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Effect of abootre (*Senna siamea)* leafy biomass and NPK (15:15:15) fertilizer on the growth and yield of hot pepper, *Capsicum frutescens* (L.)

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Abstract

Farmers in Sub-Saharan Africa are often deterred from using fertilizers on their crops due to the high cost of inorganic fertilizers and the environmental strain associated with intensive agriculture, which relies heavily on inputs. However, a comprehensive understanding of how the integration of organic biomass, such as *Senna siamea* leafy biomass, and conventional fertilizers like NPK (15:15:15) impacts the growth and yield of specific crops like hot pepper is lacking. A field experiment was carried out at the Faculty of Renewable Natural Resources Demonstration Farm, KNUST-Kumasi, Ghana in 2023 to assess the effect of *S. siamea* leafy biomass and NPK (15:15:15) inorganic fertilizer on the growth and yield of hot pepper (*Capsicum frutescens* L.) in a randomized complete block design. Four treatments were used and allocated as T1 (Control), T2 (0.096kg of NPK), T3 (0.32063kg of *S. siamea* leafy biomass) and T4 (0.1532kg of *S. siamea* leafy biomass + 0.048kg of NPK). The treatments were replicated four times. The parameters investigated were; height, number of leaves, fruit yield and fruit dry weight. Treatments showed significant difference between them in the parameters investigated on, $p \leq 0.05$. The combined application of *S. siamea* leafy biomass and NPK (15:15:15) fertilizer significantly increased the growth in height (42.75 cm), number of leaves (40.75), fruit yield (305291 fruits/ha) and dry fruit weight (484 kg/ha) of hot pepper compared to the sole application of the individual materials and the control, $p \leq 0.05$. In terms of effect of these treatments, T4 [(0.1532 kg of *S. siamea* leafy biomass + 0.048 kg NPK (15:15:15)] favored the growth and yield of hot pepper the most, followed by the sole application of *S. siamea* leafy biomass T3 (0.32063 kg of *S. siamea* leafy biomass), sole NPK (0.09 kg of NPK) and then T1 (control) recording the lowest growth in height (19.32 cm), number of leaves (21.25), fruit yield (129693 fruits/ha) and fruit dry weight (115 kg/ha) of hot pepper. Therefore, the combined application of T4[(0.1532 kg of *S. siamea* leafy biomass + 0.048 kg NPK (15:15:15)] could be adopted by farmers as an economically fit fertilizer treatment for optimum hot pepper performance. Additionally, *S. siamea* leafy biomass might be adopted by hot pepper farmers as an alternative to inorganic in terms of cost and availability in sub-Saharan Africa.

1. INTRODUCTION

In the tropics, vegetable crops play a significant role in agricultural production, alongside the primary staple food crops (Chourasia et al., 2022; Imathiu, 2021). According to Kumar et al., (2020) and Sarkar et al., (2022), vegetables play a vital role in the diet of people in the tropics as they serve as sources of minerals and vitamins of which hot pepper cannot be overemphasized.

Hot pepper, *Capsicum frutescens* (L.) from the family *solanaceous* thrives year-round in Ghana and similar environmental conditions found in the humid and semi-arid tropics (Abbas et al., 2022; Bekele, 2022). The vegetable is considered the third most significant crop globally, following tomato and onion (Noopur et al., 2023; Opoku et al., 2022). Pepper, akin to various other vegetable crops, plays a significant role in fulfilling essential nutrients for the human body that might be deficient in other food sources to enhance its taste, leading to increased consumption and improved digestion (Azlan et al., 2022; Subedi et al., 2023). According to Bhattarai (2022) and Ajibola & Amao (2019), pepper is frequently utilized as a seasoning, with mild varieties (*Capsicum annum*) consumed raw in salads, and the spicier types (chilies) being widely embraced in various cuisines due to their strong flavors. Pepper serves as a seasoning in sauces, soups, and various dishes, and it also holds medicinal value (Banu & Aswini, 2023; Oluwole and Ademuyiwa, 2021). It is utilized for both flavor enhancement and for its

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medicinal properties, aiding in preventing and treating colds and fevers (Panse, 2023).

