Journal of Applied Life Sciences and Environment
https://jurnalalse.com

Article
https://doi.org/10.46909/alse-572132
Vol. 57, Issue 2 (198) / 2024: 197-216

EFFECT OF OKORO [(*Albizia zygia* (J.F.) Macbr)] LEAFY BIOMASS AND NPK FERTILISER ON THE GROWTH AND YIELD OF SWEET PEPPER (*Capsicum annum* L.)

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Received: Dec. 15, 2023. Revised: Jan. 30, 2024. Accepted: Feb. 13, 2024. Published online: Apr. 04, 2024

ABSTRACT. Agricultural productivity and sustainable crop management are pivotal aspects of global food security and economic stability. The quest for efficient and environmentally friendly practices in crop production has led to a surge in research exploring the utilisation of organic materials alongside conventional fertilisers to enhance crop growth and yield. An experiment was conducted over a growing period of three months, starting in August 2023 at the research field of Kwame Nkrumah University of Science and Technology, Kumasi-Ghana, to investigate the effects of *Albizia zygia* leafy biomass in combination with NPK fertiliser on the growth and yield of sweet pepper (*Capsicum annum* L.). A randomised complete block design was employed with four treatment groups replicated four times, including various combinations of *A. zygia* leafy biomass and NPK fertiliser, alongside control groups of sole fertiliser application and untreated plots (T1). The treatments were as follows: T1 = No biomass, no NPK (control); T2 = 0.5348 kg of *A. zygia* leafy biomass per 4.86 m^2 (1100.5 kg/ha of *A. zygia* leafy biomass); T3 = 0.2463 kg of NPK per 4.86 m^2 (506.7 kg/ha of NPK); and T4 = 0.2674 kg of *A. zygia* leafy biomass per 4.86 m^2 + 0.1231 kg of NPK (550.3 kg/ha of *A. zygia* leafy biomass + 253.4 kg/ha of NPK). The assessed parameters were plant height, number of leaves, number of branches, fruit yield and fresh fruit weight. Significant variations ($p < 0.05$)

were observed in the growth parameters (plant height, number of leaves, number of branches) and yield attributes (fruit yield and fresh fruit weight) of sweet pepper among the treatments. The combined application of *A. zygia* leafy biomass and NPK fertiliser (T4) exhibited increased effects on plant height, number of leaves, number of branches, fruit yield and fresh fruit weight compared to individual treatments and control groups ($p < 0.05$). Notably, the treatment combining *A. zygia* leafy biomass and NPK fertiliser (T4) demonstrated a substantial increase in plant height (44.58 cm), a significant improvement in the number of leaves (42.98) and a remarkable enhancement in the number of branches (11.33) compared to the sole applications and the control group. Furthermore, the combined treatment significantly increased ($p < 0.05$) the yield parameters, including fruit yield and fresh fruit weight per hectare, showcasing an increase of 8796/ha and 23.91 t/ha, respectively, compared to sole fertiliser application and the control. The findings from this study demonstrated that the incorporation of *A. zygia* leafy biomass, either solely or in combination with NPK fertiliser, positively impacted the growth and yield of sweet pepper plants. These results highlight the potential of *A. zygia* leafy biomass as a valuable organic amendment for sustainable and enhanced crop production, offering promising implications for agricultural practices aimed at improving yield and plant growth.

Keywords: *Albizia zygia*; *Capsicum annum* (L.); NPK fertiliser; organic amendment; sweet pepper.

INTRODUCTION

The pursuit of sustainable agricultural practices and the enhancement of crop productivity have been pivotal concerns in modern agronomy (Singh *et al.*, 2021; Xie *et al.*, 2019). The quest for innovative and eco-friendly approaches to improve crop yield while ensuring soil health remains an ongoing endeavour (Ameta and Ameta, 2021; Rani *et al.*, 2019; Rebouh *et al.*, 2023). Sweet pepper, scientifically termed *Capsicum annum* (L.) and commonly referred to as sweet pepper, belongs to the Solanaceae family and is cultivated extensively across tropical and subtropical regions worldwide or under greenhouse cultivation in many temperate regions (Agmadi and Souri, 2019; Jaiswal *et al.*, 2021; Mamphogoro *et al.*, 2020; Mardanluo *et al.*, 2018; Uarrota *et al.*, 2021). According to Brezeanu *et al.* (2022) and Senya *et al.* (2023), these non-spicy fruits are frequently utilised in their immature or green state for culinary purposes, such as stuffing or inclusion in salads. Esteemed as a lucrative crop, sweet peppers hold a significant position in global agriculture due to their substantial profitability and nutritional richness, contributing significantly to human wellbeing (Guevara *et al.*, 2021; Kaur *et al.*, 2020). Additionally, this vegetable crop is widely cultivated for its esteemed nutritional value and economic significance, and it is a compelling subject for investigations into optimising growth and yield (Olędzki and Harasym, 2023).

According to Aloo *et al.* (2021), Kodzwa *et al.* (2023) and Nordey *et al.* (2020), achieving optimal growth and yield of sweet pepper necessitates a balance of nutrient availability, soil fertility and sustainable agricultural practices in sub-Saharan Africa. Amid this quest, the utilisation of organic materials as supplements to conventional fertilisers has garnered substantial attention in agroecological research (Rhioui *et al.*, 2023; Umair *et al.*, 2024). *Albizia zygia*, a fast-growing nitrogen-fixing tree species prevalent in tropical regions, offers a valuable source of organic biomass (Adelani, 2023; Ogunniyi *et al.*, 2023). The leaves, being readily available and nutrient rich, present an opportunity to augment soil fertility and enhance plant growth when utilised as organic matter (Olupot, 2022). The decomposition of leafy biomass enriches soil with essential nutrients, potentially enhancing soil fertility and promoting plant growth (Adelani, 2023). Concurrently, chemical fertilisers, such as NPK (15:15:15), constitute a conventional method of providing plants with essential nutrients, ensuring optimal growth and yield (Abebe *et al.*, 2022; Roy *et al.*, 2022; Vasco *et al.*, 2021). Nevertheless, the application of chemical fertilisers in excess and at improper rates is common and has resulted in significant environmental degradation and sustainability loss (Mitra *et al.*, 2021; Patle *et al.*, 2019; Srivastav, 2020; Verma *et al.*, 2020).

The utilisation of organic materials and synthetic fertilisers in agricultural practices significantly influences crop growth and yield (Bhatt *et al.*, 2019; Gao *et al.*, 2020). However, comprehensive studies examining the combined effects of *A. zygia* leafy biomass and NPK (15:15:15) fertiliser on the growth and yield of sweet pepper (*C. annum* L.) are lacking. Therefore, understanding the potential synergistic or antagonistic impacts of these two fertilisation methods is essential to optimise sustainable agricultural practices, enhance crop productivity and minimise environmental impacts on sweet pepper cultivation in the tropics (Firmanda *et al.*, 2022; Sharma *et al.*, 2020; Verma *et al.*, 2020). Furthermore, within contemporary agriculture, there is a growing need for farming methods that prioritise sustainability and environmental friendliness (Fasusi *et al.*, 2021; Zin *et al.*, 2020). Integrating *A. zygia* leafy biomass with conventional synthetic fertilisers, such as NPK, presents a potential approach to achieving sustainable crop production (Kugedera *et al.*, 2022; Rao *et al.*, 2021). Despite individual studies on the efficacy of organic or synthetic fertilisers in crop production, there is a scarcity of comprehensive research examining the combined effects of *A. zygia* leafy biomass and NPK fertiliser, specifically on sweet pepper cultivation. The synergistic or contrasting effects resulting from the combined application of organic biomass and chemical fertilisers on crop performance, particularly in sweet pepper cultivation, present an area of considerable interest and investigation. Therefore, addressing this knowledge gap is essential for advancing agricultural practices and contributing valuable insights to the scientific community.

When incorporated into the soil, leafy biomass from leguminous tree species, including *A. zygia*, which is well-known for its cheap and sustainable source of plant nutrients, can have beneficial effects on fertility and productivity, subsequently increasing sweet pepper yields in sub-Saharan Africa, more importantly Ghana.

The aim of this study was to explore the effects of *A. zygia* leafy biomass, used either individually or in conjunction with NPK fertiliser, on the growth and yield parameters of sweet pepper (*C. annum L.*). By investigating the interactive effects of these organic and inorganic components, we sought to elucidate their impact on plant growth and, ultimately, the yield of sweet pepper.

