



Effectiveness of Fortified Liquid Organic Manure and Inorganic Fertilizer on the Growth, Physiological and Pesticidal Response of African Nightshade (*Solanum scabrum*)

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: To assess the effectiveness of fortified liquid organic manure, zero fertilizer applications and urea on the growth, physiological and pesticidal response of *Solanum scabrum*.

Study Design: Complete randomized block experimental design.

Place and Duration of Study: The green house facility and agricultural research farm at the Pan African Institute for Development – West Africa (PAID-WA), Buea, Cameroon, from August to November 2017.

Methodology: Four experimental units with 4 treatments including: two fortified liquid organic manure (T1 and T2,) control (T3) and urea (T4), were established using 96 planting pots. The quantity and application rates for the liquid manure and urea were 4000 L/ha, once and twice a

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week, and 200 kg/ha, respectively. Leaf colour, leaf size, number of leaves per plant, plant height, stem collar diameter and growth rate were measured. Two plots with three soil beds each, was also established to record pesticide treatment response by counting the number of leaves eaten by insects

Results: T2 had darker green leaves, tallest plants (27.57 ± 11.87 cm), highest number of leaves (27.65 ± 25.46 units), largest leaf size (38.56 ± 21.96 cm²), biggest stem collar diameter (1.54 ± 0.41 cm) and highest growth rates (2.54 ± 1.02 , 5.18 ± 3.40 , and 0.11 ± 0.03 cm/week for height, number of leaves and stem collar diameter, respectively). T2 effects differed significantly ($P = 0.00$) from T3 and T4. T2 and T1 also reduced pest attacks on leaves significantly ($P = 0.00$) compare to T3.

Conclusion: Liquid extracts concoctions of biomass and pesticidal botanicals prove useful towards the development of effective bio-repellent organic fertilizers. These can contribute to reducing the use of synthetic agro-chemicals, hence decreasing residual environmental and human health hazards.

Keywords: Agriculture; biofertilizer; biopesticide; organic; manure; agro-chemical; health.

1. INTRODUCTION

The new world's population is projected to touch 9.8 billion by 2050 [1], emulating that more food will be needed to sustain all these people. Thus, where possible, this food should be produced where it is needed, especially in developing countries [2]. To meet this demand, however, many African countries will have to increase their production substantially, though there will be implications on the limited natural resources on which farming rely, mainly water for irrigation and livestock farming, land for growing crops and grazing, and depleted soil nutrients, such as nitrogen and phosphate.

The anticipating food demand from Africas' rising rural and urbanizing populaces offers opportunities for resource-poor farmers if they can assure the necessary production [3]. However, the soils in many areas are already degraded [4], new pest and diseases prevail, and water resources continue to be exploited unsustainably. In addition, agricultural biodiversity has markedly reduced as farming became industrialized [2]. The latter explicated that these conjures urgencies that justify the advancement of global awareness, towards curbing unsustainable agriculture through sustainable actions.

In Cameroon, the African nightshade (*Solanum scabrum*), also known as the garden huckleberry is amongst the many traditional leafy vegetables that continue to be cultivated by small-scale farmers. Like many favorite vegetables, African nightshades support food security and are a source of healthier nutrition as they are rich in nutrients such as calcium, iron, and vitamins A and C [5]. Cultivation of nightshades is also a

vital source of income for the rural poor in Cameroon. It has been reported that many market opportunities exist for these cultural vegetables especially in areas where they have a comparative advantage over essential staples or commercial crops [6]. Aside from all its cultural and socio-economic importance, the African nightshades are still underutilized by the contemporary community, and indigenous farmers mainly cultivate the vegetable for subsistence.

Many researchers have reported on the bio-fertilizer potentials of organic matter. The use of bio-fertilizers could be an exciting alternative for the reuse of organic waste since they have high energetic content and significant amounts of macro and micronutrients [7]. The organic matter supplied through organic fertilizers improves soil chemical and physical characteristics and reduces costs compared to chemical fertilizers, besides allowing better use and storage of water in the soil [8]. Although animal waste such as cow dung and chicken droppings have been reported to increase crop yields, they are not usually available in sufficient quantities, their processing, and their application are laborious [9]. Therefore, it is important to use alternative sources of organic fertilizers such as green manure, even in the liquid state, to enrich soil organic carbon stocks, as well as improving soil moisture, fertility and health.

Organic farming employs the use of materials and ingredients of natural and biological origins which avoids to a greater extent, the use of inorganic or synthetic fertilizers and pesticides. The objectives of ensuring ecological (environmental, social, and economic) sustainability are the bases of organic farming.

Some standard features in the organic agriculture include soil conservation and fertility improvements, by retaining high levels of soil organic matter, promoting soil microbial activity, cautious mechanical mediation, nitrogen self-reliance through the use of leguminous plants and biological nitrogen fixation, actual recycling of organic materials such as crop residues, livestock wastes, weed, pest and disease control, relying primarily on crop rotations, natural products and predators, diversity, organic manuring, and resistant varieties [10]. Considerable emphasis is usually placed on maintaining soil fertility by returning all the wastes to it, primarily through compost application, to minimize the gap between nitrogen, phosphorus and potassium addition and removal from the soil. Today, the burgeoning population pressure has forced many countries to use chemicals and fertilizers to increase farm productivity for meeting their ever-increasing food requirements. There's no doubt that the prolonged and over usage of chemicals has, however, resulted in human and soil health hazards along with environmental pollution. Farmers in developed countries have, therefore, been encouraged to convert their existing farms into organic farms. The goal is to conserve our vital soil resource while ensuring a sustainable crop production that meets the increasing demand and hence towards achieving relevant sustainable development goals of the 2030 Agenda.

Though, efforts are being made towards improving its production through intensification, the present yield decline or stagnation is the cumulative effect related to soil constraints, pest, and diseases. In sub-Saharan Africa (SSA), traditional farming methods have led to severe nutrient depletion, low crop yields, and poverty, leaving many farm families disappointed [11]. Although many international organizations (IFDC and USAID) have attributed these to the low use of chemical fertilizers by farmers, the hidden cost and environmental consequences of using these chemicals in high amounts cannot be overemphasized. Chemical fertilizers contain ingredients that are toxic to human health (skin or respiratory system). These chemical fertilizers also affect soil health and structure due to its' acidic nature and cementing ability, hence a high potential to cause soil fertility decline [12]. The high use of chemical fertilizers in modern farming systems has resulted in high nitrogen concentrations in the soil, which is indirectly related to fungal and bacterial disease in plants

and vegetables [13]. The use of synthetic fertilizers as well as pesticides also causes eutrophication, thereby negatively impacting aquatic ecosystems. The cost incurred by poor farmers to obtain the right quantity of these synthetic chemicals is appalling. There is a need for establishing new ways for improving crop yields while avoiding environmental pollution and soil degradation using cost-effective and locally available organic inputs. This will go a long way to maintain soil fertility and ensure the safe consumption of farm produce.