Furthermore, hot pepper productivity is significantly influenced by soil fertility and nutrient availability in the tropics (Berhe et al., 2022; Hunde, 2020; Mensah et al., 2021). In many regions, soil degradation and nutrient depletion have become pressing concerns, limiting crop yields and threatening food security (Singh & Chaudhary, 2023; Susumu et al., 2023; Ziadat et al., 2022). Traditional farming practices often rely heavily on chemical fertilizers, which, when used indiscriminately, can lead to adverse environmental effects such as soil erosion, water pollution, and disruption of natural ecosystems (Anagah, 2023; Rashimi et al., 2020; Warra & Prasad, 2020). Additionally, the high costs associated with purchasing and applying these synthetic fertilizers pose economic challenges for farmers, especially smallholders (Abay et al., 2022; Jindo et al., 2023). In contrast, organic alternatives, like *S. siamea* leafy biomass, have shown promise in enhancing soil fertility and crop growth while being more environmentally sustainable (Giri et al., 2023).

Senna siamea, commonly known as *Siamese cassia* or cassod tree, is a fast-growing tree species with various applications, including its use as a source of organic matter in agriculture (Ajmani et al., 2019; Logah et al., 2020). Its leaves, being rich in essential nutrients, can potentially serve as a valuable organic biomass for improving soil fertility and enhancing crop growth (Alamu et al., 2023; Lemage & Tsegaye, 2020). *Senna siamea* trees are abundant at the Faculty of Renewable Natural Resources Demonstration Farm at the Kwame Nkrumah University of Science and Technology, occupying an acre of land with approximately 450 trees. The leaves of *S. siamea* are nutrient-dense, containing significant amounts of nitrogen, phosphorus, potassium, and other micronutrients. When these leaves decompose, they release these essential nutrients back into the soil, enriching it and promoting healthy plant growth (Rani et al., 2021). Concurrently, the application of chemical fertilizers, such as NPK (15:15:15), is a conventional practice to provide plants with essential nutrients required for their growth and development (Ichwan et al., 2022; Sulok et al., 2021). However, a comprehensive understanding of how the integration of organic biomass, such as *S. siamea* leafy biomass, and conventional fertilizers like NPK (15:15:15) impacts the growth and yield of specific crops like hot pepper is lacking (Antar et al., 2021). Addressing this knowledge gap is crucial for developing sustainable agricultural practices that improve productivity, ensure resource efficiency, and minimize environmental harm.

This study's significance lies in addressing the critical need for sustainable agricultural practices that balance productivity and environmental responsibility. By assessing the effects of combining *Senna siamea* leafy biomass and NPK (15:15:15) fertilizer on hot pepper growth and yield, we aim to provide farmers and agricultural practitioners with viable, eco-friendly alternatives. Utilizing organic biomass not only enhances soil fertility but also aids in waste reduction by utilizing plant material that would otherwise go unused (Thompson et al., 2023). Moreover, understanding the synergistic effects of organic and inorganic inputs can help tailor fertilizer applications to optimize plant growth, reduce dependence on synthetic inputs, and minimize environmental impacts (Breza et al., 2023).

Ultimately, the results of this study have the potential to guide farmers in making informed decisions regarding the optimal utilization of organic and inorganic fertilizers for improved crop productivity, contributing to sustainable agricultural practices and ensuring food security in the face of a growing global population. The objectives of this study were to assess the effect of *S. siamea* leafy biomass and NPK (15:15:15) fertilizer on the morphological growth (height and number of leaves) of hot pepper; the yield (fruit yield and fruit dry weight) of hot pepper; investigate the combined effect of *S. siamea* leafy biomass and NPK (15:15:15) fertilizer on the growth and yield of hot pepper (*C. frutescens* L.).

2. MATERIALS AND METHODS

2.1. Location of the study area

The study took place at the demonstration farm of the Agroforestry Department Faculty, situated within the Kwame Nkrumah University of Science and Technology (KNUST) campus in Kumasi, Ghana (Figure 1). Positioned within Ghana's humid Semi-Deciduous Forest zone, the farm is located at around 6.40°N latitude and 1.37°W longitude (Mohammed et al., 2023).

The region displays a unique rainfall pattern, characterized by two main cycles each year. On average, the rainfall varies between 1250 to 1500 mm. The major wet season, occurring from May to July, constitutes the primary rainy period, followed by a secondary rainy season from September to November. Additionally, there are two dry intervals: a longer dry season extending from December to March and a shorter one in August (Mohammed et al., 2023).

