is situated between Latitudes 7°15' and 8°5'N, and Longitudes 4°45' and 5°13'E, in South-Western Nigeria. The site is in the rainforest zone, with mean annual temperatures of 28 and 27°C for the assumed hottest months; February and March, respectively. The major soil types identified are Iregun, Apomu and Ondo Series[23]. Arable and cash crops, such as maize, yam, cassava, cocoa, oil palm, and kolanut, are the major crops of the area.

Experimental site: Samples of the soil of the experimental site were prepared for normal routine analysis. The sample preparation and laboratory analysis were done in the Soil Laboratory of the Department of Soil Resources and Environmental Management, Ekiti State University, Ado-Ekiti, Ekiti State, Nigeria. The particle size distribution was determined using the hydrometer method of particle size determination. The pH values of the soil samples were determined both in water and KCl. The organic matter content of the soil was determined using the Walkley-Black method[24]. Total N was determined by the Kjeldahl digestion and distillation method. Available phosphorus was determined, using the Bray P1 method. The exchangeable bases were determined using the Flame Photometry method for Na and K, and atomic absorption spectrophotometry for Ca and Mg, and the exchangeable acidity was extracted with 1 N KCl and determined by titration with 0.05 N NaOH using phenolphthalein indicator[25].

Chemical analysis of the enriched compost: The compost (CDS) was reported to be alkaline, with a pH of 8.3, while its total N and K were reported to be 6.4 and 6.1 g/kg, respectively[26]. The N content was however raised to 60 g/kg using neem leaf meal.

The soil at the experimental site was observed to be sparingly acidic, with pH of 5.8 and 6.6 in KCl and water, respectively. It was loamy sand with organic matter content at 14.6 g/kg. Soil N was 0.8 g/kg; P was 13 mg/kg and the exchangeable cations; K, Ca, Mg and Na were sequentially recorded as: 0.3, 7.0, 1.8, and 0.1 cmol/kg (Table 1).

Table 1: Chemical attributes and particle distribution of experimental soils

Property	Value
pH (1:1 Kcl)	5.8
pH (H_2O)	6.6
Total Nitrogen (g/kg)	0.8
Organic matter (g/kg)	14.6
Available P (mg/kg)	13
Exchangeable cations	
Calcium (cmol/kg)	2.8
Magnesium (cmol/kg)	1.8
Potassium (cmol/kg)	0.3
Sodium (cmol/kg)	0.1
Exchangeable acidity (cmol/kg)	0.6
ECEC (cmol/kg)	5.6
Base saturation (g/kg)	893
Particle distribution (g/kg)	
Sand (mm)	799
Silt (mm)	132
Clay (mm)	69
Textural class (USDA)	Loamy sand

Growth and yield responses of *Worowo* to compost enriched with neem (CDSNM): A new experimental site (Main site) was made beside the previously used site (Residual). The CDS enriched with neem (CDSNM) treatment was applied at different rates of 0, 10, 20, 30, and 40 t/ha. Inorganic fertilizer, NPK 15-15-15, applied at 400 kg/ha was included in the experiment for comparison. The experiment was conducted from March to October, 2020. The experiment comprised of six treatments which were replicated four times, making a total of 24 beds. Matured stems of *Worowo* were cut into 20 cm long pieces, defoliated, and planted at 40×60 cm on the 2×4 m beds such that there were 30 stands per bed. Artificial shades were made for the vegetables, and trellises were also built to provide support. Staking was done at 30 DAP and the vines of *Worowo* were trained to climb onto the trellises and round the erected sticks. Weeding was done at 30, 90, and 150 DAP. The parametric quantities measured included: vine length, number of leaves and branches, leaf area index, vine girth, and edible shoot output. The specified measurements were taken at 60, 120, and 180 DAP. Matured edible shoots, at 20 cm away from the soil surface represented the edible shoot output, with stumps left on beds for further studies. Data generated were submitted to analysis of variance and the means were separated using Duncan's Multiple Range Test (DMRT) at $\alpha_{0.05}$.