Research on potentials of bio-fertilizers has focused on the sole use of organic manure such as cow dung, and chicken droppings and compost [14], in its solid form. Limited research [15,16] introduced the use of green biomass such as sunflower (*Tithonia diversifolia*), as mulch (chopped, dried and ground) or compost, for a sustainable land management technique. Green biomass of *T. diversifolia* contains 3.17 to 3.5% N, 0.3 to 0.37% P, 3.22 to 4.1% K, 2.0% Ca and 0.3% Mg [17,18], making it a good source of nutrients. The leaves and roots of *Ageratum conyzoides* and *Emilia coccinea* are reported to contain significantly high mineral (Ca, Mg, K, Na, P, Zn, Mn, and Fe) content in Nigeria [19,20], which comprises of some important macro and micro plant nutrient. These plants are also relevant to human nutrition. However, insufficient information exists about the use of these organic materials in its liquid form, albeit its' plausible bio-fertilizer potential.

Thirty plant species, whose parts and products are used by local farmers in Edo state, Nigeria, for crop protection have been identified [21]. Research experience also reveals that many locally used organic crop protection products exhibit bioactivity potentials for agricultural use. For example, lectins in *A. sativum* are promising candidate molecules for the protection against chewing (lepidopteran) as well as sap sucking (homopteran) insect pests [22]. *Aloe vera* is recognized as a very important traditional plant that possesses a wide range of biological activities [23], due to its possession of numerous phytochemical constituents including phenolic compounds and glycosides which have insecticidal properties [24]. Capsaicin is the compound found in *Capsicum annum* that gives it the "hot" taste enjoyed by many humans. Capsaicin, however, gives *C. annum* an ability to repel all mammals and kill insects, a reason why the United States Environmental Protection Agency (US EPA) approved capsaicin as a

biochemical pesticide to be used in repelling and killing insects [25]. Anecdotal evidence reveals that the admixture of water from fermented cassava (*Manihot esculentus*) and bitter leaf (*Vernonia colorata* L.) showed potency against “tailor ants” infesting pear fruit and leaves in the Edo State, Nigeria. However, given these pesticide potentials, insufficient information exists about their prospective use in integrated soil and nutrient management.

In an attempt to fill this gap, this study assesses the influence of two fortified organic liquid manure, inorganic and zero fertilizer applications on the growth, physiological and pesticidal response of African nightshade (*S. scabrum*). The objectives include: (i) to assess the influence of liquid organic manure, inorganic and zero fertilizer applications on growth indicators of *S. scabrum*; and (ii) to assess the crop protection potentials of fortified liquid organic manure on *S. scabrum*. This study attempts to test the following hypothesis: H1₀: there is no statistically significant difference in the effects of liquid organic manure, inorganic and zero fertilizer on growth and physiological response of *S. scabrum*; H1_A: there is a statistically significant difference in the effects of organic liquid manure, inorganic and zero fertilizer on growth and physiological response of *S. scabrum*; H2₀: There is no statistically significant difference in crop protection potential between the application of fortified bio-pesticide and zero application. H2_A: There is a statistically significant difference in crop protection between the application of fortified bio-pesticide and zero application.

2. METHODOLOGY

This study established pot and field experiments which were carried out in a green house facility and on the farm respectively, at the Pan African Institute for Development – West Africa, Buea, Cameroon. The study was organized into three phases, a preparatory phase, an experimental phase, and a data collection and phase.

2.1 Preparatory Phase

Involved the production of liquid manure and the preparation of planting pots and field plots in the experimental sites:

2.1.1 Production of liquid manure

Employed materials including: metallic drums (200L capacity), poultry manure mixed with ash

(biochar), cow dung, garlic (*Allium sativum*), pepper (*Capsicum* sp.), Aloe vera L., pawpaw (*Carica papaya*) leaves, scarlet tassel flower (*Emilia coccinea*), leaves of sunflower (*Tithonia diversifolia*). Yeast (for microbial activation in the mixture), wood ash, chickweed (*Ageratum conyzoides*), Cassava leaves (*Manihot esculent*), measuring scale, hoe, knife, notebook, cutlass, and water.

2.1.1.1 Procedures for preparing liquid manure

The leaves of selected plants were chopped, while the selected ingredients were ground and all these were placed into two drums (drum A and B, each of 200L capacity) representing two fortified liquid manure treatments (T1 and T2 respectively). The selected plant-ingredient composition, quantity and dilution ratios considered for the respective treatments are presented in Table 5. Water was then added to each drum following a 1:1 rate (X kg organic materials for treatment: X L of water). A hard stick was used to stir these mixtures every day for one week and later on, once a week for at least 5 to 10 minute and allowed to stand for 21 days to allow for organic matter decomposition. After day 21, the liquid mixture from each drum was then extracted using a sieve and stored in containers. It was then diluted following a dilution factor 1:12 (one cup of raw liquid manure to twelve cups of tap water) to avoid plant damage (such as burns) due to acidity.

2.1.2 Preparation of experimental pots, field plots and testing of liquid manure

Soil, plastic pots (1L), and seedlings of *S. scabrum* were obtained and used to prepare 96 experimental pots, while six beds were prepared on the field. Tools including hoe, electronic scale, pen and notebook, water, urea, and photographic camera, were used. Raw (undiluted) liquid manure samples initially produced were tested on two separate *S. scabrum* plantlets in pots to identify any possibility of plant damage by the treatments. It was realized that plants were not affected negatively in any way but showed remarkable results. However, in this study, liquid manure was diluted before it was applied to the soils in the pots (without touching the leaves of the plants) at a rate of 4000L/ha, once and twice a week, in the pot experiment. On the other hand, a knapsack of 15L capacity was used to apply the diluted liquid organic manure onto the plants in the field experiment as required (every week and immediately after any rainfall, since it was a rainy season) by spraying.

2.2 Experimentation Phase

This research was conducted from August to November 2017, and it was designed to constitute two sub-experiments: a pot experiment (experiment 1, Fig. 1a) and a field experiment (experiment 2, Fig. 1b). Experiment 1 was set out to assess growth, and physiological responses, by the different treatments whose composition is described in Table 1, at different application rates (once and twice a week). This experiment was laid out in a Complete Randomized Block design (CRBD) with four treatments. Each experiment had four treatments, each treatment had six replicates, but each replicate had four experimental units (4x6x4 = 96 pots) to ensure a sufficient number of plant samples for the duration of the trial. Table 1 describes the composition, quantity and dilution ratio of the different treatments while Table 2 presents the chemical properties, bio-activity components and the costing for the different treatments. Experiment 2 was set out to assess the pesticidal/insecticidal responses (by counting the number of leaves eaten by insects) of the two types of liquid organic manure (T1 and T2) and zero application (control) in the field. This experiment was laid out randomly in two plots, with three beds each (2 x 3 = 6 beds) (Fig. 1b).