According to the research carried out by Mohammed et al. (2023), the average daily temperature at the specified location is 25.6°C. During the coldest months from December to February, the mean temperature drops to approximately 20°C. Conversely, in the warmest month, March, the mean high temperature reaches 33°C. Across the year, the average temperature at this site is around 26.61°C, accompanied by a relative humidity of about 67.6%. In a research conducted by Mohammed et al. (2023), they observed that the soil at the experimental location is classified as Ferric Acrisol, exhibiting high

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acidity and efficient drainage. Moreover, the soil was determined to have a sandy-loam texture.

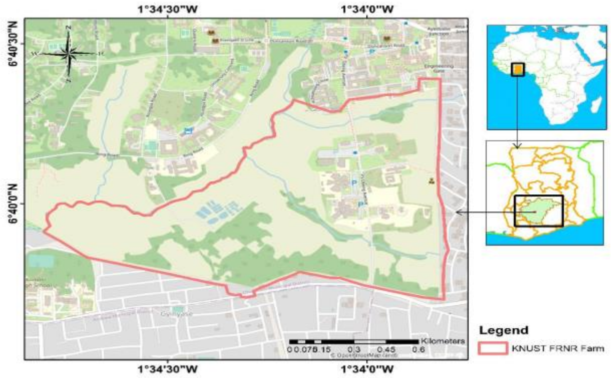

Figure 1. Map of the study area showing the Faculty of Renewable Natural Resources Demonstration Farm, KNUST-Kumasi, Ghana.

2.2. Experimental Approach and Procedure

The trial area was meticulously cleared of any vegetation and foreign debris using traditional hand tools such as a hoe, cutlass, and rake. The leafy biomass of *S. siamea* was sourced from the Agroforestry research farm within Kwame Nkrumah University of Science and Technology (KNUST) in Kumasi, Ghana while NPK (15:15:15) inorganic fertilizer was procured from an agrochemical shop at Adum-Kumasi. These components were administered either independently or in various combinations at different dosage levels. The hot pepper seeds were sourced from the Crop Research Institute of Ghana, located in Fumesua-Kumasi.

A well-drained area with good sunlight exposure was chosen at the study site. The site was cleared of debris, weeds, and rocks to ensure a clean and level surface. The soil was loosened to a depth of about 15-20 cm using a hoe. Nursery beds of suitable dimensions, typically 2 meters in width and 2 meters in length was created, with pathways in between for easy access and maintenance. The bed was raised to a height of about 10-15 cm to aid in proper drainage and prevent waterlogging. The moisture level was maintained by regular and adequate watering before sowing the seeds.

Healthy, disease-free pepper seeds from the reliable source were selected. Seeds broadcasted on the prepared bed and were lightly cover with a thin layer of fine soil. A thin layer of organic mulch, such as straw was applied, to retain soil moisture and regulate soil temperature. Shade nets were installed to protect the nursery bed from harsh environmental conditions. Watering of the nursery bed was done as needed to maintain adequate moisture levels. Regular monitoring of the nursery bed for weeds, pests, and diseases was done until transplanting.

The leafy biomass of *S. siamea* was integrated into the soil as part of the treatments for the field experiment, specifically applied two weeks prior to transplanting. The treatments included varying proportions [(0.32063 kg per plot = 1696.5 kg/ha) and (0.15320 kg per plot = 1696.5 kg/ha)] of the biomass. NPK fertilizer was administered at two weeks after transplanting (2 WAT) based on the prescribed dosage corresponding to each treatment level [(0.096 kg per plot = 507.94 kg/ha) and (0.048 kg per plot = 253.97 kg/ha)].

2.2.1 Transplanting of seedlings

One week prior to transplanting, watering of the nursery was decreased to toughen the young plants and minimize shock during transplantation, and high temperature. Subsequently, the seedlings were watered while in the bed to facilitate easy uprooting and avoid undue harm to the roots. Established seedlings, adhering to standard height criteria of 20-25 cm, were chosen and transplanted onto the designated experimental plots with a spacing of 70 x 30 cm during the evening. Weeds were manually managed through the use of tools like a hoe, cutlass, and hand labour.

2.2.2 Pest and disease control

An application of Mancozeb at a rate of 5 to 10 grams per gallon (equivalent to 3.8 liters of water) was utilized. Spraying commenced two weeks after transplanting (2 WAT) and continued until maturity to manage fungal diseases such as damping off. Cypermethrin was applied at a concentration of 1.2 mm per liter following scouting, which indicated pest infestations surpassing the predetermined threshold.

2.2.3 Harvesting

When the hot pepper fruits reached maturity at 8 WAT, they were handpicked and harvested using a knife.

