GROWTH AND YIELD RESPONSE OF SWEETPOTATO *(Ipomoea batatas* [L.] Lam*)* TO THE TIMING AND RATES OF NPK APPLICATION

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INTRODUCTION

Sweetpotato (*Ipomoea batatas* (L.) Lam.) is one of the most important root crops cultivated worldwide. Because of its adaptability, high yield potential, and nutritional value, sweetpotato has become an important food crop, particularly in developing countries (Yan et al., 2022).

Sweetpotato now has a diversified market. It serves as an important staple food for small-holder farmers. This crop is highly recognized for its various uses as food, feed and raw material for industrial food products. It is also adapted to various production systems in a wide range of environmental conditions. It ranks fifth as the most important food crop after rice, wheat, maize and cassava in developing countries (Nyarko et al., 2022)

Farmers face challenges in determining the optimal timing for fertilizer application in sweetpotato production. The critical issue revolves around pinpointing the precise growth stages when the plants are most receptive to specific nutrients. Late maturing cultivars tended to have higher N recovery and physiological efficiency than early maturing cultivars (Ankumah et al., 2003). Applying fertilizers too late or not at all can delay the initiation of sweetpotato storage roots and reduce the number of tubers per plant (Dong et al., 2022). Consequently, the lack of clear guidance on ideal timing poses a practical challenge for farmers aiming to maximize their crop productivity and quality while maintaining sustainable agricultural practices (Liu et al., 2014).

In the realm of agricultural science, researchers are studying agricultural practices to increase crop productivity and quality. Timing of Fertilizer Application is crucial for growth and output. Understanding the timing of fertilizers for sweetpotato can improve agricultural efficiency and food security, as it is a staple in many regions worldwide (Jama & Pizarro, 2008).

The timing of fertilizer application holds a crucial key to unlocking the full yield potential of sweetpotato while minimizing environmental impacts. In doing so, the research not only contributes to the scientific understanding of sweetpotato cultivation but also holds practical implications for farmers, offering evidence-based insights to optimize fertilization practices and ultimately elevate agricultural outcomes.

Adjusting the timing of fertilizer application, based on critical growth stages of sweetpotato plants, can significantly influence their overall performance. It is anticipated that precise timing of fertilizer application, aligned with the specific nutrient demands during key developmental phases, could enhance root development, increase yield, and optimize the nutritional content of sweetpotato. Through a comprehensive analysis of growth metrics, yield outcomes, and nutritional profiles, this research seeks to contribute valuable insights to the realm of agricultural practices, potentially leading to improved sweet potato cultivation techniques and sustainable food production systems.

Objectives of the study

The general objectives of this study is to evaluate the appropriate timing and rates of NPK fertilization. Specifically, it aims to:

1. Determine the effects of timing and rates of NPK application on the growth and yield of sweetpotato NSIC Sp25;
2. Find out the appropriate timing and rates of NPK application on sweetpotato NSIC Sp25; and
3. Assess the economic profitability of sweetpotato NSIC Sp25 to the timing and rates of NPK fertilization.

Scope and Limitation

This study intends to focus the effects of timing and rates of fertilizer application on sweet potato growth and yield.

Date and Place of the Study

The experiment will be conducted at Caraga State University, Ampayon, Butuan City from December 2023 to March 2024.

REVIEW OF RELATED LITERATURE

Facts About Sweetpotato

Sweetpotato (*Ipomoea batatas* [L.] Lam) belongs to the botanical family Convolvulaceae. In many countries, its culture and production are essential, because it contributes to reduce food shortages in times of crisis (natural disasters or wars). It is amongst the world's most important, versatile and under-exploited food crops with more than 90 million tons in annual production, contributed mostly by Asian and African countries, especially China (Alam, 2021). Sweetpotato could potentially be used as an alternative to corn-based ethanol production to reduce fertilizer, water, and pesticide inputs and to utilize its ability to fix relatively large amounts of solar energy into starch in storage roots (Ziska et al., 2009).

In the 2017 International Potato Center (IPC) data, the Philippines has made few contributions to overcoming the global market's challenges. The center has reported that the Philippines' sweet potato production has been declining. It used to be 250,000 hectares in 1980, and in 2017 it is less than 80,000 hectares. There is a gap of 170,000 hectares over the three decades. The IPC has suggested that the government's best way to fill this gap is to link the farmers to the market through science and technology intervention (Mustacisa-Lacaba et al., 2023).

Effects of fertilizer on Sweet Potato Production

Fertilizers are widely used in agriculture to increase crop production. In sweet potato, soil amendment using manure and inorganic fertilizers has a significant impact on plant growth and storage root development. Among chemical fertilizers, nitrogen, phosphorus, and potassium are the major elements required for supporting shoot and root growth in sweet potato (Sakamoto & Suzuki, 2020).

As in other crops, correct and timely fertilization are very important to get high yields. Sweet potato productivity is constrained by poor fertility, especially low potassium (K), phosphorus (P), nitrogen (N), sulfur (S), and some micronutrients. Phosphorus requirements are quantitatively lower than K and N doses, but it affects increasing the average weight and the number of roots, and then, crop yields. Due to its slow diffusion and high degree of fixation, phosphorus is generally less available in the soil solution but its uptake and utilization are essential on the final yield of agricultural crops. On the other hand, the application of chemicals in agriculture is often the cause of soil erosion and environmental deterioration, mainly when used indiscriminately (Santana-Fernández et al., 2021). .