2.3 Data Collection and Analyses Phase

2.3.1 Data collection

The study employed a quantitative approach to collect data for analyses, using the growth rate model to measure how different treatments influenced the growth indicators and the crop

protection model to estimate the crop protection potentials of the two fortified liquid organic manures on the African nightshade, respectively. Data were collected weekly, for 10 weeks. On the one hand, the growth rate model (equation 1) calculated the average weekly growth rate of the four different growth indicators by taking the change in each indicator and dividing it by the amount of time it has been growing:

$$GRI = (X_2 - X_1)/T \quad (1)$$

Where, X1= the first measurement, X2 = the second measurement, and T = the number of weeks between each measurement, and GRI = the growth rate of indicators including: Number of leaves: (measured by physically counting leaves form per plant); Plant height: (calculated using a meter ruler to measure the shortest distance between the upper boundary of the main photosynthetic tissues on the plant and the ground level [26]); Stem collar diameter: (measured using a vernier caliper, about 2.5 cm above ground level [27]); Leaf surface area (LA): (determined by the non-destructive length by width method [28]) using the relation: LA=0.75 (length × width), where 0.75 is a constant).

On the other hand, the crop protection model (equation 2) estimated the pesticidal properties of the two different liquid manure (crop protection potentials) was determined by counting the numbers of leaves eaten by insect pests:

$$CP = n \quad (2)$$

Where CP = crop protection potential and n = number of leaves eaten by pests.



Fig. 1. Experiment 1, constituting the pot experiment carried out in the greenhouse (left-a); and experiment 2, constituting the field experiment carried out on the school farm (right-b)

Table 1. Description of the composition, quantity and dilution ratios of the different treatments

Treatment	Composition	Quantity	Property	Family	Function
T1 200ml (dilution ratio 1:12)	chicken droppings mixed with bio char	2 kg	Nutrient	-	Fertility
	cow dung,	2 kg	Nutrient	-	Fertility
	Chopped leaves of Sunflower (<i>Tithonia diversifolia</i>)	2 kg	Nutrient + medicinal	Daisy	Fertile+ bitter
	Chopped leaves of Chickweed (<i>Ageratum conyzoides</i>)	2 kg	Pesticidal + nutrient	Daisy	Fertile+ bitter
	Ground bell pepper (<i>Capsicum annuum</i>)	1 kg	Pesticidal	Nightshade	Hot
	Ground Garlic (<i>Allium sativum</i>)	1 kg	Nutrient + Pesticidal	Amaryllidaceae	Fertile+smell
	Chopped leaves of Pawpaw (<i>Carica papaya</i>)	2 kg	Nutrient+ Pesticidal	Caricaceae	Fertile+bitter
	Chopped leaves of Scarlet tassel flower (<i>Emilia coccinea</i>)	2 kg	Nutrient + Pesticidal	Asteraceae	Fertile+bitter
	Chopped leaves of <i>Aloe vera</i>	2 kg	Nutrient + Pesticidal	Asphodelaceae	Fertile+bitter
	Chopped leaves of Cassava (<i>Manihot esculenta</i>)	2 kg	Nutrient + Pesticidal	Euphorbiaceae	Fertile+bitter
	Water	16 L		-	
T2 200ml (dilution ratio 1:12)	Chopped leaves of Sun flower (<i>Tithonia diversifolia</i>)	2 kg	Nutrient + Pesticidal	Daisy	Fertile+bitter
	Chopped leaves of Chick weed (<i>Ageratum conyzoides</i>)	2 kg	Medicinal + Pesticidal	Daisy	Fertile+bitter
	Chopped leaves of Pawpaw (<i>Carica papaya</i>)	2 kg	Nutrient + Pesticidal	Caricaceae	Fertile+bitter
	Chopped leaves of Scarlet tassel flower (<i>Emilia coccinea</i>)	2 kg	Nutrient+ Pesticidal	Asteraceae	Fertile+bitter
	Chopped leaves of <i>Aloe vera</i>	2 kg	Nutrient + Pesticidal	Asphodelaceae	Fertile+bitter
	Chopped leaves of Cassava (<i>Manihot esculenta</i>)	2 kg	Nutrient + Pesticidal	Euphorbiaceae	Fertile+bitter
	Wood Ash	1 kg	Nutrient + Pesticidal	-	Fertile+ irritaate
	Water	13 L		-	
T3	Zero fertilizer application			-	
T4	Urea (inorganic fertilizer)	200kg/ha	Nutrient	-	fertile

Table 2. Chemical properties, bio-activity components and costing for the different treatments

Parameters	T1	T2	T3	T4
C/N Ratio	10.3	10.7	11.6	-
Total N (%)	3.21	2.69	1.3	3.28
Total P ₂ O ₅ (%)	2.60	2.17	0.62	-
Total K ₂ O (%)	2.24	1.63	0.32	-
Fe (ppm)	1310	862	71	-

Parameters	T1	T2	T3	T4
Zn (ppm)	310	261	28	-
Cu (ppm)	39	26	8	-
Mn (ppm)	346	298	39	-
Ca (%)	1.06	0.82	0.12	-
Mg (%)	0.63	0.43	0.06	-
Bio-active components	Capsacin (1.22 mg/ml), Alkaloids (8.40%), Lectins, Antocyanin (11.29%), Saponin (75%), precocenes (375ppm), Ash, Aloin A, Tannin (5.31%),	Ash, Aloin A, Lectins, precocenes, Alkaloids,	-	-
Cost (FCFA)	200/L	150/L	0	500/kg

2.3.2 Data analyses

Descriptive, bivariate and multivariate statistics were used to analyze the data. A one-way Analysis of variance ratio (ANOVA) was used to compare the means of various growth parameters among the treatments. Treatment means were segregated using least significant difference (LSD) and Duncan post hoc multiple comparison tests. All level of significance was set at a 95% confidence interval limit. All statistical analyses were performed using IBM SPSS statistics, version 21.

3. RESULTS AND DISCUSSION

3.1 Influence of Liquid Manure, Inorganic and Zero Fertilizer Applications on the Growth Indicators of *Solanum scabrum*

All the fertilizer treatment applications influenced the growth indicators of *Solanum scabrum*

differently, with the plants under T2 showing taller, larger stems, darker green leaves, and first fluorescence characteristics, relatively (Fig. 2).