2.3. Experimental Design and Treatment Allocation

The study followed a Randomized Complete Block Design (RCBD) and included four treatments randomly distributed and replicated across the site. The experimental area measured 11.4 m x 6.6 m, totaling 75.24 m^2, and accommodated 16 plots. Each plot was sized at 2.1 m × 0.9 m (1.89 m^2) and contained 16 hills. A 1-meter alley was kept between plots and blocks to accurately represent each treatment within a plot. The study duration spanned three months.

The treatments were:

T1 = No biomass, no NPK (Control)

T2 = 0.096 kg NPK (507.94 kg/ha NPK)

T3 = 0.32063 kg *S. siamea* leafy biomass (1696.5 kg/ha of *S. siamea* leafy biomass)

T4 = 0.1532 kg of *S. siamea* leafy biomass + 0.048 kg NPK (848.2 kg/ha of *S. siamea* leafy biomass + 253.97 kg/ha NPK)

Nitrogen (N) demand of Hot pepper is 76 kgN/ha

2.4. Data collection and analysis

Growth parameters such as plant height and leaf count of hot pepper plants were documented at 2-weeks intervals, spanning from two to twelve weeks after transplanting (2 to 12 WAT). Plant height was gauged from the ground level to the highest leaf tip using a meter rule, while leaf count was determined through visual assessment. In addition, yield parameters including fruit quantity and fruit dry weight were gathered at the time of harvest. The number of fruits was ascertained via visual counting, and the dry weight of the fruits was measured using an electronic balance after subjecting them to oven drying at 105 degrees Celsius. The data collected pertaining to both growth and yield parameters for hot pepper was subjected to statistical analysis using the Analysis of Variance (ANOVA) method with STATISTIX 10 software, at a 5% level of significance. The Least Significant Difference (LSD) was utilized to compare means that exhibited significant differences. The outcomes of the analysis were then presented through tables and graphs.

3. RESULTS

3.1. Effect of *S. siamea* leafy biomass and NPK (15:15:15) fertilizer on the morphological growth of hot pepper

Table 1 shows the effect of the different fertilizer treatments on the growth in height of hot pepper over the 12 weeks' study period. On a weekly basis (starting from 2 WAT), there was significant differences in height for the various treatments with p-values ranging from 0.0000 to 0.0000. At 2 WAT there was a significant difference between the treatment means, $p \leq 0.05$, where T4 registered the tallest plants (4.68 cm), followed by T3 (4.12 cm), T2 (3.69 cm) while the shortest plants were recorded in T1, with similar trends recorded at 10 WAT and 12 WAT. At 4 WAT, there were significant differences between the various treatments $p \leq 0.05$ with T4 registering the tallest plants (39.1 cm) which differed significantly from the remaining treatments T1 (20.2 cm), T2 (23.6 cm) &T3 (25.2 cm). Similar pattern was observed at 6 WAT. At 8 WAT, the means of the respective treatments were significantly different, $p \leq 0.05$ where T4 had the highest growth in height (46.7 cm), followed by T3 (35.0 cm), T2 (27.6 cm) while T1 had the least growth in height (22.6 cm).

Table 1. Effect of *Senna siamea* leafy biomass and NPK (15:15:15) on the height (cm) of hot pepper from 2 to 12 WAT.

TREATMENT	2 WAT (±SeM)	4 WAT (±SeM)	6 WAT (±SeM)	8 WAT (±SeM)	10 WAT (±SeM)	12 WAT (±SeM)
T1	2.31±0.15^{d}	20.2±0.17^{b}	22.4±1.09^{b}	22.6±0.86^{c}	23.6±0.89^{d}	24.7±0.78^{d}
T2	3.69±0.06^{c}	23.6±2.56^{b}	26.7±2.71^{b}	27.6±3.26^{bc}	30.1±2.14^{c}	31.3±1.27^{c}
T3	4.12±0.06^{b}	25.2±1.77^{b}	29.7±3.36^{b}	35.0±3.72^{b}	48.6±2.14^{b}	50.2±1.22^{b}
T4	4.68±0.04^{a}	39.1±2.6^{a}	44.2±1.81^{a}	46.7±2.22^{a}	59.7±2.72^{a}	62.1±2.36^{a}
P-VALUES	0.0000	0.0001	0.0002	0.0003	0.0000	0.0000
LSD	0.27	6.26	7.41	8.45	6.41	4.69
CV(%)	4.32	13.2	14.6	15.2	9.73	6.68