The objectives of this study were to assess the effect of *A. zygia* leafy biomass and NPK fertiliser alone and in combination on the growth (height, number of leaves and number of branches) and yield (fruit yield and fresh fruit weight) of sweet pepper (*C. annum* L.).

MATERIALS AND METHODS

Location of the study area

This study was conducted at the demonstration farm of the Agroforestry Department in Kumasi, Ghana (*Figure 1*) in 2023. The farm is located in Ghana's humid semi-deciduous forest zone and is geographically located at approximately 6.40°N latitude and 1.37°W longitude (Mohammed *et al.*, 2023).

Rainfall

The region experiences a distinctive rainfall pattern with two main cycles annually. The average annual rainfall ranges from 1250 to 1500 mm. The primary wet season occurs from May to July, followed by the secondary rainy season from September to November. In contrast, there are two dry intervals: a longer one spanning from December to March and a shorter dry period in August (Mohammed *et al.*, 2023).

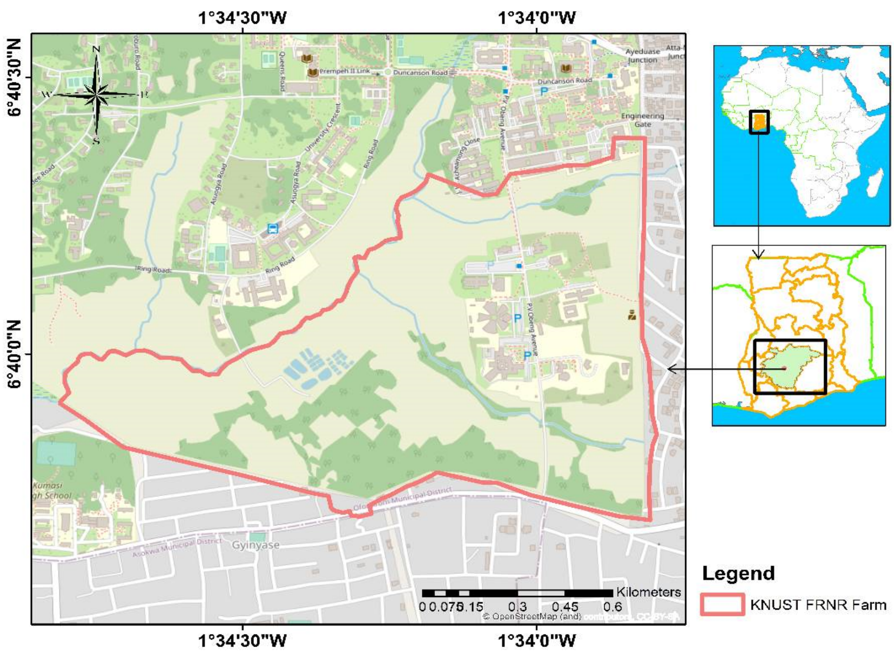


Figure 1 – Map of the study area

The prevailing climate in the area is characterised as tropical wet and dry, commonly referred to as a savanna climate.

Temperature and humidity

Mohammed *et al.* (2023) reported an average daily temperature of 25.6°C at the study location. During the coldest months (December to February), the mean temperature is around 20°C, while in the warmest month (March), the average high temperature reaches 33°C. Overall, the site experiences an annual average temperature of approximately 26.61°C, along with a relative humidity of about 67.6%.

Soil type

According to Mohammed *et al.* (2023), the soil at the research site is Ferric Acrisol, characterised by high acidity and good drainage properties, and it is in the sandy-loam textural class.

Experimental approach and procedure

Land preparation

The trial area was meticulously cleared of any vegetation and foreign debris using traditional hand tools, such as a hoe, cutlass and rake.

Sources of fertilisers

The leafy biomass of *A*. *zygia* was sourced from the Agroforestry research farm, while inorganic fertiliser was (NPK) procured from an agrochemical shop at Adum-Kumasi. These components were administered either independently or in various combinations at different dosage levels.

Source of sweet pepper seeds

The sweet pepper seeds were sourced from the Crop Research Institute of Ghana, located in Fumesua-Kumasi.

Nursery bed preparation

A site with excellent sunlight and proper drainage was selected for the study.

Preparing the area involved clearing away debris, weeds and rocks to create a smooth and debris-free surface. The soil was cultivated to a depth of approximately 15–20 cm using a hoe. Nursery beds, typically measuring 2 m wide and 2 m long, were established, allowing pathways between beds for accessibility and maintenance. Raising the beds to about 10–15 cm facilitated drainage and avoided waterlogging. Prior to seed sowing, consistent and sufficient watering was maintained to ensure optimal moisture levels.

Sowing of seeds

The seeds were spread across the prepared bed and lightly covered with a fine soil layer.

To preserve soil moisture and regulate temperature, a fine layer of natural mulch, such as straw, was applied. Shade nets were set up to shield the nursery bed from extreme environmental factors. Watering was carried out as necessary to sustain optimal moisture levels in the nursery bed.

Continuous surveillance of the bed was conducted to manage weeds, pests and diseases until the transplantation phase.

Application of *A*. *zygia* leafy biomass

The field trial incorporated leafy biomass of 10–15-year-old *A*. *zygia* into the soil two weeks prior to transplanting, in August 2023, utilising different ratios or quantities (0.5348 kg per 4.86 m^2 = 1100.5 kg/ha and 0.2674 kg per plot = 550.3 kg/ha). The leafy biomass of *A*.

zygia contained 6.91% nitrogen (N), 0.2% phosphorus (P) and 0.26% potassium (K), with a moderate decomposition rate and a half-life of 66 days (Nkyi and Acheampong, 2013).

Application of NPK (15:15:15) fertiliser

Two weeks after transplanting (2 WAT), the recommended doses of NPK fertiliser were applied for each treatment level, as per the guidelines (0.2463 kg per plot = 506.7 kg/ha and 0.1231 kg per plot = 253.4 kg/ha).

Seedling transplant

One week before transplanting, watering was reduced in the nursery to strengthen the young plants, preparing them for transplanting and exposure to high temperatures.

Later, the seedlings were watered while still in the bed to aid easy removal without causing damage to the roots. Seedlings meeting the specified height range of 20–25 cm were carefully selected and moved to the assigned experimental plots, spaced 0.9 × 0.6 m apart, in the evening.

Weed control

Weeds were manually controlled using tools, such as a hoe and cutlass, and hand labour.

Pest and disease control

Mancozeb, applied at a dosage ranging from 5 to 10 grams per gallon (equivalent to 3.8 litres of water), was employed in the process. The application started at 2 WAT and persisted until the crop reached maturity. Its purpose was to control fungal diseases, such as damping off. Cypermethrin was used at a concentration of 1.2 mg per litre after pest inspections revealed infestation levels surpassing the predetermined threshold.

Harvesting

When the sweet pepper fruits achieved maturity at 8 WAT, they were manually harvested by handpicking with a knife.

Experimental design and treatment allocation

The study employed a randomised complete block design (RCBD), consisting of four treatments that were randomly assigned and replicated four times. The land area utilised for the experiment measured 12.3 m by 8.7 m, totalling 107.01 m^2 and accommodating a total of 16 plots. Each individual plot measured 2.7 m by 1.8 m, covering an area of 4.86 m^2 and containing 16 hills per plot.

To maintain the accuracy of treatment representation within each plot, a 0.5 m alley was maintained between the plots and blocks. The study duration spanned three months. The treatments were as follows:

T1 = No biomass, no NPK (control);

T2 = 0.5348 kg of *A. zygia* leafy biomass per plot (1100.5 kg/ha of *A. zygia* leafy biomass);

T3 = 0.2463 kg of NPK per plot (506.7 kg/ha of NPK);

T4 = 0.2674 kg of *A. zygia* leafy biomass per plot + 0.1231 kg of NPK (550.3 kg/ha of *A. zygia* leafy biomass + 253.4 kg/ha of NPK);

The nitrogen (N) demand of sweet pepper was 76 kg N/ha.

Data collection and analysis

The growth parameters of sweet pepper plants were recorded every two weeks, encompassing plant height, branch count and leaf count. Plant height was measured from the ground level to the highest leaf tip using a meter rule, while branch count and leaf count were obtained through visual assessment.

At the point of harvest, yield parameters, including fruit quantity and fresh fruit weight, were gathered. The number of fruits was ascertained via visual counting, and fresh fruit weight was measured using an electronic balance. The data underwent analysis employing analysis of variance (ANOVA) in STATISTIX 10 software, utilising the least significant difference to juxtapose the means. The findings were showcased through both tabulated data and graphical representations.