3.1.1 Stem collar diameter

Generally, the results show that T2 had the largest average stem thickness (1.54 cm) followed by T1 (1.44 cm), while T4 had the lowest stem thickness (1.29 cm). Generally, the thickness of the stem collar diameter of *Solanum scabrum* under all the treatment increased steadily from week one to ten (Fig. 3a). A similar trend was noticed, when considering the application rates (once and twice a week) separately (Fig. 3b). There were significant differences ($P = .01$) in stem collar diameter for all the fertilizer treatments (Table 2). However, T2 had the highest stem growth rate (0.11 cm/week) which differed significantly from those of T3 and T4 (0.08 cm/week) but did not differ significantly ($P = .12$) with T1 (0.10 cm/week) (Table 2).



Fig. 2. Physical influence of liquid organic manure, inorganic and zero fertilizer applications on the growth and development of *Solanum scabrum*

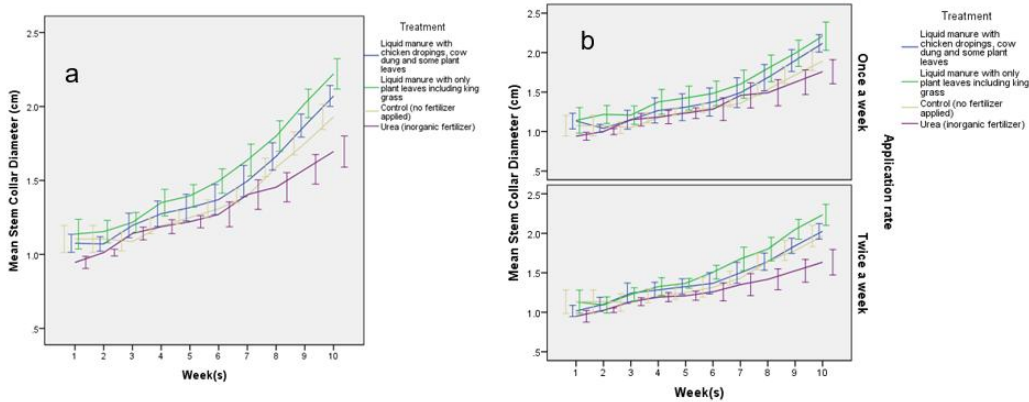


Fig. 3. Estimated marginal means of Stem Collar Diameter of *Solanum scabrum* (a), at an application rate of once and twice a week (b), for ten weeks, under the influence of liquid manure, inorganic and zero fertilizer applications.

*Error bars: 95% CI

Table 3. Result of stem collar diameter of *Solanum scabrum* at an application rate of once and twice a week

Treatment		T1	T2	T3	T4
SCD (cm)	Ap. Rate/week				
	Once per week	1.45 ^a ±0.40	1.55 ^b ±0.41	1.34 ^c ±0.31	1.31 ^d ±0.31
	Twice per week	1.44 ^a ±0.35	1.54 ^b ±0.41	1.40 ^c ±0.34	1.27 ^d ±0.26
	Total	1.44 ^a ±0.37	1.54 ^b ±0.41	1.37 ^c ±0.32	1.29 ^d ±0.29
Growth rate (cm/week)		0.10 ^{ab} ±0.02	0.11 ^a ±0.03	0.08 ^b ±0.03	0.08 ^b ±0.03

SCD= Stem collar diameter, T1= liquid manure composed of chicken droppings, cow dung, other and plant leaves, T2= liquid manure composed only plant leaves including chickweed, wood ash, and other plant leaves, T3= Control treatment (no fertilizer applied), T4= Urea, P = P-value, Means within columns with the same letter(s) are not significantly different by DMRT at P=0.05

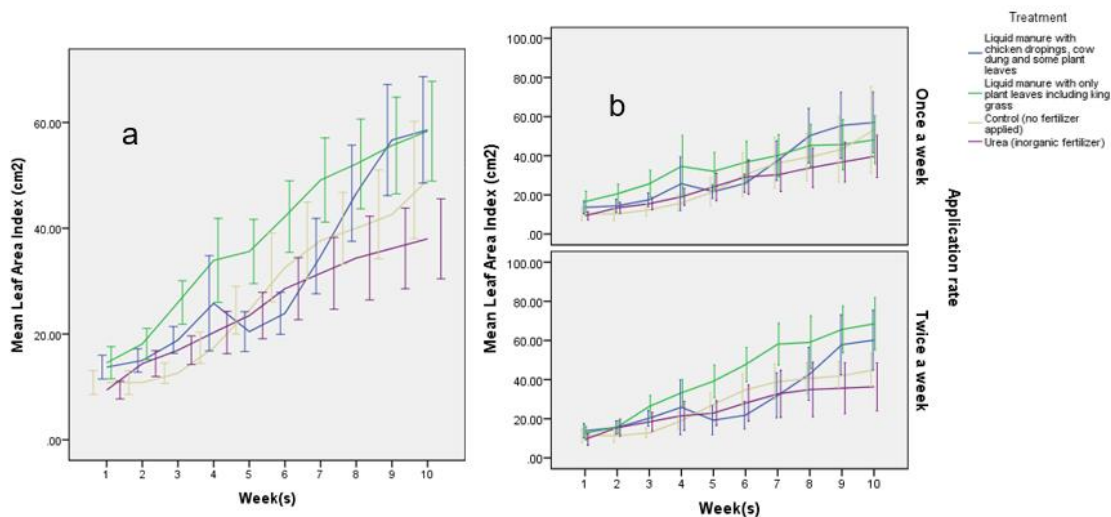


Fig. 4. Estimated marginal means of leaf area index of *Solanum scabrum* (a), at an application rate of once and twice a week (b), for ten weeks, under the influence of liquid manure, inorganic and zero fertilizer applications.

*Error bars: 95% CI

3.1.2 Leaf area index (Leaf size)

Generally, the results showed that T2 had the largest average leaf size (38.56 cm²) followed by T1 (31.44 cm²), while T4 (urea) had the smallest average leaf size (25.31 cm²). Generally, the leaf sizes of *Solanum scabrum* under T1 increased gradually from week one to six and then faster from week seven to ten compared to those of the other treatment (Fig. 4a). On one hand, the result showed that T1 had the largest average leaf area index (32 cm²), followed by T2 (31 cm²), under the application rate of once a week. On the other hand, T2 had the largest average leaf area index (42 cm²) followed by T1 (31 cm²), under the application rate of twice a week (Fig. 4b).