Means in the column accompanied by the same letter (s) are not significantly difference at ($P \leq 0.05\%$) using Least Significance Difference (LSD), where WAT=Weeks After Transplanting, SeM=Standard Error of Mean, CV=Coefficient of Variation, T=Treatment

Figure 2 shows the effect of the different treatments on the height of hot pepper over the experimental period. All treatments showed steady increase in height throughout the experimental period. T4 had the tallest plants (42.75 cm), followed by T3 (32.12 cm), T2 (23.84 cm) and finally T1 (control) had the shortest plants (19.32 cm). There was significant difference in treatment means with respect to growth in height of the hot pepper plants, $p \leq 0.05$ (p=0.0000, F=12.32, LSD=8.25, DF=3).

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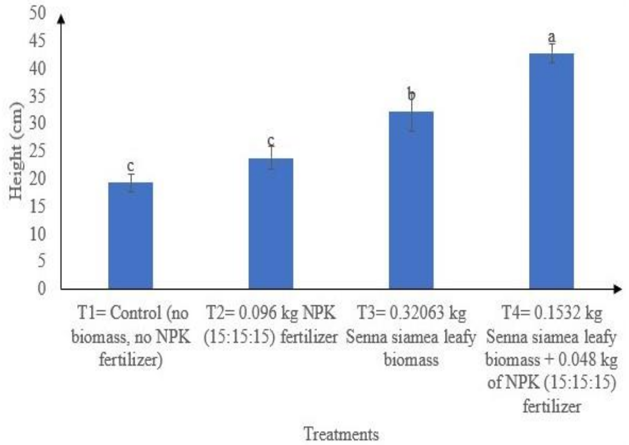

Figure 2. Effect of *S. siamea* leafy biomass and NPK (15:15:15) on the Height (cm) of hot pepper.

The changes in number of leaves as affected by *S. siamea* leafy biomass and NPK (15:15:15) is shown in Table 2. There were significant differences between treatment means from 2 to 12 WAT with p-values ranging from 0.0022 to 0.0000. At the two-week after treatment (2 WAT) mark, there emerged a notable distinction among the treatment means concerning the leaf count, showing statistical significance at a level of $p \leq 0.05$. Treatment four (T4) had the maximum number of leaves (5.2), followed by T3 (3.8), T2 (2.6) while the minimum number of leaves was registered by T1 (2.1). At 4 WAT, the highest number of leaves was recorded by T4 (27.3) which was not significantly different from T3 (24.8) but they differed significantly from the remaining treatments, T2 (18.5) with the least number of leaves recorded by T1 (10.4). At 6 WAT, T1 had the highest leaf count (40.2) which was significantly different from T2 and T3 (30.0 and 31.1 respectively) with similar patterns observed at 10 WAT and 12 WAT. The group of T2 and T3 did not differ greatly from each other but they were significantly different from T1 which had the lowest leaf count (21.7). The highest leaf count was registered by T4 (54.3) at 8 WAT, followed by T3 (47.3), T2 (40.2) with the lowest in T1 (23.9).

The leaf count mirrored the height growth pattern closely. Notably, there was a substantial contrast between the treatment averages, indicating statistical significance at $p \leq 0.05$ ($p=0.0014$, $F=5.62$, LSD=9.72, DF=3). Again, T4 had the highest leaf count (40.75), followed by T3 (34.73), T2 (30.38) while the lowest leaf count was recorded in T1 (21.25) (Figure 3).

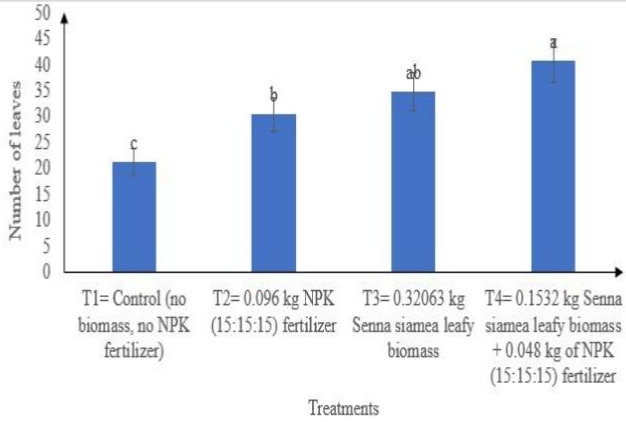

Figure 3. Effect of *S. siamea* leafy biomass and NPK (15:15:15) on the number of leaves of hot pepper.