RESULTS

Effect of *A. zygia* leafy biomass and NPK (15:15:15) fertiliser on the growth of sweet pepper

Plant height (cm) from 2 to 12 WAT

This study investigated how different fertiliser treatments affected the growth of sweet pepper plants over a 12-week period from 2 to 12 WAT. Significant differences in height were observed across various treatments, with p-values falling within the range of 0.0000–0.0001.

At 2 WAT, there was a notable distinction among the treatment averages, with a significance level of $p \leq 0.05$. T4 exhibited the tallest plants, measuring 5.31 cm, followed by T2 at 4.74 cm and T3 at 4.31 cm, while the shortest plant height was observed in T1 at 2.94 cm. By 4 WAT, notable distinctions were evident among the treatments at a significance level of $p \leq 0.05$.

Specifically, T4 had the tallest plant height at 41.62 cm, differing from the other treatments (T1, 22.59 cm; T2, 27.66 cm; T3, 26.11 cm). A comparable trend persisted at 6 WAT. At 8 WAT, the means of the treatments were significantly different ($p \leq 0.05$). T4 had the highest growth in height (49.22 cm), followed by T2 (37.5 cm) and T3 (30.1 cm), while T1 had the lowest growth in height (25.11 cm). At 10 WAT, the tallest plants were found at T4 (62.22 cm), although their height was not significantly from those at T2 (51.05 cm). They were significantly different from plants in T3 (32.61 cm) and T1 (26.13 cm), with similar observations at 12 WAT (*Table 1*).

Mean height (cm)

Figure 2 illustrates how the various treatments impacted the growth in height of sweet pepper plants over the duration of the experiment. Each treatment exhibited a consistent and gradual increase in plant height throughout the experimental timeline. The tallest plants were registered in T4 (44.58 cm), followed by T2 (34.14 cm), T3 (25.86 cm) and T1 (21.31 cm). There was a significant difference in the treatment means with respect to the growth in height of the sweet pepper plants ($p = 0.0000$, $F = 10.80$, $LSD = 8.74$, $DF = 3$, $CV = 55$).

Number of leaves from 2 to 12 WAT

The changes in the number of leaves affected by treatment with *A. zygia* leafy biomass and NPK (15:15:15) from 2 to 12 WAT are shown in *Table 2*. There were significant differences between treatment means from 2 to 12 WAT, with p-values ranging from 0.0000 to 0.0167. By 2

WAT, a clear difference became evident among the treatment averages regarding the number of leaves, indicating statistical significance at $p \leq 0.05$. At 2 WAT, T4 had the most leaves (5.53), followed by T2 (4.18), T3 (3.39) and T1 (2.46). At 4 WAT, the most leaves were recorded in T4 (29.73), which was not significantly different from T2 (27.15); however, they displayed notable distinctions compared to the other treatments (T3, 22.32; T1, 12.8). At 6 WAT, there was no significant difference in the means of the applied treatments with regards to the number of leaves ($p > 0.05$). At 8 WAT, T4 had the highest leaf count (56.75), which was significantly different from T2 (49.78) and T3 (42.66), and the least leaves were recorded in T1 (26.39). At 10 WAT, noticeable distinctions existed among the treatments, showing statistical significance ($p \leq 0.05$), with T4 (62.22) having the most leaves, followed by T2 (53.17), T3 (47.91) and T1 (37.15). A similar pattern occurred at 12 WAT.

Mean number of leaves

Figure 3 illustrates the effect of various treatments on the quantity of sweet pepper leaves, with a trend in leaf count mirroring that of plant height.

Notably, there was a noteworthy distinction in leaf quantity among the treatments throughout the experimental phase ($p = 0.0032$, $F = 4.93$, $DF = 3$, $CV = 55$, $LSD = 10.24$).

Table 1 – Effect of *Albizia zygia* leafy biomass and NPK (15:15:15) fertiliser on the height (cm) of sweet pepper from 2 to 12 weeks after transplant (WAT)

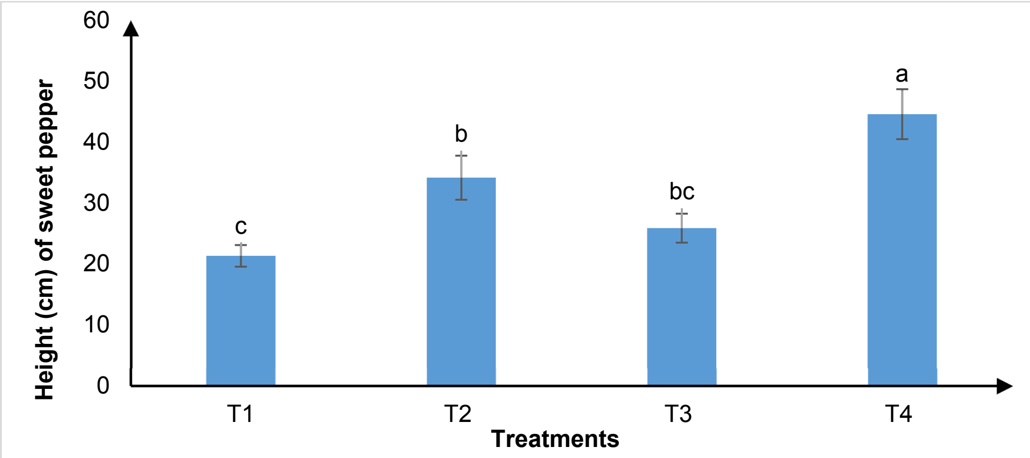
Treatment	2WAT (±SeM)	4 WAT (±SeM)	6 WAT (±SeM)	8 WAT (±SeM)	10 WAT (±SeM)	12 WAT (±SeM)
T1	$2.94{\pm}0.1^{d}$	$22.59{\pm}1.1^{c}$	$24.92{\pm}2.1^{c}$	$25.11{\pm}0.3^{c}$	$26.13{\pm}0.2^{b}$	$26.18{\pm}1.05^{b}$
T2	$4.74{\pm}0.0^{b}$	$27.66{\pm}1.3^{b}$	$27.66{\pm}1.3^{b}$	$27.66{\pm}1.3^{b}$	$27.66{\pm}1.3^{b}$	$51.70{\pm}3.83^{a}$
T3	$4.31{\pm}0.0^{c}$	$26.11{\pm}0.4^{b}$	$29.2{\pm}0.6^{b}$	$30.1{\pm}3.4b^{c}$	$32.61{\pm}4.2^{b}$	$32.76{\pm}5.83^{b}$
T4	$5.31{\pm}0.0^{a}$	$41.62{\pm}0.3^{a}$	$46.7{\pm}1.8^{a}$	$49.22{\pm}1.6^{a}$	$62.22{\pm}4.4^{a}$	$62.64{\pm}3.86^{a}$
P value	0.0000	0.0000	0.0001	0.0052	0.0001	0.0001
CV (%)	2.94	5.36	12.12	17.18	15.35	16.85
LSD (0.05)	0.23	2.79	7.04	12.06	11.61	16.85

Means in the column accompanied by the same letter(s) are not significantly different at $p \leq 0.05$ using the least significant difference (LSD) test. SeM = standard error of the mean, CV = coefficient of variation

Table 2 – Effect of *Albizia zygia* leafy biomass and NPK (15:15:15) fertilizer on the number of sweet pepper leaves from 2 to 12 weeks after transplant (WAT)

Treatment	2WAT (±SeM)	4WAT (±SeM)	6 WAT (±SeM)	8 WAT (±SeM)	10 WAT (±SeM)	12 WAT (±SeM)
T1	$2.46{\pm}0.42^{b}$	$12.8{\pm}0.99^{c}$	24.3±2.35	$26.39{\pm}1.58^{c}$	$37.15{\pm}0.95^{d}$	$37.73{\pm}0.72^{d}$
T2	$4.18{\pm}0.32^{ab}$	$27.15{\pm}0.95^{a}$	37.46±8.81	$49.78{\pm}4.1^{ab}$	$53.17{\pm}0.68^{b}$	$53.74{\pm}0.44^{b}$
T3	$3.39{\pm}0.77^{b}$	$22.32{\pm}0.92^{b}$	32.63±1.15	$42.66{\pm}1.14^{b}$	$47.91{\pm}1.86^{c}$	$48.51{\pm}1.28^{c}$
T4	$5.53{\pm}0.67^{a}$	$29.73{\pm}1.46^{a}$	42.78±1.12	$56.75{\pm}1.04^{a}$	$62.22{\pm}4.35^{a}$	$61.66{\pm}1.71^{a}$
P value	0.0167	0.0000	0.0828	0.0000	0.0000	0.0000
CV (%)	22.28	9.39	19.50	9.27	4.21	4.27
LSD (0.05)	1.77	3.40	14.35	7.13	3.53	3.54

Means in the column accompanied by the same letter(s) are not significantly different at $p \leq 0.05$ using the least significant difference (LSD) test. SeM = standard error of the mean, CV = coefficient of variation



T1= (No biomass, no NPK (Control); T2= (0.53482kg of Albizia zygia leafy biomass);
T3= (0.24627kg of NPK); T4= (0.26741kg of Albizia zygia leafy biomass + 0.12314kg of NPK)

Figure 2 – Effect of *Albizia zygia* leafy biomass and NPK (15:15:15) fertiliser on the height (cm) of sweet pepper. Different lowercase letters above the bars indicate significant differences between values, according to least significant difference ($p \leq 0.05$)

T4 had the highest leaf count (42.98), followed by T2 (37.58), T3 (32.84) and T1 (21.31).