Residual effects of compost enriched with neem (CDSNM) on growth parameters and edible shoot output of *Worowo*: The residual effects of CDSNM on the growth and production of *Worowo* edible shoots were also measured. Defoliated, matured stems of *Worowo* were concurrently planted on the previously used experimental site, having the same layout and treatment applications as in the newly cultivated main site. Weeding, staking, provision of artificial shades, data collection, and analysis were repeated as in the main site.

RESULTS

Growth and shoot output of *Worowo* as affected by the enriched compost CDSDNM: Table 2 shows the growth and output parameters of *Worowo* at 60 DAP in the second planting season of the year 2020 (main site). There were no notable differences in the vine length from various treated plots, except between NPK, which gave the least vine length (69.25 cm), and CDSNM applied at 40 t/ha with the longest vines (124 cm). The CDSNM-treated plots at 30 t/ha yielded the leafiest vegetables (77.5), which did not significantly differ from other treated plots. Values for leave production observed from other examined plots not differed significantly from one another but the least leafy vegetables (31.75 leaves) were brought forth by CDSNM-treated plots at 10 t/ha. Notable significant differences were not recorded in the output

Table 2: Growth and shoot output of *Worowo* as influenced by CDSNM at 60 DAP

Treatments	Vine length (cm)	Number of leaves	Number of branches	Stem girth (cm)	Leaf area index	Edible shoot yield (t/ha)
A	85.25[ab]	42.75[b]	1.50	2.75[ab]	3.32[a]	2.28[b]
B	69.25[b]	47.25[b]	1.50	2.00b	3.14[a]	7.55[ab]
C	124.00[a]	35.50[b]	1.50	3.50[a]	2.88[a]	8.98[a]
D	120.75[ab]	77.50[a]	2.25	3.25a	6.17b	8.77[a]
E	100.00[ab]	35.50[b]	2.00	2.75[ab]	2.57[a]	5.95[ab]
F	105.50[ab]	31.75[b]	1.50	3.00[a]	1.70[a]	4.86[ab]

Means with the same alphabets in the same column do not differ significantly at $\alpha_{0.05}$. DAP: Days After Planting, CDSNM: Cattle dung+saw dust enriched with neem. A: CONTROL, B: NPK 15-15-15, C: CDSNM at 40 t/ha, D: CDSNM at 30 t/ha, E: CDSNM at 20 t/ha and F: CDSNM at 10 t/ha

Table 3: Growth and output of *Worowo* as influenced by CDSNM at 120 DAP

Treatments	Vine length (cm)	Number of leaves	Number of branches	Stem girth (cm)	Leaf area index	Edible shoot yield (t/ha)
A	67.00[b]	40.25[b]	1.25[b]	3.00[bc]	1.84[a]	1.83[c]
B	56.75[b]	54.50[a]	2.75[a]	2.13c	3.05[b]	1.95[c]
C	121.75[a]	38.00[b]	2.50[a]	4.75[a]	2.98[bc]	12.88[a]
D	92.50[ab]	57.25[a]	2.00[ab]	3.75[ab]	2.46[c]	9.75[ab]
E	89.75[ab]	35.50[b]	2.00[ab]	3.25[b]	2.55[c]	5.05[bc]
F	83.75[b]	46.00[ab]	2.75[a]	3.50b	2.60[bc]	3.88[c]

Means with the same alphabets in the same column do not differ significantly at $\alpha_{0.05}$. DAP: Days after planting, CDSNM: Cattle dung+saw dust enriched with neem. A: CONTROL, B: NPK 15-15-15, C: CDSNM at 40 t/ha, D: CDSNM at 30 t/ha, E: CDSNM at 20 t/ha and F: CDSNM at 10 t/ha