3.2. Effect of *S. siamea* leafy biomass and NPK (15:15:15) fertilizer on the morphological growth of hot pepper

Figure 4 shows the effect of different *S. siamea* leafy biomass and NPK (15:15:15) fertilizer application regimes on the fruit yield of hot pepper at harvest. Mean values indicated that, T4 fertilizer application regime recorded the highest number of fruits (305291 fruits/ha) followed by T3 (198413 fruits/ha), T2 (173456 fruits/ha) and the lowest number of fruit yield was recorded in fertilizer application regime of T1 (129693 fruits/ha). Treatment means displayed a notable disparity concerning fruit yield, meeting the criteria of statistical significance at $p \leq 0.05$ ($p=0.0001$, $F=19.4$, LSD=296456, DF=3).

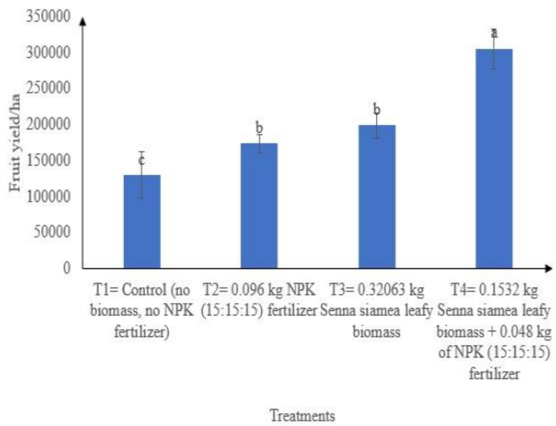

Figure 4. Effect of *S. siamea* leafy biomass and NPK (15:15:15) fertilizer on the fruit yield/ha of hot pepper.

Figure 5 depicts the effect of different fertilizer application regimes on the fruit dry weight of hot pepper at harvest. There was a substantial variance among treatment means, indicating statistical significance at the $p \leq 0.05$ level ($p=0.0002$, $F=15.3$, LSD=120.8, DF=3). The highest dry weight of fruits at harvest was registered in T4 (484 kg/ha) followed by T3 (330.3 kg/ha), T2 (262.8 kg/ha) while the lowest fruit dry weight was recorded in T1 (115 kg/ha).

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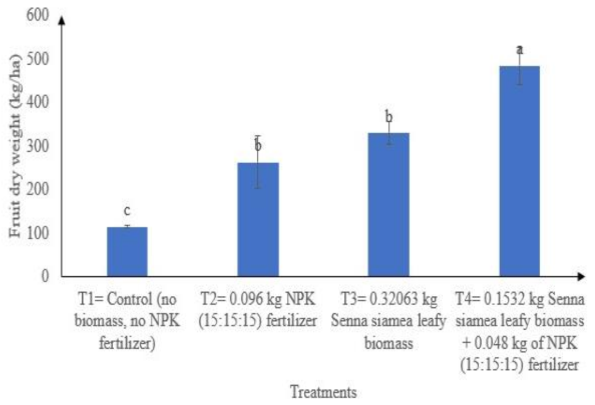

Figure 5. Effect of *S. siamea* leafy biomass and NPK (15:15:15) fertilizer on the fruit dry weight (kg/ha) of hot pepper.

4. DISCUSSION

4.1 Plant Height Growth

The results indicate that T4, which included a combination of 0.1532 kg of *S. siamea* leafy biomass and 0.048 kg of NPK fertilizer, significantly increased the height growth of hot pepper plants. This suggests that a combined application of organic matter (*S. siamea* leafy biomass) and inorganic nutrients (NPK) had a synergistic effect on plant height, promoting vigorous vertical growth (Aboyeji et al., 2023; Siddiqui et al., 2020). Treatment three (T3), involving 0.32063 kg of *S. siamea* leafy biomass, also showed a positive effect on plant height due to higher levels of organic matter, albeit to a lesser extent than T4 (Lemage and Tsegaye, 2020). Treatment two (T2), with 0.096 kg of NPK, followed in promoting plant height growth which could be attributed to the presence of essential nutrient elements needed by plants for growth and development (Kwon et al., 2019; Varma et al., 2022). The control group (T1) showed the least height growth, highlighting the necessity of supplementary inputs for optimal plant growth (Pokhrel et al., 2023; Xiao et al., 2023).