Number of branches from 2 to 12 WAT

The effect of *A. zygia* leafy biomass and NPK (15:15:15) on the number of branches from 2 to 12 WAT is detailed in *Table 3*.

Weekly assessments, starting 2 WAT, revealed noteworthy variations among treatments.

Statistical analysis demonstrated substantial differences between treatments, with p-values ranging from 0.0000 to 0.0027, indicating statistical significance. At 2 WAT, T4 had the most branches, showing a significant difference ($p \leq 0.05$) compared to T2 and T3 (5.93 and 5.75, respectively).

Although T2 and T3 had similar branch counts ($p > 0.05$), both differed significantly ($p \leq 0.05$) from T1, which had the lowest branch count at 3.51.

Mean number of branches

Figure 4, displaying the quantity of sweet pepper branches at the experiment's conclusion, illustrates a pattern similar to that observed in plant height and leaf count.

Notably, there was a statistically significant difference among the treatments at the conclusion of the experiment ($p = 0.0026$, $F = 5.31$, $DF = 3$, $CV = 36.7$, $LSD = 2.18$). Specifically, T4 had the most branches (11.33), followed by T2 (9.41), T3 (9.23) and T1 (6.98).

Effect of *A. zygia* leafy biomass and NPK (15:15:15) fertiliser on the yield of sweet pepper

Fruit yield/ha

Figure 5 depicts the effect of varying levels of *A. zygia* leafy biomass and NPK (15:15:15) application on the yield of sweet pepper per hectare at the time of harvest.

The statistical analysis revealed a noteworthy distinction between treatments, as indicated by a highly significant p value (p = 0.0000, F = 94.8, DF = 3, LSD = 9379.2, CV = 9.2).

An examination of sweet pepper fruit yield throughout the experimental phase revealed that the T4 fertiliser application regimen exhibited the highest fruit yield per hectare of 87,963 fruits/ha, followed by T2 (66,523 fruits/ha), T3 (52,716 fruits/ha) and T1 (17,383 fruits/ha).

Fresh fruit weight (tonnes/ha)

The effect of varied fertiliser application methods on the fresh fruit weight at harvest is depicted in *Figure 6*. The analysis revealed a notable distinction among the treatment averages (p = 0.0000, F = 224, DF = 3, LSD = 1.47, CV = 5). The highest fresh fruit weight was observed in T4 (23.91 tonnes/ha), followed by T2 (19.11 tonnes/ha) and T3 (11.40 tonnes/ha). The lowest fresh fruit weight was observed in T1, with 8.25 tonnes/ha.

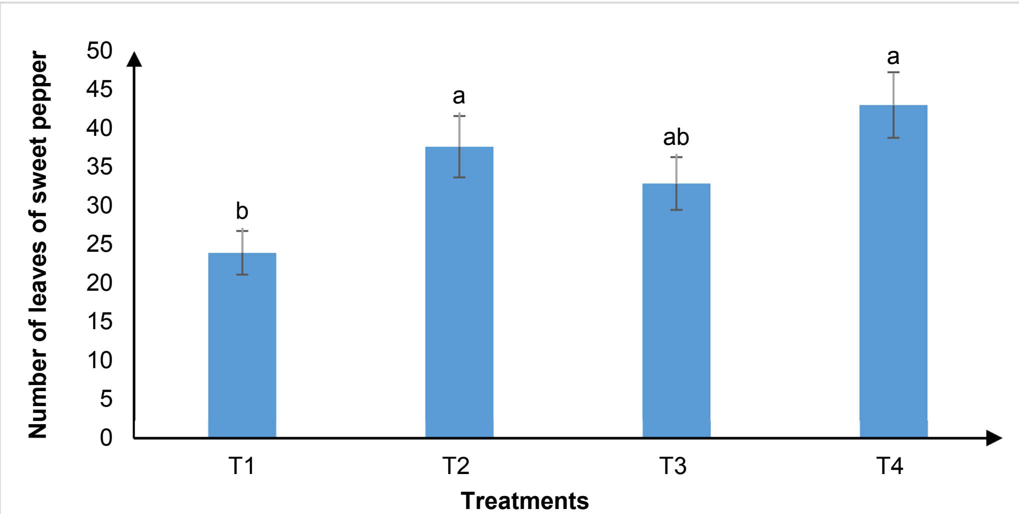


Figure 3 – Effect of *Albizia zygia* and NPK (15:15:15) fertiliser on the number of sweet pepper leaves. Different lowercase letters above the bars indicate significant differences between values, according to least significant difference (p ≤0.05)

Table 3 – Effect of *Albizia zygia* leafy biomass and NPK (15:15:15) fertilizer on the number of sweet pepper branches from 2 to 8 weeks after transplant (WAT)

Treatments	2 WAT (±SeM)	4 WAT (±SeM)	6 WAT (±SeM)	8 WAT (±SeM)
T1	3.51±0.27c	5.30±0.11^c	7.80±0.34^c	11.30±0.11^c
T2	5.93±0.59^b	7.73±0.34^b	10.23±0.10^b	13.73±0.04^b
T3	5.75±0.82^b	7.55±0.26^b	10.05±0.14^b	13.55±0.24^b
T4	7.85±0.63^a	9.65±0.25^a	12.15±0.25^a	15.65±0.13^a
P value	0.0027	0.0000	0.0000	0.0000
CV (%)	20.14	6.35	3.77	1.92
LSD (0.05)	1.88	0.78	0.65	0.46

Means in the column accompanied by the same letter(s) are not significantly different (p ≤ 0.05) using the least significant difference (LSD) test. SeM = standard error of the mean, CV = coefficient of variation

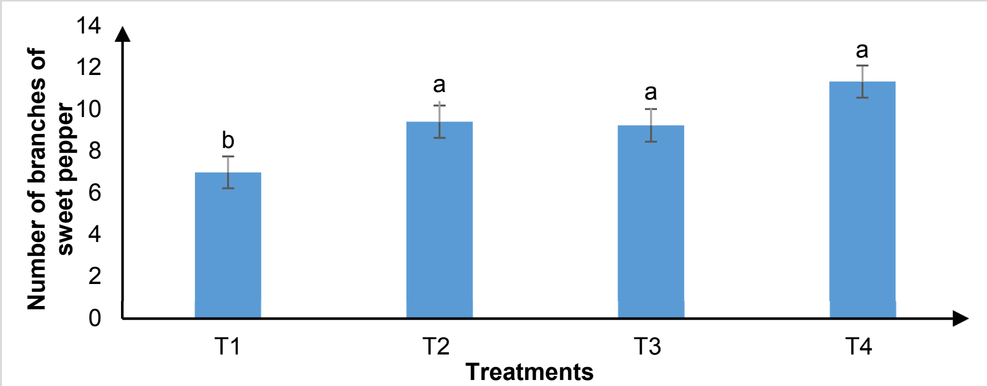


Figure 4 – Effect of *Albizia zygia* and NPK (15:15:15) fertiliser on the number of sweet pepper branches. Different lowercase letters above the bars indicate significant differences between values, according to least significant difference (p ≤0.05).