Contrarily, T4 recorded the smallest average leaf area index in both once and twice a week application rates (25.09 and 25.54 cm², respectively). Both liquid organic manure (T1 and T2) significantly differed ($P = .00$) in leaf area indices with zero fertilizer and urea treatments (T3 and T4, respectively). However, there was no significant difference ($P = 1.35$) in leaf area index between zero fertilizer and urea treatments (T3 and T4, respectively). T1 had the highest leaf area growth rate (4.48 cm²/week) followed by T2 (4.38 cm²/week) while T4 had the slowest leaf area growth rate (2.86 cm²/week). Furthermore, there were no significant differences ($P = 1.56$) in leaf area growth rate for all the treatments, during the ten weeks period of the experiment (Table 4).

Table 4. Result of leaf area index of *Solanum scabrum* at the application rate of once and twice a week

Treatment		T1	T2	T3	T4
LAI (cm ²)	Ap. Rate/week				
	Once per week	31.91 ^a ±22.54	30.96 ^b ±22.82	27.30 ^c ±22.75	25.09 ^d ±15.10
	Twice per week	30.96 ^a ±22.82	42.62 ^b ±23.97	28.33 ^c ±16.35	25.54 ^d ±16.88
	Total	31.44 ^a ±22.64	38.56 ^b ±21.96	27.81 ^c ±19.78	25.31 ^d ±15.98
Growth rate (cm ² /week)		4.48 ^a ±2.66	4.38 ^a ±2.61	3.82 ^a ±2.63	2.86 ^a ±1.92

LAI= Leaf area index, T1= liquid manure composed of chicken droppings, cow dung, other and plant leaves, T2= liquid manure composed only plant leaves including chickweed, wood ash, and other plant leaves, T3= Control treatment (no fertilizer applied), T4= Urea, P = P-value, Means within columns with the same letter(s) are not significantly different by DMRT at P=0.05

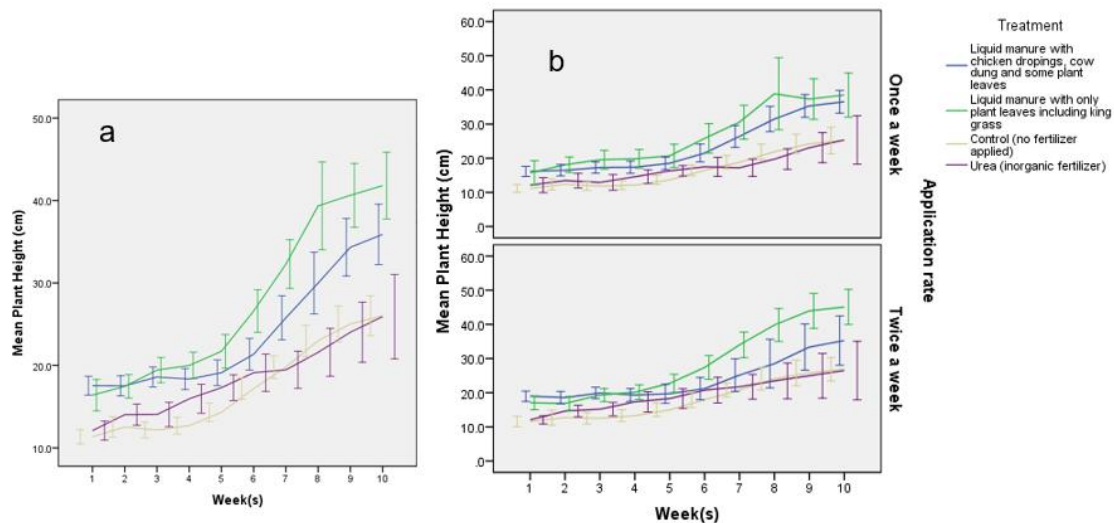


Fig. 5. Estimated marginal means of plant height of *Solanum scabrum* (a), at an application rate of once and twice a week (b), for ten weeks, under the influence of liquid manure, inorganic and zero fertilizer applications.

*Error bars: 95% CI

Table 5. Result of plant height at the application rate of once and twice a week.

Treatment	T1	T2	T3	T4
PH (cm)				
Ap. Rate/week				
Once per week	23.71 ^a ±8.65	26.50 ^b ±11.76	16.77 ^c ±6.04	17.23 ^c ±6.60
Twice per week	24.00 ^a ±9.06	28.63 ^b ±11.94	18.04 ^c ±6.80	19.48 ^c ±8.11
Total	23.85 ^a ±8.84	27.57 ^b ±11.87	17.41 ^c ±6.45	18.35 ^c ±7.46
Growth rate (cm/week)	1.83 ^{ab} ±0.88	2.54 ^a ±1.02	1.47 ^b ±0.58	1.38 ^b ±1.30

PH= Plant height, T1= liquid manure composed of chicken droppings, cow dung, other and plant leaves, T2= liquid manure composed only plant leaves including chickweed, wood ash, and other plant leaves, T3= Control treatment (no fertilizer applied), T4= Urea, P = P-value, Means within columns with the same letter(s) are not significantly different by DMRT at P=0.05

3.1.3 Plant height

Generally, T2 had the tallest average plant height (27.57 cm) followed by T1 (23.85 cm), while T3 had the shortest average plant height (17.41 cm). The average plant height of *S. scabrum* under the treatment T1, T2 and T3 increased gradually from week one to five and then faster from week six to nine, compared to those of the T4 treatment which showed a steady increase from week three, then gradually to the end (Fig. 5a). The same trends were observed when considering the different application rates (once and twice a week) (Fig. 5b).

The result also showed a significant difference ($P = 0.00$) in average plant height influenced by the two fortified liquid manure, urea and zero fertilizer treatments (Table 5). Average plant height for both organic liquid manures (T1 and T2) differed significantly ($P = 0.00$) from all the other treatments. However, there was no significant difference ($P = 1.85$) in average plant height between zero fertilizer and urea treatment (T3 and T4, respectively). T2 had the highest growth rate (2.54 cm/week) followed by T1 (1.83 cm/week) while T4 had the slowest growth rate (1.38 cm/week) (Table 4). In addition, there were no significant differences ($P = 2.21$) in growth rate between T1 and T2, as well as between T1, T3, and T4, but a significant difference exist ($P = 0.00$) between T2 and T3 as well as between T2 and T4