The results suggest that a combination of both organic (*S. siamea* leafy biomass) and inorganic (NPK) inputs led to the highest plant height growth. This aligns with the concept of integrated nutrient management, where utilizing a mix of organic and inorganic sources provides a balanced nutrient supply to the plants, enhancing their growth (Bhattacharya et al., 2023; Kumar et al., 2019; Thakur et al., 2023). *Senna siamea* leafy biomass appeared to have a positive effect on plant growth, especially in treatments T3 and T4. This organic material likely contributed essential nutrients and organic matter to the soil, enhancing soil structure, nutrient availability, and ultimately promoting plant growth (Raza et al., 2023; Siedt et al., 2021; Vida et al., 2020).

The presence of NPK fertilizer in treatments T2 and T4 highlights the significance of balanced nutrient application, particularly the essential macronutrients nitrogen (N), phosphorus (P), and potassium (K). NPK fertilizer supplements the soil with these crucial elements, promoting overall plant health and growth (Arrobas et al., 2023; Bana et al., 2022; Chojnacka, 2023; Ramdan et al., 2023).

4.2 Number of leaves

The findings suggest that the application of *S. siamea* leafy biomass in combination with NPK (15:15:15) fertilizer had a significant positive effect on the number of leaves of hot pepper (*C. frutescens*) which could be attributed to nutrient content and availability. *Senna siamea* leafy biomass is likely rich in essential nutrients, including nitrogen, phosphorus, and potassium (NPK), which are vital for plant growth (Mohammed et al., 2022). When combined with NPK fertilizer, it may have provided a well-rounded nutrient supply, promoting better growth and development of the pepper plants. Additionally, the combined application of *S. siamea* leafy biomass and NPK may have led to a synergistic or complementary effect, enhancing nutrient uptake and utilization by the pepper plants (Camargo et al., 2022).

The organic matter from the *S. siamea* leafy biomass could have improved soil structure, water retention, and microbial activity, facilitating better nutrient absorption and utilization (Giri et al., 2023; Kumari et al., 2022). The results might be attributed to the presence of organic matter in *S. siamea* leafy biomass which could have acted as a slow-release nutrient source, providing a sustained supply of nutrients to the plants over an extended period. This slow nutrient release could have supported continuous growth and development, resulting in increased number of leaves. In addition, *S. siamea* leafy biomass might have encouraged beneficial microbial activity in the soil (Zine et al., 2020). These microbes could have facilitated nutrient cycling and decomposition of organic matter, releasing essential nutrients in a plant-available form that enhanced plant growth (Prasad et al., 2021; Ram et al., 2023; Raza et al., 2023; Zhao et al., 2023).

Furthermore, the presence of natural growth-promoting substances in *S. siamea* leafy biomass could have stimulated the production of plant growth regulators, such as auxins and cytokinins. These regulators play a crucial role in promoting leaf development, leading to an increased number of leaves in the hot pepper plants (Altaf et al., 2023; Lian et al., 2022; Zhao et al., 2021). The specific combination and quantity of *S. siamea* leafy biomass and NPK (15:15:15) fertilizer in T4 (0.1532 kg of *S. siamea* leafy biomass + 0.048 kg NPK) might have hit an optimal balance, delivering the right amount of nutrients for

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maximum growth without causing nutrient imbalances or stress. The observed increase in the number of leaves may have also influenced overall plant height and growth. Adequate nutrients and favorable soil conditions can contribute to taller, more vigorous plants with an increased leaf count (Choudhary et al., 2023; Monono et al., 2023).

4.3 Number of Fruits

The findings demonstrated that T4 (0.1532 kg of *S. siamea* leafy biomass + 0.048 kg NPK) resulted to a significantly higher fruit yield compared to the remaining treatments. This could be that *S. siamea* leafy biomass may have contributed essential nutrients and organic matter to the soil, enhancing soil fertility and creating a favorable environment for plant growth (Rani et al., 2021; Kizito et al., 2022). The addition of NPK fertilizer (15:15:15) provided a balanced mix of essential nutrients, including nitrogen, phosphorus, and potassium, promoting robust plant growth and fruit production (Mohammed et al., 2023; Thakur et al., 2023). Additionally, T3 (0.32063 kg *S. siamea* leafy biomass) came next which might be attributed to a higher amount of *S. siamea* leafy biomass likely provided a substantial organic matter source, enriching the soil with nutrients, improving soil structure, and enhancing water retention capacity (Chhabra and Chhabra, 2021; Maiti et al., 2021).