of branches of *Worowo* produced at 60 DAP in the main site, but the most branched vegetables were brought forth by plots treated with CDSNM at 30 t/ha which had 2.25 branches, followed closely by CDSNM-treated plots at 20 t/ha which produced 2.00 branches. The thickest vines produced by CDSNM at 40 t/ha (3.50 cm) and CDSNM at 30 t/ha (3.25 cm) were similar but differed significantly from the stem girth values obtained from NPK which had the thinnest vines (2.00 cm). The significant best leaf area index (6.17) was from CDSNM applied at 30 t/ha, while the lowest leaf area index value of 1.70 was observed in the plots treated with CDSNM applied at 10 t/ha. The largest quantities of marketable vegetables were yielded by CDSNM-treated plots at 40 t/ha (8.98 t/ha) and plots treated with CDSNM applied at 30 t/ha (8.77 t/ha). The duo did not differ significantly from each other, but rather from the CONTROL plot which had the least shoot output (2.28 t/ha).

The impacts of the enriched additive on *Worowo* output at 120 DAP are showcased in Table 3. The CDSNM-treated plots at 40 t/ha gave the longest vegetable vines (121.75 cm), with CDSNM-treated plots at 30 t/ha following, with vines that were 92.50 cm long. These two treatments were observed not to have differed significantly from each other. Shortest vegetable vines were obtained from the NPK plots (56.75 cm). Vegetables from the plots treated with CDSNM applied at 30 t/ha had 57.25 leaves which were more than other treatments though not significantly different from NPK and CDSNM applied at 10 t/ha while CDSNM applied at 20 t/ha brought forth the least leafy vegetables (35.50). Plots treated with NPK and CDSNM at 10 t/ha produced 2.75 branches followed by CDSNM at 40 t/ha which produced 2.50 branches and differed significantly from the CONTROL which produced the least number of branches (1.25). Plots treated with CDSNM applied at 40 t/ha produced the thickest vegetable vines (4.75 cm) and was significantly different from the CONTROL, NPK and CDSNM-treated plots at 20 and 10 t/ha. Plots assigned to NPK fertilizer gave the thinnest vegetable vines of 2.13 cm. The highest leaf area index of 3.05 was obtained from the NPK plots followed by CDSNM at applied at 40 t/ha (2.98). The CONTROL which gave the lowest index differed significantly from all compared treatments while NPK which gave the highest values differed significantly from the CONTROL and CDSNM-treated plots at 30 and 20 t/ha. Plots assigned to CDSNM at 40 t/ha application rate yielded more vegetables (12.88 t/ha) than the other plots, though not significantly different from CDSNM-treated plots at 30 t/ha which produced a vegetable weight of 9.75 t/ha. The CONTROL plots yielded the least edible shoot of *Worowo* (1.83 t/ha).

Table 4: Growth and output of *Worowo* as influenced by CDSNM at 180 DAP

Treatments	Vine length (cm)	Number of leaves	Number of branches	Stem girth (cm)	Leaf area index	Edible shoot yield (t/ha)
A	44.00^{d}	36.50^{ab}	1.25^{b}	3.00^{cd}	1.72^{a}	1.53^{c}
B	45.75^{d}	47.75^{a}	1.50^{bc}	2.50c	2.27^{bd}	1.41^{c}
C	114.75^{a}	38.00^{ab}	2.75^{a}	4.75^{a}	2.94^{c}	10.55^{a}
D	87.00^{ac}	48.25^{a}	2.25^{ac}	4.25^{ab}	2.62^{bc}	7.30^{ab}
E	82.75^{ac}	34.75^{b}	2.00^{ab}	3.75^{bd}	2.39^{bd}	3.48^{bc}
F	79.50^{bc}	41.50^{ab}	1.75^{bc}	3.50^{bc}	1.91^{ad}	3.32^{bc}

Means with the same alphabets in the same column do not differ significantly at $\alpha_{0.05}$. DAP: Days After Planting, CDSNM: Cattle dung+saw dust enriched with neem. A: CONTROL, B: NPK 15-15-15, C: CDSNM at 40 t/ha, D: CDSNM at 30 t/ha, E: CDSNM at 20 t/ha and F: CDSNM at 10 t/ha

Table 5: Residual impacts of Neem-enriched compost (CDSNM) on growth and shoot output of *Worowo* at 60 DAP