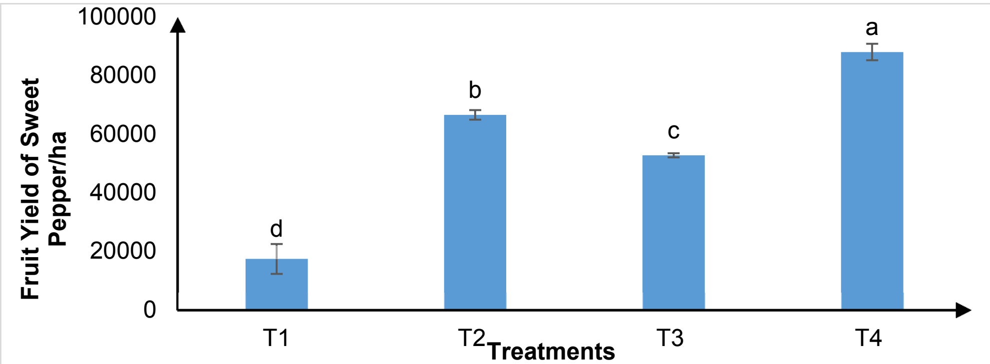


Figure 5 – Effect of *Albizia zygia* leafy biomass and NPK (15:15:15) fertiliser on the fruit yield/ha of sweet pepper. Different lowercase letters above the bars indicate significant differences between values, according to least significant difference (p ≤0.05)

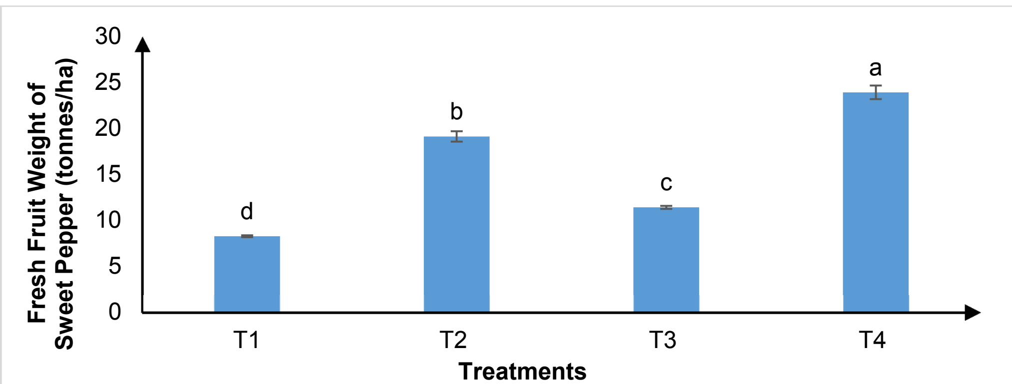


Figure 6 – Effect of *Albizia zygia* leafy biomass and NPK (15:15:15) fertiliser on the fresh fruit weight (tonnes/ha) of sweet pepper. Different lowercase letters above the bars indicate significant differences between values, according to least significant difference (p ≤0.05)

DISCUSSION

Effect of *A. zygia* leafy biomass and NPK fertiliser on sweet pepper vegetative growth

The tallest sweet pepper plants and highest leaf and branch counts were registered in T4 (0.2674 kg of *A. zygia* leafy biomass + 0.1231 kg of NPK), followed by T2 (0.5348 kg of A. zygia leafy biomass), T3 (0.2463 kg of NPK) and the control group (T1 = No biomass, no NPK). Many factors related to nutrient availability, soil enrichment and plant growth dynamics might be accountable for this (*Figures 2-4*). T4, which was provided with a mixture of *A. zygia* leafy biomass and NPK fertiliser, had the tallest plants with the highest leaf and branch counts. This could be attributed to the synergistic effect of organic biomass and synthetic fertiliser, which might have provided an optimal balance of essential nutrients, including nitrogen, phosphorus and potassium, fostering robust plant growth (Ghimire *et al.*, 2023; Singh *et al.*, 2023).

The combination of organic and inorganic nutrients in T4 possibly provided a more balanced and diverse nutrient profile for the plants, supporting their optimal growth compared to treatments with single nutrient sources (Ariyanti *et al.*, 2019; Thakur *et al.*, 2023). T2, solely supplemented with *A. zygia* leafy biomass, showed relatively tall plants and high leaf and branch counts. This is an indication that the organic nutrients from *A. zygia* leafy biomass contributed significantly to plant height and high leaf and branch growth, showcasing the efficacy of organic matter in promoting morphological plant growth (Elsherbiny *et al.*, 2020; Rouphael and Colla, 2020; Usman *et al.*, 2020). Additionally, *A. zygia* leafy biomass provides organic matter rich in nitrogen, phosphorus, potassium and other micronutrients upon decomposition (Farooq *et al.*, 2023; Singh *et al.*, 2023).

This organic input might have enhanced soil fertility, fostering a conducive environment for increased leaf and branch development in sweet pepper plants (Alamu *et al.*, 2023; Sileshi *et al.*, 2020).

The presence of these nutrients, particularly nitrogen, might have stimulated vegetative growth, resulting in a higher branch count in T2 (Jia *et al.*, 2019; Omari *et al.*, 2023).

Albizia zygia leafy biomass might have facilitated a slow-release mechanism of nutrients, providing a sustained supply of organic compounds and minerals beneficial for leaf growth, which could explain the relatively higher leaf and branch counts in treatments involving this biomass (Chaudhary *et al.*, 2020; Younis *et al.*, 2022). T3, receiving only NPK fertiliser, resulted in taller plants and higher leaf and branch counts than the control group (T1) but lower than those in T2 and T4.

This implies that, while synthetic fertiliser alone supported growth, the absence of organic biomass might have limited the plant's access to a broader range of nutrients and organic compounds necessary for optimal growth (Creegan *et al.*, 2023; Marañón-Jiménez *et al.*, 2022). The addition of organic biomass (T2 and T4) might have improved soil structure, increased microbial activity and enhanced nutrient availability through decomposition processes (Das *et al.*, 2022; Sileshi *et al.*, 2020). This enhanced soil fertility likely facilitated better nutrient uptake and overall plant growth compared to the control and NPK-only treatments (Kebede, 2021; Murugaragavan *et al.*, 2022). T1 served as the control group, devoid of both *A. zygia* leafy biomass and NPK fertiliser.The absence of these organic and inorganic nutrients might have limited the availability of essential nutrients crucial for robust plant growth (Briat *et al.*, 2020; Etesami and Adl, 2020). Consequently, the plants in T1 lacked the supplementary nutrients required for optimal branch development, leading to shorter plants with lower leaf and branch counts compared to the other treatment groups. These findings highlight the significance of organic and inorganic nutrient sources, the importance of nutrient balance and the potential synergy between different fertilisation methods (Sharma *et al.*, 2023).

Effect of *A. zygia* leafy biomass and NPK fertiliser on sweet pepper yield

T4 (0.2674 kg of *A. zygia* leafy biomass + 0.1231 kg of NPK) resulted in the highest fruit yield per hectare and fresh fruit weight, followed by T2 (0.5348 kg of *A. zygia* leafy biomass) and T3 (0.2463 kg of NPK), while T1 (Control: No biomass, no NPK) showed the lowest fruit yield/ha and fresh fruit weight (*Figure 4* and *Figure 5*). This could be attributed to several factors related to nutrient availability, soil fertility and plant growth. The combination of *A. zygia* leafy biomass and NPK fertiliser (T4) likely provided a balanced nutrient supply, incorporating organic matter from the biomass along with the essential nutrients from the fertiliser. This synergy might have supported optimal plant growth, enhanced soil fertility and improved nutrient uptake by the sweet pepper plants, resulting in higher yields. The findings of this study agree with Mohammed *et al.* (2023), who indicated that the combination of *Gliricidia sepium* leafy biomass and NPK fertiliser significantly increased the fruit yield and fresh fruit weight of tomato plants compared to their applications alone and the control. T2, consisting solely of *A. zygia* leafy biomass, demonstrated a positive effect on fruit yield. The organic matter from the biomass likely contributed to soil structure improvement, increased microbial activity and the slow release of nutrients, fostering favourable conditions for plant growth and yield enhancement (Farooqi *et al.*, 2023; Manikandan *et al.*, 2023; Skrzypczak *et al.*, 2023; Zhao *et al.*, 2023). T3, comprising only NPK fertiliser, exhibited moderate results compared to T2 and T4. While the application of NPK supplies vital macronutrients, using it alone may result in nutrient imbalances or swift nutrient leaching, potentially detrimentally affecting plant growth and yield, in contrast to utilising a combination of organic and inorganic inputs (Akbar *et al.*, 2023; Ayamba *et al.*, 2023; Sarwar *et al.*, 2021). T1 (control), lacking both biomass and NPK input, resulted in the lowest fruit yield. The absence of any external nutrient supply likely limited the availability of essential nutrients in the soil, leading to compromised plant growth and reduced yield potential. Mohammed *et al.* (2022, 2023) showed comparable findings. Their research indicated that the absence of any fertiliser in the control plots led to reduced tomato and okra plant yields, with diminished fruit weights observed in both cases.