3.1.4 Number of leaves

The results showed that T2 had the highest mean number of leaves (27.65 units) followed by T1 (21.22 units), while T3 had the lowest (13.21 units). Generally, the mean number of leaves of *Solanum scabrum* under T1 and T2 increased gradually from week one to four and then faster from week five to ten compared to those of the other treatments which showed a gradual steady

increase (Fig. 6a). It was also noticed that the leaves of the plants under T2 and T1 treatments were greener (dark green) in color compare to those of T3 and T4, which had pale green leaves (Fig. 1). T1 had the highest average number of leaves (24 units), followed by T2 (23 units), under the application rate of once a week, while T2 had the highest average number of leaves (32 units) followed by T1 (18 units), under the application rate of twice a week (Fig. 6b). T3 recorded the lowest number of leaves under twice a week application rates (12 units) after ten weeks. Furthermore, there exist significant differences ($P = 0.01$) in number of leaves amongst all the fertilizer treatments (Table 6). T2 had the highest average increase in number of leaves (5 leaves/week) followed by T1 (4 leaves/week), while T4 had the lowest leaf number growth rate (2 leaves/week) (Table 6). However, the result showed that although there was no significant difference ($P = 2.84$) in leaf number growth rate between the two treatments with liquid organic manure applications (T1 and T2), T2 significantly differed from T3 and T4 ($P = 0.00$).

Overall, T2 gave the best growth rate response since it produced the largest stem thickness, largest leaf size, tallest height, and a higher number of leaves within the duration of ten weeks (Fig. 7).

3.1.5 The influence of liquid manure on crop protection of *Solanum scabrum*

Some pests such as the larvae (caterpillars) of the Monarch butterfly (*Danaus plexippus*) and the Luna moths (*Actias luna*) were observed eating and boring holes on the leaves of the experimental plants on the field (Fig. 8a). The beds under the control treatment had the highest average number of leaves attacked by pests (119 units) followed by the beds which received T1 (88 units), while the bed which received T2

had the lowest average number of leaves attacked by pests (66 units) (Fig. 8b). The number of pest attacks was not significantly

different ($P = 1.59$) between T1 and T2, but it differed significantly ($P = .00$) between T1 and T3 as well as between T2 and T3.

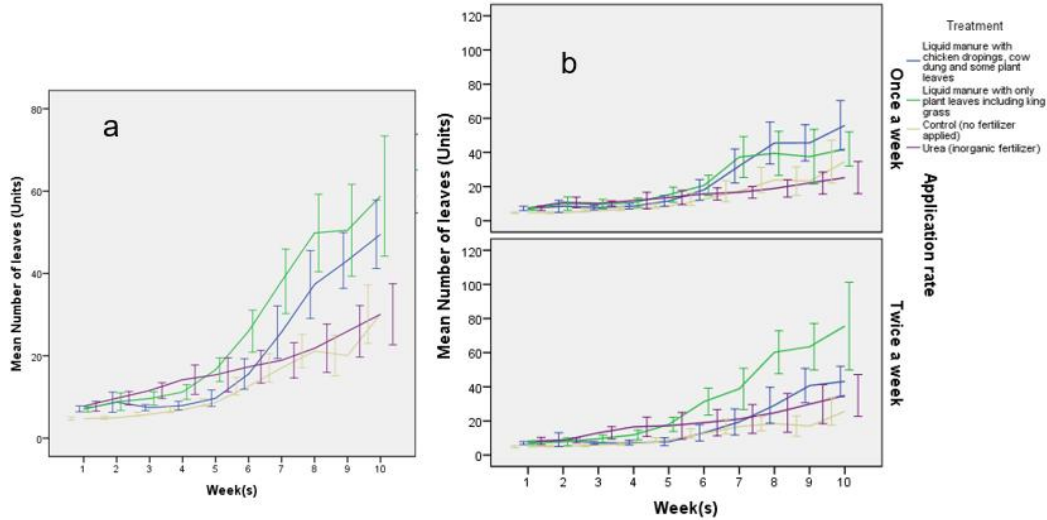


Fig. 6. Estimated marginal means of plant height of *Solanum scabrum* (a), at an application rate of once and twice a week (b) for ten weeks, under the influence of liquid manure, inorganic and zero fertilizer applications.

*Error bars: 95% CI

Table 6. Result of number of leaves at the application rate of once and twice a week.

Treatment		T1	T2	T3	T4
NL (Units)	Ap. Rate/week				
	Once per week	24.06 ^a ±21.71	22.93 ^b ±19.00	14.23 ^c ±13.11	15.22 ^d ±9.12
	Twice per week	18.39 ^a ±16.62	32.38 ^b ±29.93	12.19 ^c ±8.88	19.33 ^d ±14.75
	Total	21.22 ^a ±19.50	27.65 ^b ±25.46	13.21 ^c ±11.22	17.28 ^d ±12.41
Growth rate (leaf/week)		4.24 ^{ab} ±1.96	5.18 ^a ±3.40	2.54 ^b ±1.66	2.23 ^b ±1.82

NL= Number of leaves, T1= liquid manure composed of chicken droppings, cow dung, other and plant leaves, T2= liquid manure composed only plant leaves including chickweed, wood ash, and other plant leaves, T3= Control treatment (no fertilizer applied), T4= Urea, P = P-value, Means within columns with the same letter(s) are not significantly different by DMRT at P=0.05

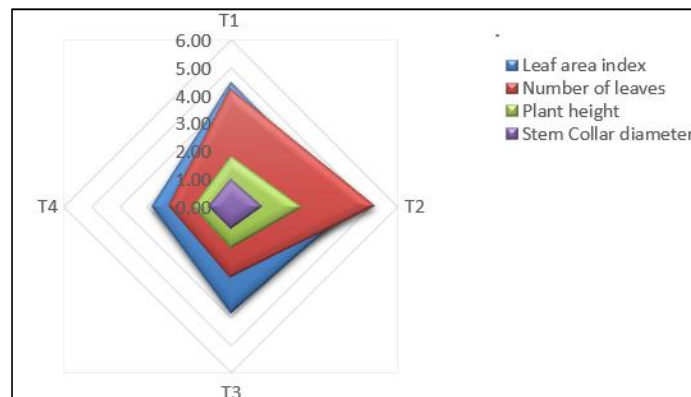


Fig. 7. An overall growth rate radar of *Solanum scabrum*, for ten weeks, under the different fertilizer applications

T1= liquid manure composed of chicken droppings, cow dung, other and plant leaves, T2= liquid manure composed only plant leaves including chickweed, wood ash, and other plant leaves, T3= Control treatment (no fertilizer applied), T4= Urea