Treatments	Vine length (cm)	Number of leaves	Number of branches	Stem girth (cm)	Leaf area index	Edible shoot yield (t/ha)
A	87.25	39.00^{b}	1.50^{ab}	3.00^{ab}	2.55^{bc}	8.33^{b}
B	85.25	34.00^{b}	1.50^{ab}	2.50^{b}	2.00c	7.50^{b}
C	125.75	74.25^{a}	2.50^{a}	4.00^{a}	8.06^{a}	15.42^{a}
D	125.00	47.25^{ab}	1.50^{ab}	3.63^{a}	4.75^{b}	13.58^{a}
E	107.38	29.50^{b}	1.50^{ab}	3.38^{ab}	2.33^{bc}	12.00^{ab}
F	97.75	26.50^{b}	1.25^{b}	3.38^{ab}	2.00^{c}	9.00^{b}

Means with the same alphabets in the same column do not differ significantly at $\alpha_{0.05}$. DAP: Days After Planting, CDSNM: Cattle dung+saw dust enriched with neem leaf meal. A: CONTROL, B: NPK 15-15-15, C: CDSNM at 40 t/ha, D: CDSNM at 30 t/ha, E: CDSNM at 20 t/ha and F: CDSNM at 10 t/ha

At 180 DAP, the CDSNM applied at 40 t/ha gave the best vine length (114.75 cm) which was followed by CDSNM applied at 30 t/ha (87.00 cm) while vines measured from the plots assigned to CONTROL were the shortest (44.00 cm) (Table 4). The CDSNM employed at 40 t/ha differed significantly from CONTROL, NPK and CDSNM applied at 10 t/ha. The CDSNM applied at 30 t/ha produced more leaves (48.25) than the other treatments while CDSNM-treated plots at 10 t/ha yielded *Worowo* with the least leaves (34.75) which differed significantly from CDSNM at 30 t/ha and NPK. Plots treated with CDSNM applied at 40 t/ha gave 2.75 branches which was the highest and differed significantly from the CONTROL, NPK, and CDSNM at 10 t/ha plots. The CONTROL plots yielded the least branches of 1.25. The plots treated with CDSNM applied at 40 t/ha had a stem girth of 4.75 cm followed by CDSNM applied at 30 t/ha with 4.25 cm while NPK produced the thinnest vegetables with a stem girth of 2.50 cm. The highest leaf area index value of 2.94 was from CDSNM applied at 40 t/ha and differed not significantly from CONTROL, NPK, and CDSNM at 20 and 10 t/ha with leaf area index values of 1.72, 2.27, 2.39 and 1.91, respectively. The CONTROL gave the lowest leaf area index value. The yields obtained were in the order CDSNM at 40>CDSNM at 30>CDSNM at 20>CDSNM at 10>CONTROL>NPK. The highest marketable yield of 10.55 t/ha emerged from the CDSNM at 40 t/ha which differed significantly from other treated plots, except CDSNM at 30 t/ha which yielded 7.30 t/ha . Plots treated with NPK gave the least marketable yield (1.41 t/ha).

Residual effects of the enriched compost (CDSNM) on growth and shoot output of *Worowo*: Table 5 evaluates the residual impacts of CDSNM on the growth and shoot output of *Worowo* at 60 DAP. However, there were no notable differences in the vine length of *Worowo* vines from CDSNM-treated plots were longer than CONTROL and the NPK-treated plots. The CDSNM at 40 t/ha produced the longest vines (125.75 cm) and was followed by CDSNM at 30 t/ha whose vegetable vines were 125.00 cm long. The shortest vines of 85.25 cm were produced from NPK plots. The CDSNM at 40 t/ha differed significantly from other treated plots, except CDSNM at 30 t/ha in leaf production. Vegetables from the CDSNM-treated plots at 40 t/ha yielded the best leafy vegetables (74.25) while vegetables from the CDSNM-treated plots at 10 t/ha were the least leafy (26.50). The CDSNM applied at 40 t/ha yielded the most branched vegetables (2.50) which differed significantly from CDSNM utilized at 10 t/ha with the least value (1.25). The thickest vegetable vines were from CDSNM applied at 40 t/ha (4.00 cm) which differed