CONCLUSIONS

The findings of this study underscore the significant impact of *A. zygia* leafy biomass and NPK (15:15:15) fertiliser on the growth and yield of sweet pepper. The results clearly demonstrate that the combined application of *A. zygia* leafy biomass and NPK fertiliser (T4: 0.2674 kg of *A. zygia* leafy biomass + 0.1231 kg of NPK) resulted in significantly higher growth and yield of sweet pepper compared to the remaining treatments. Subsequently, the application of *A. zygia* leafy biomass alone (T2: 0.5348 kg) showed a considerable improvement in the growth and yield of sweet pepper compared to the use of NPK fertiliser alone (T3: 0.2463 kg of NPK), which registered lower growth and yield. The control group (T1: no biomass, no NPK) exhibited the lowest growth and yield of sweet pepper plants among all treatments. Based on the study's outcomes, it is recommended that agricultural practices by farmers with poor resources include a combination of *A. zygia* leafy biomass and NPK fertiliser for sweet pepper cultivation to optimise growth and yield. The superior performance of the combined application (T4) suggests its potential as an effective approach for enhancing sweet pepper production in the tropics. Moreover, research exploring the extended impacts of these organic and inorganic additives on soil vitality, sustainability and economic feasibility would offer significant knowledge for farmers seeking improved crop yields through sustainable practices.

Author Contributions: Conceptualization, methodology, analysis, data curation, writing, review: ALM. The author declares that he has read and approved the publication of the manuscript in this present form.

Funding: There was no external funding for this study.

Acknowledgments: An extended to my family, friends for their moral and financial support.

Conflicts of Interest: There was no conflict of interest.

REFERENCES

Abebe, T.G.; Tamtam, M.R.; Abebe, A.A.; Abtemariam, K.A.; Shigut, T.G.; Dejen, Y.A.; Haile, E.G. Growing use and impacts of chemical fertilizers and assessing alternative organic fertilizer sources in Ethiopia. *Applied and Environmental Soil Science*. **2022**, 1-14. https://doi.org/10.1155/2022/4738416

Adelani, D.O. Improving Growth of *Chrysophyllum albidum* G. Don Seedlings Using Leaf Litters of Selected Nitrogen-Fixing *Albizia* Trees. *Journal of the Cameroon Academy of Sciences*. **2023**, 18, 607-622. https://doi.org/10.4314/jcas.v18i3.4

Akbar, W.A.; Rahim, H.U.; Irfan, M.; Alatalo, J.M.; Mudasssir, M.; Bundschuh, J. Effects of incorporating pine-woodchip biochar with reduced NP fertilizer on calcareous soil characteristics, organic carbon, NPK availability, and maize productivity. *Journal of Soils and Sediments*. **2023**, 1-12.

Ahmadi, M.; Souri, M.K. Nutrient uptake, proline content and antioxidant enzymes activity of pepper (*Capsicum annuum* L.) under higher electrical conductivity of nutrient solution created by nitrate or chloride salts of potassium and calcium. *Acta Scientiarum Polonorum Hortorum Cultus*. **2019***,* 18, 113-122. https://doi.org/10.24326/asphc.2019.5.11

Alamu, E.O.; Joyce, N.; Juliet, A.; Joel, N.; Chazangwe, R.; Tesfai, M.; Udaya Sekhar, N. Assessing the impact of Gliricidia agroforestry-based interventions on crop nutritional, antinutritional, functional, and mineral compositions in eastern Province, Zambia. *Agroecology and Sustainable Food Systems*. **2023**, 47, 1440-1460. https://doi.org/10.1080/21683565.2023.2254711

Aloo, B.N.; Mbega, E.R.; Tumuhairwe, J.B.; Makumba, B.A. Advancement and practical applications of rhizobacterial biofertilizers for sustainable crop production in sub-Saharan Africa. *Agriculture & Food Security*. **2021**, 10, 1-12.

Ameta, S.K.; Ameta, S.C. Eco-friendly approaches of using weeds for sustainable plant growth and production. In *Plant Performance Under Environmental Stress: Hormones, Biostimulants and Sustainable Plant Growth Management.* Husen A, Springer, Cham, Switzerland. 2021, 559-592.

Ariyanti, M.; Dewi, I.R.; Natali, G. Utilization of organic fertilizer made out of oil palm midbrid in oil palm nursery. *International Journal on Advance Science Engineering Information Technology*. **2019**, 9, 1324-1329.

Ayamba, B.E.; Abaidoo, R.C.; Opoku, A.; Ewusi-Mensah, N. Mechanisms for nutrient interactions from organic amendments and mineral fertilizer inputs under cropping systems: a review. *PeerJ.* 2023, 11. https://doi.org/10.7717/peerj.15135

Bhatt, M.K.; Labanya, R.; Joshi, H.C. Influence of long-term chemical fertilizers and organic manures on soil fertility-A review. *Universal Journal of Agricultural Research*. **2019**, 7, 177-188. https://doi.org/10.13189/ujar.2019.070502

Brezeanu, C.; Brezeanu, P.M.; Stoleru, V.; Irimia, L.M.; Lipşa, F.D.; Teliban, G.C.; Murariu, O.C. Nutritional value of new sweet pepper genotypes grown in organic system. *Agriculture*. **2022**, 12, 1863. https://doi.org/10.3390/agriculture12111863

Briat, J.F.; Gojon, A.; Plassard, C.; Rouached, H.; Lemaire, G. Reappraisal of the central role of soil nutrient availability in nutrient management in light of recent advances in plant nutrition at crop and molecular levels. *European Journal of Agronomy*. **2020**, 116. https://doi.org/10.1016/j.eja.2020.126069

Chaudhary, I.J.; Neeraj, A.; Siddiqui, M.A.; Singh, V. Nutrient management technologies and the role of organic matrix-based slow-release biofertilizers for agricultural sustainability: A review. *Agricultural Reviews*. 2020, 41, 1-13. http://dx.doi.org/10.18805/ag.R-1958

Creegan, E.F.; Flynn, R.; Brewer, C.E.; Heerema, R.J.; Darapuneni, M.; Velasco-Cruz, C. Pecan Biomass and Dairy Manure Utilization: Compost Treatment and Soil In-Situ Comparisons of Selected Pecan Crop and Soil Variables. *Processes*. **2023**, 11, 2046. https://doi.org/10.3390/pr11072046

Das, S.K.; Ghosh, G.K.; Avasthe, R. Valorizing biomass to engineered biochar and its impact on soil, plant, water, and microbial dynamics: a review. *Biomass conversion and biorefinery*. **2022**, 12, 4183-4199.

https://doi.org/10.1007/s13399-020-00836-5

Elsherbiny, E.A.; Amin, B.H.; Aleem, B.; Kingsley, K.L.; Bennett, J.W. Trichoderma volatile organic compounds as a biofumigation tool against late blight pathogen Phytophthora infestans in postharvest potato tubers. *Journal of agricultural and food chemistry*. **2020**, 68, 8163-8171. https://doi.org/10.1021/acs.jafc.0c03150

Etesami, H.; Adl, S.M. Plant growth-promoting rhizobacteria (PGPR) and their action mechanisms in availability of nutrients to plants, In *Phyto-Microbiome in stress regulation.* Springer, Singapore, 2020, 147-203. https://doi.org/10.1007/978-981-15-2576-6_9

Farooq, T.H.; Nawaz, M.F.; Qasid, M.; Shakoor, A.; Ahmad, I.; Gul, S.; Chen, X. Divergent consequences of bio-resources on morphological plasticity and biochemical responses in early-stage leguminous species: Sustainable productivity approaches. *Geoscience Frontiers*. **2023**. https://doi.org/10.1016/j.gsf.2023.101660

Farooqi, Z.U.R.; Qadir, A.A.; Alserae, H.; Raza, A.; Mohy-Ud-Din, W. Organic amendment-mediated reclamation and build-up of soil microbial diversity in salt-affected soils: fostering soil biota for shaping rhizosphere to enhance soil health and crop productivity. *Environmental Science and Pollution Research*. **2023**, 1-32.