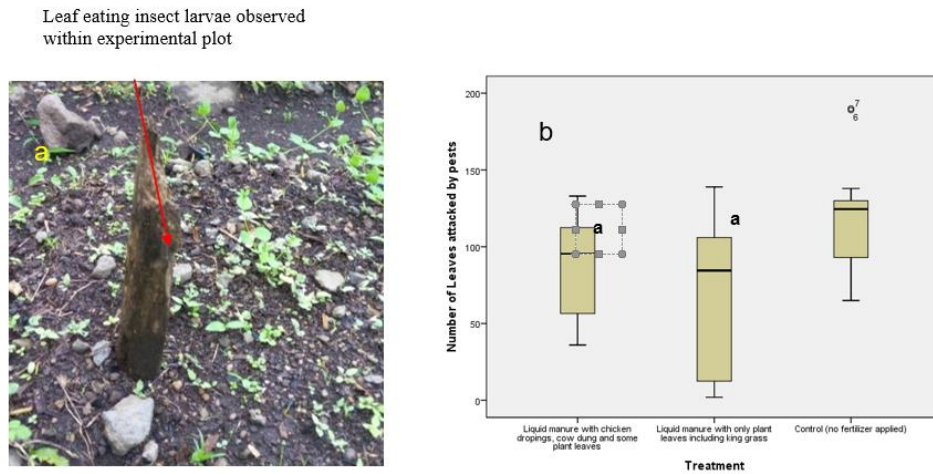


Fig. 8. Image of leaf eating caterpillar observed on the field experimental site (a) and the means of number of *S. scabrum* leaves attacked by pests (b) for ten weeks. Means with the same letter(s) are not significantly different by LSDMCT at $P = 0.05$

3.2 Discussion

The significant differences in growth rate, stem thickness, leaf size, height, and the number of leaves resulting from T2 influence can be due to its nutrient-rich composition. This is probable because the liquid extract of the green biomass and wood ash composition mixture of T2 contained significant, readily available amounts of macronutrients including nitrogen, potassium, and phosphorus, as well as micronutrients such as calcium, magnesium, and sodium. Higher amounts of essential nutrients in the soil in available forms have been reported to increase growth parameters of crops as a result of increased photosynthetic efficiency [29,30,31]. Comparatively, the liquid manure treatment T2 was more energetic as it enhanced the growth parameters of *S. scabrum* the most. These results corroborate those of related studies [13,17,18,19].

This result implies that the organic liquid fertilizer (T1 and T2) improved soil fertility, and encouraged the growth and development of *S. scabrum*. This is probably due to its possession of high amounts of readily available essential nutrients, mainly nitrogen, which is concomitant with the photosynthetic activity capable of encouraging roots and vegetative growth of plants. The assertion that organic matter, in the liquid state normally contains a high amount of immediately available nitrogen, although the quantity of the readily available nitrogen in the form of $\text{NH}_4\text{-N}$, in inorganic fertilizers, are higher

than that of organic manures [32], is not frivolous. The quantity of liquid manure incorporated in the soil pots of this study corresponded to the recommended inorganic fertilization rates for crops and effectively enhanced crop growth, yield, and nutrient uptake and maintain soil fertility at desirable levels, without causing any adverse effects to the plants, soils and the environment as a whole. This implies that organic liquid fertilizer can conveniently replace chemical nitrogen fertilizers which are usually costly to resource-poor smallholder farmers and environmentally unfriendly due to their ability to reduce soil pH (acidic) when continuously used, and their high water pollution potentials. In fact, organic matter enhances soil buffering capacity [4,12].

The results confirm the assertion that cow dung and chicken droppings contained a substantial amount of macronutrients, especially nitrogen [12], which influenced the growth and development of *S. scabrum*. This result ties with related findings [33,34,35] and also indicate that the absence of either poultry manure or cow dung, in any community should not preclude the use of locally available weeds and other unwanted farm plants, which may be more effective as biofertilizer. In this light, it can be suggested that, where there is no cow dung or poultry manure or both, the use of liquid extracts of green biomass including *Tithonia diversifolia*, *Ageratum conyzoides*, *Carica papaya*, *Emilia coccinea*, *Aloe vera*, and *Manihot esculenta*, mixed with wood ash or bio char, appears very

promising. However, it is advisable that farmers should carry out their own research, to identify the biofertilizer potentials of the different types of biomass found in their community, especially those plants that are commonly recognized as weeds. Particular attention could be attached to the leaves of the plants that are rejected by cattle, sheep, and goat. Furthermore, the larger leaf size and the highest number of leaves resulting from the “twice a week” application rate of T2 indicated that a better yield is obtained when the frequency of application is increased. In fact, results from this study revealed that the application of liquid organic manure provides an added crop irrigation advantage, as it combines fertilization and irrigation (fertigation), which is convenient, economical, results in a better quality crop, increases nutrient efficiency and ultimately increases crop yields.

The global interest in using plants as pesticides is gaining prominence [36,37] due to their environmental and user-friendliness as well as their local availability and cost-effectiveness. They can be trusted by farmers, making it difficult to be adulterated. This, therefore, reveals that organic pesticidal products are alluring alternatives to synthetic pesticides. However, knowledge and technology employed in using plants as pesticides are implanted in folklores and tradition of farmers, but in many such cases, the identity of pesticidal plants are often not documented since it is usually passed on from one generation to the other by words of mouth [21]. Some plants produce a variety of secondary metabolites such as tannins, alkaloid, and phenols which are usually toxic to pathogens and pests [38].

The results of this study also revealed that the organically fortified liquid fertilizers (T1 and T2) increased crop protection by effectively reducing the number of *S. scabrum* leaves attacked by pests. This is probably due to the insecticidal properties or bioactivity of the organic ingredients that were integrated into the liquid fertilizer mixture compositions. Many researchers have reported the insecticidal potentials of *Allium sativum*, *Capsicum annuum*, *Ageratum conyzoides*, *Aloe vera* and wood ash [39,40,41,42]. The molecular mechanism of toxicity and interaction of lectins found in *Allium sativum* with mid gut receptor proteins of insects has been described in many reports. Lectins damage the membrane integrity and food recognition ability of insects by affecting sensory receptors of their mouth parts [22]. Lectins also

interact with important protein molecules such as polycalins, aminopeptidase-N, symbionin, phosphatase, sucrase, and others, in the lumen of their guts, altering their life cycle development by causing physiological disorders, resulting to death [22].

Ageratum conyzoides has long been reported to possess bioactivity that may have an agricultural use [42]. The major components of the oil from *Ageratum conyzoides*, known as precocenes, is reported to have an antijuvenile hormonal activity while a methanolic extract from the plant's fresh leaves (250 and 500 ppm) also produced a deficiency of juvenile hormone of a sorghum pest *C. partellus* [42]. In addition, it has been discovered that Alion A (hydroxy anthrone glycoside) is a principal constituent of *A. vera* [24], which has been attested to have numerous biological activities including an insecticidal activity [43].