Table 6: Residual impacts of Neem-enriched compost (CDSNM) on growth and shoot output of *Worowo* at 120 DAP

Treatments	Vine length (cm)	Number of leaves	Number of branches	Stem girth (cm)	Leaf area index	Edible shoot yield (t/ha)
A	102.00^{bc}	132.10	3.00^{a}	3.00^{ab}	6.00^{cd}	7.70^{b}
B	95.73^{c}	106.60	1.00^{a}	2.50^{b}	4.40^{d}	5.50^{b}
C	156.27^{a}	173.40	12.00^{b}	4.02^{a}	11.00^{a}	18.80^{a}
D	132.13^{ab}	169.60	10.00^{b}	3.65^{a}	10.00^{ab}	14.50^{ab}
E	124.60^{abc}	134.20	10.00^{b}	3.39^{a}	7.60^{bc}	10.00^{b}
F	112.53^{bc}	133.70	4.00^{a}	3.38^{ab}	7.10^{c}	8.50^{b}

Means with the same alphabets in the same column do not differ significantly at $\alpha_{0.05}$. DAP: Days After Planting, CDSNM: Cattle dung+saw dust enriched with neem leaf meal. A: CONTROL, B: NPK 15-15-15, C: CDSNM at 40 t/ha, D: CDSNM at 30 t/ha, E: CDSNM at 20 t/ha and F: CDSNM at 10 t/ha

Table 7: Residual impacts of Neem-enriched compost (CDSNM) on growth and output of *Worowo* at 180 DAP

Treatments	Vine length (cm)	Number of leaves	Number of branches	Stem girth (cm)	Leaf area index	Edible shoot yield (t/ha)
A	88.00	57.80^{b}	1.25^{b}	2.50^{ab}	2.81^{a}	4.02^{b}
B	83.33	51.73^{b}	2.75^{a}	2.00^{b}	2.51^{a}	3.25^{b}
C	123.93	129.10^{a}	2.50^{a}	4.02^{a}	8.01^{b}	10.25^{a}
D	122.93	107.50^{a}	2.00^{ab}	3.65^{a}	8.53^{b}	8.75^{ab}
E	117.47	91.97^{ab}	2.00^{ab}	3.39^{a}	4.60^{a}	6.46^{ab}
F	90.20	60.30^{b}	2.75^{a}	3.38^{ab}	3.77^{a}	6.04^{ab}

Means with the same alphabets in the same column do not differ significantly at $\alpha_{0.05}$. DAP: Days After Planting, CDSNM: Cattle dung+saw dust enriched with neem leaf meal. A: CONTROL, B: NPK 15-15-15, C: CDSNM at 40 t/ha, D: CDSNM at 30 t/ha, E: CDSNM at 20 t/ha and F: CDSNM at 10 t/ha

significantly from the NPK with the thinnest vines (2.50 cm). The CDSNM treatments gave thicker vines than the control and NPK plots. The highest leaf area index was observed from CDSNM at 40 t/ha (8.06) followed by the CDSNM at 30 t/ha which had 4.75. Both NPK and CDSNM applied at 10 t/ha gave the lowest leaf area index values of 2.00. The CDSNM-treated plots at 40 t/ha outputted the highest edible shoot yield (15.42 t/ha) which significantly differed from the CONTROL, NPK and CDSNM at 10 t/ha treated plots.