Fasusi, O.A.; Cruz, C.; Babalola, O.O. Agricultural sustainability: microbial biofertilizers in rhizosphere management. *Agriculture*. **2021**, 11, 163. https://doi.org/10.3390/agriculture11020163

Firmanda, A.; Fahma, F.; Syamsu, K.; Suryanegara, L.; Wood, K. Controlled/slow-release fertilizer based on cellulose composite and its impact on sustainable agriculture: review. *Biofuels, Bioproducts and Biorefining.* **2022**, 16, 1909-1930. https://doi.org/10.1002/bbb.2433

Gao, C.; El-Sawah, A.M.; Ali, D.F.I.; Alhaj Hamoud, Y.; Shaghaleh, H.; Sheteiwy, M.S. The integration of bio and organic fertilizers improve plant growth, grain yield, quality and metabolism of hybrid maize (*Zea mays* L.). *Agronomy.* **2020**, 10, 319. https://doi.org/10.3390/agronomy10030319

Ghimire, S.; Chhetri, B.P.; Shrestha, J. Efficacy of different organic and inorganic nutrient sources on the growth and yield of bitter gourd (*Momordica charantia* L.), *Heliyon.* **2023**, 9. https://doi.org/10.1016/j.heliyon.2023.e22135

Guevara, L.; Domínguez-Anaya, M.Á.; Ortigosa, A.; González-Gordo, S.; Díaz, C.; Vicente, F.; Corpas, F.J.; Pérez del Palacio, J.; Palma, J.M. Identification of compounds with potential therapeutic uses from sweet pepper (*Capsicum annuum* L.) fruits and their modulation by nitric oxide (NO). *International Journal of Molecular Sciences*. **2021**, 22, 4476. https://doi.org/10.3390/ijms22094476

Jaiswal, V.; Gahlaut, V.; Kumar, N.; Ramchiary, N. Genetics, genomics and breeding of chili pepper *Capsicum frutescens* L. and other *Capsicum* species, In *Advances in Plant Breeding Strategies: Vegetable Crops,* Springer Cham, Switzerland, 2021, 59-86.

Jia, Y.; Wang, J.; Qu, Z.; Zou, D.; Sha, H.; Liu, H.; Zhao, H. Effects of low water temperature during reproductive growth on photosynthetic production and nitrogen accumulation in rice. *Field Crops Research*. **2019**, 242.

https://doi.org/10.1016/j.fcr.2019.107587

Kaur, R.; Kaur, K.; Wagh, R.V.; Kaur, A.; Aggarwal, P. Red bell pepper (*Capsicum annuum* L.): Optimization of drying conditions and preparation of functional bread. *Journal of Food Science*. **2020**, 85, 2340-2349. https://doi.org/10.1111/1750-3841.15317

Kebede, E. Contribution, utilization, and improvement of legumes-driven biological nitrogen fixation in agricultural systems. *Frontiers in Sustainable Food Systems*. **2021**, 5. https://doi.org/10.3389/fsufs.2021.767998

Kodzwa, J.J.; Madamombe, G.; Masvaya, E.N.; Nyamangara, J. Optimization of African indigenous vegetables production in sub Saharan Africa: a review. *CABI Agriculture and Bioscience*. **2023**, 4, 44. https://doi.org/10.1186/s43170-023-00184-0

Kugedera, A.T.; Nyamadzawo, G.; Mandumbu, R.; Nyamangara, J. Potential of field edge rainwater harvesting, biomass transfer and integrated nutrient management in improving sorghum productivity in semi-arid regions: a review. *Agroforestry Systems*. **2022**, 96, 909-924. https://doi.org/10.1007/s10457-022-00751-w

Mamphogoro, T.P.; Babalola, O.O.; Aiyegoro, O.A. Sustainable management strategies for bacterial wilt of sweet peppers (*Capsicum annuum*) and other *Solanaceous* crops. *Journal of Applied Microbiology*. **2020**, 129, 496-508. https://doi.org/10.1111/jam.14653

Manikandan, S.; Vickram, S.; Subbaiya, R.; Karmegam, N.; Chang, S.W.; Ravindran, B.; Awasthi, M.K. Comprehensive review on recent production trends and applications of biochar for greener environment. *Bioresource Technology*. **2023**, 388. https://doi.org/10.1016/j.biortech.2023.129725

Marañón-Jiménez, S.; Serrano-Ortíz, P.; Peñuelas, J.; Meijide, A.; Chamizo, S.; López-Ballesteros, A.; Fernández-Ondoño, E. Effects of herbaceous covers and mineral fertilizers on the nutrient stocks and fluxes in a Mediterranean olive grove. *European Journal of Agronomy*. **2022**, 140, https://doi.org/10.1016/j.eja.2022.126597

Mardanluo, S.; Souri, M.K.; Ahmadi, M. Plant growth and fruit quality of two pepper cultivars under different potassium levels of nutrient solutions. *Journal of plant nutrition*. **2018**, 41, 1604-1614. https://doi.org/10.1080/01904167.2018.1463383

Mitra, B.; Chowdhury, A.R.; Dey, P.; Hazra, K.K.; Sinha, A.K.; Hossain, A.; Meena, R.S. Use of agrochemicals in agriculture: alarming issues and solutions. In *Input use efficiency for food and environmental security*, 1 Edition. Springer, Singapore, **2021**, 85-122. https://doi.org/10.1007/978-981-16-5199-1_4

Mohammed, A.L.; Nartey, E.K.; Addai, F.; Arthur, S.; Bawah, E. Effect of *Gliricidia sepium* Leafy Biomass and NPK Fertiliser on the Growth and Yield of Tomato, *Solanum lycopersicum* (L.). *Journal of Applied Life Sciences and Environment*. **2023**, 56, 273-288. https://doi.org/10.46909/alse-562100

Mohammed, A.L.; Nasim, K.N.K.; Moro, A. Effect of *Leucaena Leucocephala* Leafy Biomass and NPK Fertiliser on the Growth and Yield of Okra, *Abelmoschus Esculentus* (L.) Moench. *Journal of Applied Life Sciences and Environment*. **2022**, 55, 419-439. https://doi.org/10.46909/alse-554074

Murugaragavan, R.; Rangasami, S.S.; Arulkumar, V.; Venkatakrishnan, D.

Eco-friendly organic resources utilization for enhancing soil fertility and crop productivity: A review. *Pharma Innovation.* **2022**, 11, 2382-2388.

Nkyi, K.A.; Acheampong, M. Decomposition rate and chemical composition of leafy mulch of some tree species in Ghana. *Ghana Journal on Forestry.* **2013**, 29, 45-59.

Nordey, T.; Schwarz, D.; Kenyon, L.; Manickam, R.; Huat, J. Tapping the potential of grafting to improve the performance of vegetable cropping systems in sub-Saharan Africa. A review. *Agronomy for Sustainable Development.* **2020**, 40, 23. https://doi.org/10.1007/s13593-020-00628-1

Ogunniyi, Q.A.; Ogbole, O.O.; Akin-Ajani, O.D.; Ajala, T.O.; Bamidele, O.; Fettke, J.; Odeku, O.A. Medicinal Importance and Phytoconstituents of Underutilized Legumes from the Caesalpinioideae DC Subfamily. *Applied Sciences.* **2023**, 13. https://doi.org/10.3390/app13158972

Olędzki, R.; Harasym, J. Boiling vs. microwave heating - The impact on physicochemical characteristics of bell pepper (*Capsicum annuum* L.) at different ripening stages. *Applied Sciences*. **2023**, 13. https://doi.org/10.3390/app13148175

Olupot, W. The potential of natural succession to restore degraded areas of a Ugandan rainforest dominated by the exotic paper mulberry *Broussonetia papyrifera* (L.) L'Hér. ex Vent. *Forest Ecology and Management*. **2022**, 504. https://doi.org/10.1016/j.foreco.2021.119861

Omari, S.; Tamim, A.T.; Saeedi, M.; Qadiri, A.S.; Akrami, M.J. Studies on the effect of Plant spacing and Different Doses Nitrogen on Growth and Yield of Chilli (*Capsicum annum* L.) under the Open Field Conditions in Kabul, Afghanistan. *Journal for Research in Applied Sciences and Biotechnology.* **2023**, 2, 1-9. https://doi.org/10.55544/jrasb.2.6.1

Patle, P.N.; Kadu, P.R.; Gabhane, A.R.; Pharande, A.L.; Bhagat, A.P.; Bhoyar, S.M.; Rahangdale, M.K. Consequences provoked due to excess application of agrochemical on soil health deterioration–A review for Sustainable Agriculture. *Journal of Pharmacognosy and Phytochemistry.* **2019**, 8, 63-66.