The increased organic matter might have stimulated beneficial microbial activity in the soil, facilitating better nutrient uptake and growth of the hot pepper plants (Fasusi et al., 2021; Santoyo et al., 2021; Lakhdar et al., 2023). More so, the presence of NPK (15:15:15) fertilizer in T2 (0.096 kg NPK) could have supplied essential nutrients to the plants, especially nitrogen (N), phosphorus (P), and potassium (K), which are crucial for plant growth, flowering, and fruiting (Alkharpotly et al., 2019; Zoumana et al., 2023). While the NPK fertilizer contributed vital nutrients, the absence of additional organic matter (compared to T4 and T3) may have limited the soil's long-term fertility and overall soil health (Mohammed et al., 2023; Zheng et al., 2024). The control group received no additional amendments, relying solely on the natural soil nutrient content and any nutrients released during the decay of organic matter in the soil. The absence of supplemental nutrients or organic matter may have resulted in suboptimal soil conditions, restricting plant growth and fruit production (Katel et al., 2023).

4.4 Dry fruit weight

The findings regarding the effects of *S. siamea* leafy biomass and NPK (15:15:15) fertilizer on the dry fruit weight of hot pepper (*C. frutescens*) can be explained through the impact of nutrients, organic matter, and their combinations on plant growth and fruit development in T4 (0.1532 kg of *S. siamea* leafy biomass + 0.048 kg NPK). This treatment involved both organic matter from *S. siamea* leafy biomass and the balanced NPK fertilizer. The NPK fertilizer provided essential macronutrients (nitrogen, phosphorus, and potassium) that are vital for plant growth and fruit development (Chen et al., 2022). The combination of organic matter and mineral nutrients likely enhanced nutrient availability and uptake, promoting robust growth and higher dry fruit weight in hot pepper plants (Mensa et al., 2021; Rady et al., 2023). In addition, T3 (0.32063 kg *S. siamea* leafy biomass) involved a significant amount of organic matter from *S. siamea* leafy biomass which could have contributed to soil health, enhances soil structure, improves water retention, and provides a slow-release source of nutrients as it decomposes (Adekiya et al., 2020; Ding et al., 2020).

The decomposition of organic matter released nutrients gradually, sustaining plant growth over an extended period. The organic matter likely enriched the soil, facilitating better nutrient availability and uptake by the plants, leading to improved growth and fruit yield (Andrews et al., 2021; Malik et al., 2022). The T2 (0.096 kg NPK) provided only the NPK fertilizer without organic matter, while NPK fertilizer supplied essential nutrients, it lacked the soil-conditioning and organic matter benefits (Gumelar et al., 2020; Uttran et al., 2023). As a result, although the plants received necessary nutrients, they may not have experienced optimal soil conditions for growth compared to T4 and T3. The control group did not receive any added nutrients or organic matter beyond what was naturally present in the soil. As a result, the plants in this group had limited access to essential nutrients, likely leading to suboptimal growth and lower fruit yield compared to the treated groups (Mohammed et al., 2023; Mohammed et al., 2022).

5. CONCLUSION

The findings suggest that a combination of S. siamea leafy biomass and NPK fertilizer (T4) had a synergistic effect on promoting the growth and yield of hot pepper plants. Senna siamea leafy biomass alone (T3) also had a positive impact, likely due to its organic matter content and nutrient contribution. The application of NPK fertilizer (T2) showed benefits in terms of nutrient supply, although not as effective as the combination with S. siamea biomass. The control group (T1) lacking additional amendments had the least favorable growth and yield outcomes due to the absence of supplemental nutrients and organic matter. The study recommends that smallholder farmers in sub-Saharan Africa can be encouraged to integrate S. siamea trees in their agricultural systems since its leafy biomass can be used as a valuable organic resource to enhance soil fertility and promote crop growth. There can be advocacy for the balanced use of NPK fertilizer in conjunction with organic materials like S. siamea leafy biomass providing guidance on appropriate dosage and application methods to optimize

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its benefits. Additionally, studying the long-term effects of these combinations on soil health and sustainability will provide valuable insights for sustainable agricultural practices. Finally, facilitate soil testing for farmers to assess their soil's physicochemical properties before and after the experiment since the present study did not look at that.

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