At 120 DAP, the CDSNM-treatments produced longer vines than the CONTROL and NPK though they not differed significantly in values (Table 6). The CDSNM at 40 t/ha produced the longest vegetable vines of 156.27 cm followed by CDSNM at 30 t/ha (132.13 cm) while NPK produced the shortest vegetable vines (95.73 cm). The outputted branches differed significantly, with CDSNM treatments giving the highest number of branches. Plots treated with CDSNM at 40 t/ha produced the thickest vegetable vines with a stem girth value of 4.02 cm which significantly differed only from NPK with the thinnest vines of 2.50 cm. The leaf area index of *Worowo* vegetables differed significantly in the observed values. The highest leaf area index values of 11.00 were obtained from CDSNM at 40 t/ha which did not differ significantly from CDSNM at 30 t/ha . The NPK plots gave the least leaf area index values of 4.40. *Worowo* output from the various treated plots differed significantly, with CDSNM applied at 40 t/ha giving the largest marketable yield (18.80 t/ha) closely marked by CDSNM applied at 30 t/ha which produced 14.50 t/ha. This duo did not differ significantly from each other. The NPK plots outputted the least *Worowo* vegetables (5.50 t/ha).

At 180 DAP, the CDSNM at 40 t/ha treatment produced the longest vines followed by plots treated with 30 t/ha CDSNM (Table 7). The vine lengths recorded for the two plots were 123.93 and 122.93 cm respectively while NPK gave the shortest length (83.33 cm). The 40 t/ha CDSNM produced the leafiest vegetables (129.10) which differed significantly from the CONTROL, NPK and 10 t/ha CDSNM. The least leafy vegetables (51.73) were from the NPK plots. The plots treated with 10 t/ha CDSNM produced 2.75 branches followed by 40 t/ha CDSNM which produced 2.50 branches and were significantly different from the NPK treatment which produced 1.25 branches. Vegetables from the plots treated with 40 t/ha CDSNM had stem girth of 4.02 cm and were followed by the vegetables from the plots treated with

30 t/ha CDSNM with 3.65 cm thickness while the NPK plots produced the thinnest vegetables with stem girth of 2.00 cm. *Worowo* with the biggest leaf area index of 8.53 was outputted by 30 t/ha CDSNM and it differed significantly from other treated plots, except 40 t/ha CDSNM. The smallest leaf area index was from plots treated with NPK with a value of 2.51. The Edible shoot yield was in the order 40 t/ha CDSNM>30 t/ha CDSNM>20 t/ha CDSNM>10 t/ha CDSNM>Control>NPK.

DISCUSSION

Soil productivity diminution remains a major confinement to sustainable crop output. The soils used for this study were deficient in organic matter, N, K, and other exchangeable bases. The low nutrient levels in the soils of the study site have resulted from continuous nutrient depletion due to crop removal without sufficient replenishment[14]. Factors such as cropping history and tillage practices, including continuous cropping, have also contributed to this situation, making the soils suitable for the experiments conducted[21].

The luxuriant growth and better shoot output recorded in the residual plot might mean that the initial application of CDSNM had improved the physical and chemical properties of the soil. Organic fertilizers and composts have high residual effects on soil properties and hence, fertility, which thereafter affects crop performances. This is in line with the findings[27] that in many experiments conducted to compare organic manure with chemical fertilizers to supply an equivalent amount of N, the result had often favored manure application because of the ability of manure to modify the soil physical, biological, and chemical properties. Omolayo *et al.*[21] and Fawole[28] reported better main and residual performances of organic fertilizers over the inorganic fertilizers.