Rani, K.; Sharma, P.; Kumar, S.; Wati, L.; Kumar, R.; Gurjar, D.S.; Kumar, D.; Kumar, R. Legumes for sustainable soil and crop management. *Sustainable management of soil and environment.* Springer, Singapore. **2019**, 193-215. https://doi.org/10.1007/978-981-13-8832-3_6

Rao, D.L.N.; Dey, P.; Reddy, K.S. Plant Demand Adapted Fertilization in Organic and Precision Farming, In *Soil and Recycling Management in the Anthropocene Era*, first edition. Springer Cham, Singapore, 2021, 137-166.

Rebouh, N.Y.; Khugaev, C.V.; Utkina, A.O.; Isaev, K.V.; Mohamed, E.S.; Kucher, D.E. Contribution of Eco-Friendly Agricultural Practices in Improving and Stabilizing Wheat Crop Yield: A Review. *Agronomy.* **2023**, 13. https://doi.org/10.3390/agronomy13092400

Rhioui, W.; Al Figuigui, J.; Lahlali, R.; Laasli, S.E.; Boutagayout, A.; El Jarroudi, M.; Belmalha, S. Towards Sustainable Vegetable Farming: Exploring Agroecological Alternatives to Chemical Products in the Fez-Meknes Region of Morocco. *Sustainability.* **2023**, 15. https://doi.org/10.3390/su15097412

Rouphael, Y.; Colla, G. Biostimulants in agriculture. *Frontiers in plant science.* **2020**, 11, 40.

https://doi.org/10.3389/fpls.2020.00040

Roy, S.;Bhowmik, S.;Chowdhury, A.D.; Dhara, B.; Mitra, A.K. Plant growth-promoting rhizobacteria: an alternative for NPK fertilizers. In *Microbes and Microbial Biotechnology for Green Remediation*. Elsevier, 2022, pp. 149-167.

Sarwar, N.; Farooq, O.; Wasaya, A.; Hussain, M.; El-Shehawi, A.M.; Ahmad, S.; Farooq, S. Integrated nitrogen management improves productivity and economic returns of wheat-maize cropping system. *Journal of King Saud University-Science*. **2021**, 33, 101475. https://doi.org/10.1016/j.jksus.2021.101475

Senya, E.K.; Nartey, J.E.A.; Arthur, F.O. The Preparation of Canned Pepper Puree for Culinary Purposes. *ADRRI Journal of Agriculture and Food Sciences*. **2023**, 7 1-11. https://journals.adrri.org/index.php/adrrijafs/article/view/1045

Sharma, N.; Shukla, Y.R.; Singh, K.; Mehta, D.K. Soil fertility, nutrient uptake and yield of bell pepper as influenced by conjoint application of organic and inorganic fertilizers. *Communications in Soil Science and Plant Analysis*. **2020**, 51, 1626-1640. https://doi.org/10.1080/00103624.2020.1791155

Sharma, V.; Bhardwaj, D.R.; Kumar, D.; Sharma, P.; Verma, S.C.; Bishist, R. Defoliator attack (*Diorhabda lusca* maulik) on Kharik (*Celtis australis* L.): effect on nutritive value, phenology and biomass productivity. *Agroforestry Systems*. **2023**, 1-16. https://doi.org/10.1007/s10457-023-00929-w

Sileshi, G.W.; Mafongoya, P.L.; Nath, A.J. Agroforestry systems for improving nutrient recycling and soil fertility on degraded lands. In *Agroforestry for Degraded Landscapes: Recent Advances and Emerging Challenges-Vol. 1*, first edition. Springer, Singapore, 2020, 225-254.

Singh, A.K.; Goswami, T.; Majumdar, B.; Kar, G. Mitigation of CO2 Emissions in Agro-Ecosystems by Composting of Tree Leaf Litter with Effective Microorganisms and Green Sunnhemp Plants. *Communications in Soil Science and Plant Analysis*. **2023**, 1-14. https://doi.org/10.1080/00103624.2023.2269187

Singh, H.; Sharma, A.; Bhardwaj, S.K.; Arya, S.K.; Bhardwaj, N.; Khatri, M. Recent advances in the applications of nano-agrochemicals for sustainable agricultural development. *Environmental Science: Processes & Impacts*. **2021**, 23, 213-239. https://doi.org/10.1039/D0EM00404A

Skrzypczak, D.; Izydorczyk, G.; Taf, R.; Moustakas, K.; Chojnacka, K. Cellulose-based fertilizers for sustainable agriculture: Effective methods for increasing crop yield and soil health. *Industrial Crops and Products*. **2023**, 205. https://doi.org/10.1016/j.indcrop.2023.117500

Srivastav, A.L. Chemical fertilizers and pesticides: role in groundwater contamination. In *Agrochemicals detection, treatment and remediation* Butterworth-Heinemann. 2020, 143-159. https://doi.org/10.1016/B978-0-08-103017-2.00006-4

Thakur, S.; Sharma, A.K.; Thakur, K.; Sharma, S.; Gudeta, K.; Hashem, A.; Abd_Allah, E.F. Differential responses to integrated nutrient management of cabbage–capsicum–radish cropping sequence with fertilizers and plant-growth-promoting rhizobacteria. *Agronomy*. **2023**, 13, 1789. https://doi.org/10.3390/agronomy13071789

Uarrota, V.G.; Maraschin, M.; de Bairros, A.D.F.M.; Pedreschi, R. Factors affecting the capsaicinoid profile of hot peppers and biological activity of their non-pungent analogs (Capsinoids) present in sweet peppers. *Critical Reviews in Food Science and Nutrition*. **2021**, 61, 649-665. https://doi.org/10.1080/10408398.2020.1743642

Umair, M.; Zafar, S.H.; Cheema, M.; Usman, M. New insights into the environmental application of hybrid nanoparticles in metal contaminated agroecosystem: A review. *Journal of Environmental Management*. **2024**, 349, 119553. https://doi.org/10.1016/j.jenvman.2023.119553

Usman, M.; Farooq, M.; Wakeel, A.; Nawaz, A.; Cheema, S.A.; ur Rehman, H.; Sanaullah, M. Nanotechnology in agriculture: Current status, challenges and future opportunities. *Science of the Total Environment*. **2020**, 721, 137778. https://doi.org/10.1016/j.scitotenv.2020.137778

Vasco, C.; Torres, B.; Jácome, E.; Torres, A.; Eche, D.; Velasco, C. Use of chemical fertilizers and pesticides in frontier areas: A case study in the Northern Ecuadorian Amazon. *Land Use Policy*. **2021**, 107. https://doi.org/10.1016/j.landusepol.2021.105490

Verma, B.C.; Pramanik, P.; Bhaduri, D. Organic fertilizers for sustainable soil and environmental management. *Nutrient dynamics for sustainable crop production*. **2020**, 289-313.

Xie, H.; Huang, Y.; Chen, Q.; Zhang, Y.; Wu, Q. Prospects for agricultural sustainable intensification: A review of research. *Land*. **2019**, 8, 157. https://doi.org/10.3390/land8110157

Younis, A.; Ahsan, M.; Akram, A.; Lim, K.B.; Zulfiqar, F.; Tariq, U. Use of Organic Substrates in Sustainable Horticulture. *Biostimulants for crop production and sustainable agriculture/ Mirza Hasanuzzaman*. **2022**, 122. https://doi.org/10.1079/9781789248098.0009

Zhao, Y.; Hu, Z.; Lu, Y.; Shan, S.; Zhuang, H.; Gong, C.; Li, P. Facilitating mitigation of agricultural non-point source pollution and improving soil nutrient conditions: The role of low temperature co-pyrolysis biochar in nitrogen and phosphorus distribution. *Bioresource Technology*. **2023**, 130179. https://doi.org/10.1016/j.biortech.2023.130179

Zin, N.A.; Badaluddin, N.A. Biological functions of Trichoderma spp. for agriculture applications. *Annals of Agricultural Sciences*. **2020**, 65, 168-178. https://doi.org/10.1016/j.aoas.2020.09.003

Academic Editor: Dr. Isabela Maria Simion