The abilities of different botanicals as pesticides have been experimented [44] and it was noted that *A. vera* was the most effective in reducing aphid attack on Canola (*Brassica napus* L.). Capsaicin in *C. annuum* has also been attested to cause membrane damage and metabolic disruption to insects, and also affects the nervous system of invertebrates [25]. Most insects are repelled by pepper spray and will definitely avoid pepper treated plants. Therefore, the bioactivity influence of all the selected bio-pesticidal products in this study is suggested to be responsible for the low leaf attacks on *S. scabrum*, by insect pests, due to their combined insecticidal and/or repellency effects.

The bioactive effects of most botanicals are usually ephemeral in nature, vanishing within 6-12 days, while other last for up to 14-21 days, thereby making them environmentally friendly and reasonably safe to valuable organisms such as insect pollinators, termite, earthworms and ultimately, humans [45]. The pesticidal response of the fortified liquid manure is in line with the assertion that liquid extracts from *Musa paradisiaca* L, *Cymbopogon citratus* Staph., *Hyptis suaveolens* Point, *Eucalyptus camaldulensis* Dehnh, *Lantana camara* L., *Vernonia amygdalina* Delile and *Nicotiana tabacum* L. was very effective against kola weevils [46]. More so, the result concurs the allegation that extracts of *Capsicum annuum* in mixture with *Allium sativum* L, *Cymbopogon citrates* Staph. were very effective against leaf eating insect pests of crops [21].

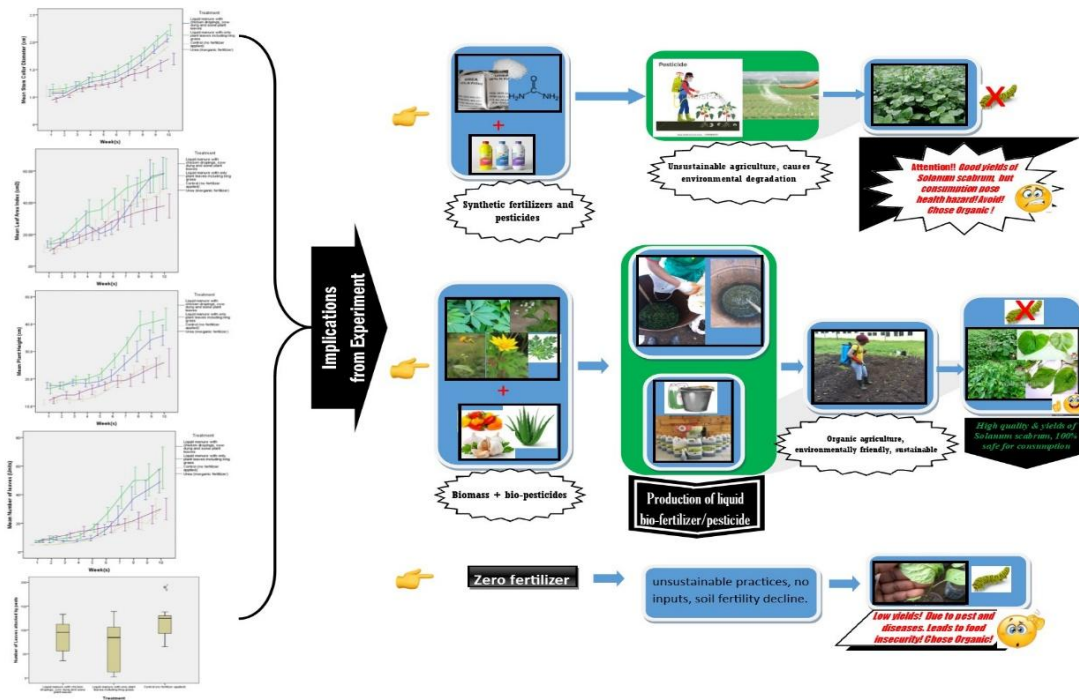


Fig. 9. Summary implication of findings, showing an option for sustainable agriculture and healthy food production and consumption

Though not significantly different, the result clearly indicates that wood ash presented an additional crop protection potential for T2 and may be attributed to the lowest average number of leaves attacked by leaf eating pests. Wood ash has been reported to be alkaline rendering it a fungicide and a pesticide. It has been reported that dusting pawpaw crop with wood ash by farmers in Northern Guinea Savanna agro-ecological zone of Nigeria checked the incidence of pest attack and improved pawpaw pod quality [47]. Recently, it was also publicized that small-holder farmers in Kenya tremendously sliced production costs by using urine and wood ash mixture to deal with crop pests and diseases [48]. These findings can contribute towards reducing the residual effects of synthetic fertilizers and pesticides on humans and the environment (Fig. 9).

The results, therefore, contribute to recent efforts geared toward attaining sustainable development by providing cost-effective biological options for sustainable agriculture, through the use of non-chemical strategies to boost yields while protecting human health and the environment.

4. CONCLUSION

There is a statistically significant difference in effects of liquid organic manure, inorganic and zero fertilizer on growth and physiological response of *S. scabrum*. In addition, there is a statistically significant difference in crop protection between the application of fortified bio-pesticide and zero application. In this light, liquid extracts from locally available biomass can be used as organic fertilizers and present a cost-effective option for cultivating *S. scabrum* by resource-poor farmers who might not be able to afford the costly inorganic fertilizers. The pesticidal potentiality of local organic plant extracts proves useful towards the development of effective bio repellent fertilizers. This can significantly reduce farm losses and contribute to the reduction of the use of synthetic agro chemicals, hence reducing their associated environmental and human health hazards. Therefore, organic concoctions of liquid organic manure and indigenous bio-pesticides based on cassava, aloe, papaw, chick weed, tassel flower, sunflower, bell pepper, garlic, and wood ash, can be developed for home gardening and even extended to field crops. However, its applications

on the field may be labor intensive as agricultural fields increase in size. Furthermore, the findings of this study support the global advocacy for organic farming, towards addressing the goals of the 2030 agenda for sustainable development.

However, farmers should carry out individual research to identify potential bio fertilizers using locally available biomass including those that are commonly recognized as weeds. Further research is also encouraged to identify other ingredients that have insecticidal and pesticidal properties. Policy makers should consider agricultural policy reorientation to integrate the use of local knowledge to produce and use bio-fertilizers and bio-pesticides. Research grants should be provided to encourage young farmers to take up the initiative to upscale fortified organic liquid manure production. Government extension services should consider raising awareness on the production and of organic liquid manure. Restrictions should be placed on the importation and purchase of synthetic agro chemical inputs within the country to encourage the production and use of bio-fertilizers and bio-pesticides.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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