In this study, the tallest, thickest, leafiest, and highest-yielding vegetables were from the plots fertilized with enriched compost at 40 and 30 t/ha. Oluwafisayo[22] earlier reported the better and preferred performance of CDSNM over the inorganic fertilizer (NPK) in the improved and sustainable production and domestication of *Worowo*. The shortest, thinnest, least leafy, and least-yielding vegetables were from the control and NPK plots. This confirmed the non-residual effect of the inorganic fertilizers compared to organic fertilizers. Some microorganisms that could help improve the physical and chemical structures of soil, thereby supporting plant growth, may be negatively impacted by the addition of NPK fertilizer, as NPK fertilizers can sometimes be too concentrated and toxic to these microorganisms. Kisetu and Heri[14] from their findings from comparing the residual effects of poultry manure and NPK fertilizers on nutrient content and uptake by tomatoes in the forest and derived Savannah soils of Edo State, concluded that all levels of poultry manure had better residual effects compared to all levels of NPK fertilizer. Adediran *et al.*[17] conducted a comparison between organic-based fertilizers and mineral fertilizers in terms of their effectiveness on crop yield. They concluded that the use of organic-based fertilizers enhanced the nutrient status of the soil, improved maize grain yield, and also had significant residual effects on soil fertility. The advantages of organic-based fertilizers compared to mineral fertilizers can be attributed to the role of various bacteria and fungi. These microorganisms break down chemicals, plant matter, and animal waste into essential nutrients for the soil. As a result, soils treated with organic fertilizers tend to be richer in nutrients, leading to increased fertility and improved crop performance[29]. According to Pacini *et al.*[30] and Wood *et al.*[31]. Soils managed under organic farming conditions generally exhibit lower bulk density, greater water-holding capacity, increased microbial biomass, and higher nitrogen levels, as well as enhanced soil respiration activities when compared to conventional farms. This suggests that the higher amounts of nutrients available to crops result from improved microbial activity in organic farming systems. Additionally, unlike synthetic fertilizers, compost provides benefits that extend beyond the short term; when applied consistently over many years, it can significantly enhance the long-term productive capacity of the soil, thereby promoting plant growth.

The enriched organic fertilizers gave better residual effects on the soil than NPK fertilizer alone and would supply soil organic matter, Ca and Mg that are not supplied by NPK fertilizer[32]. The organic fertilizer would also ameliorate the physical and chemical properties of soils such as the plastic limit, water retention, aggregate stability, total N, soil OM, pH, and CEC. The improvement of these parameters leads to a higher yield of the crops planted[33]. Kekong *et al.*[15] demonstrated the efficacy of cattle dung and poultry dung in enhancing the fertility of Savannah and rainforest soils for sustainable vegetable cultivation. The best performance overall recorded from the residual site can equally be linked to the improvements recorded in the physical and chemical parameters of soils due to the addition of the enriched composts in the first planting season which led to improved fertility[33]. Omolayo *et al.*[21] observed that degraded soils could be restored and rehabilitated to an optimum level of productivity by proper and regular additions of various organic wastes, including plants and animal manure, especially poultry droppings.

The yield values produced by the enriched compost in this study increased with the levels of the organic waste. The yield values, from both the main and residual plots were in the order of 40>30>20>10 t/ha, but there were no significant differences between the 30 and 40 t/ha treatments. However, the inorganic fertilizer, NPK gave the least values of the measured parameters on residual basis compared to organic materials. The organic N-enriched compost competed well with the inorganic fertilizer both in the main and residual plots, and can therefore replace inorganic fertilizers in sustainable production of crops and vegetables, especially *Worowo*.

CONCLUSION

The study concluded that CDSNM applied at 30 t/ha is the most sustainable and efficient treatment for optimal production of *Worowo*, as it provided comparable growth and yield parameters to the 40 t/ha application. The 40 t/ha rate showed the highest values across seasons, but the lack of significant difference between the two rates supports the adoption of 30 t/ha for economic and environmental sustainability. Inorganic fertilizer, including the control and NPK treatments, showed minimal residual effects, reinforcing the advantage of organic compost for soil fertility. The findings recommend CDSNM at 30 t/ha for consistent productivity and enhanced soil health in *Worowo* cultivation.

SIGNIFICANCE STATEMENT

Worowo (*Senecio biafrae*) is medicinal and nutritious plant; hence the demand for the vegetable keeps increasing. Vegetable farmers have shown little or no interest in its production, whether subsistence or commercial. This could be because little is known about its fertilizer requirement. The use of organic nutrient sources which are regarded as more environmental friendly than inorganic fertilizers is being encouraged. This study identified cattle dung-sawdust compost enriched with neem leaf meal, as being beneficial for improved production of *Worowo*. Findings from this study will assist researchers, in further uncovering critical areas in *Worowo* production that have remained unexplored by many, and probably, a new theory on the fertilizer requirement, leading to sustainable production, and domestication of *Worowo* may be developed.

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