Fertilizer Rates and Timing of its Application

According to Caruana & Cagasan, (2020) timing of nutrient application is guided by some basic considerations which include nutrient availability when crops need it, avoiding waste and enhancing nutrient use efficiency.

Researchers investigated that the application of nitrogen fertilizer (NPK) at a rate of 140-60-150 kg ha^{-1} has been found to increase germination, fruit size, and yield in crops. This fertilizer ratio leads to a healthier crop stand, increased fruit production, and larger, more desirable fruits for marketability. However, the delay in flowering, fruit setting, and maturity may affect the overall cropping schedule and the choice of planting dates and harvest times. Despite these challenges, the benefits suggest that the 140-60-150 kg ha^{-1} NPK ratio could be a valuable option for growers, especially if they can manage delayed maturation in their crop management practices

(Waseem et al., 2008).

Bourke, (1985) suggested that nitrogen (N) increased leaf area duration, resulting in increased tuber weight and yield. K increased the proportion of dry matter diverted to tubers and increased tuber number per plant. The effect of K occurred 7 weeks after planting, suggesting early application of K fertilizer. Zotarelli et al., (2015) also observed that from the time of sprout development until the beginning of vegetative growth, the demand for N is low, however some N is required to stimulate plant growth and tuber initiation. Application of low rates of N fertilizer rates at planting, supplemented with N applications during tuber development may have the potential to improve early-season tuber growth and to increase nitrogen use efficiency.

In a study conducted by Stalin et al. (1999), found that applying 150 kg ha^{-1} of nitrogen across five stages of rice growth led to significantly higher yields. The nitrogen management strategy involved allocating 25 kg of nitrogen at each stage of rice development, including transplanting, tillering, panicle initiation, mid-heading, and first flowering. This approach was highly effective in promoting crop growth and increasing overall rice yield. In the other hand, applying 250-55-104 kg N, P and K ha^{-1} resulted in higher ammonia and leaching losses compared to the recommended dose of 150-33-62 kg N, P and K ha^{-1}. Split application of NPK up to the beginning of grain filling stage improved N recovery efficiency and grain yield (Reddy et al., 2009).

According to Afreh et al., (2022), fertilizer timing significantly impacts grain yield. Open-pollinated variety showed the highest yield of 4.7 tha-1 when fertilizer was applied during planting, while the Pioneer hybrid variety showed an increased yield of 6.5 tons per hectare when fertilizers were applied two to four weeks after planting. However, these differences did not significantly affect maize growth and yield parameters. To optimize maize production, farmers should apply a balanced NPK fertilizer with a 15-15-15 ratio during planting and 14 to 28 days after planting.

In a study conducted by Nwofia, (2015), the research found that applying NPK fertilizer at a rate of 120 kilograms per hectare (kg/ha) during the early planting season had a profound impact on the cucumber crops under rain-fed conditions in the humid tropics. This approach positively influenced fruit production, suggesting that the timing and dosage of the fertilizer played a crucial role in maximizing yields.

In a study conducted by Kartika et al., (2017), showed that inorganic fertilizer treatment generally improved the growth and yield of crop. The recommended fertilization rate stands at 136 $kgha^{-1}$ of inorganic fertilizer, which is to be applied in two stages during the crop's growth cycle. The first application should take place at 1 week after planting (WAP), followed by a second application at 4 WAP. This precise timing ensures that the cabbage crop receives the necessary nutrients to support its growth and development, with Urea contributing to nitrogen supplementation and SP-36 supplying essential phosphorous. Adhering to this fertilization schedule can enhance cabbage yields and promote healthy, robust plant growth, making it a critical practice in cabbage farming.

In a study conducted by Phillips et al., (2005), suggests that growers should apply nitrogen fertilizer at a rate of 28 $kgha^{-1}$ during transplanting and an additional 28 to 56 $kgha^{-1}$ when vines begin to proliferate, typically 4 to 5 weeks after transplanting. However, these recommendations have remained largely unchanged over the years, with a significant portion of growers applying nitrogen at rates closer to the upper range of 56 to 67 $kgha^{-1}$, possibly due to increased yields or a tendency to err on the side of caution.

MATERIALS AND METHODS

The Study Site Characteristics

The study will be conducted at Caraga State University, Ampayon, Butuan City. The climate type in Caraga region is Type II, with no pronounced wet and dry season. The field soil type is Clay loam with moderate plasticity and moderately shiny surfaces.

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Soil Sampling Analysis

Initial soil samples will be collected from the experimental area before the conduct of the experiment. The soil samples will be collected at 0-20 cm depth. The soil samples gathered will be set for air-drying; pulverized and sieved. A one kilogram (kg) of sieved and air-dried soil samples will be submitted for soil analysis to the Department of Agriculture Regional Soils Laboratory, Taguibo, Butuan City. For the analyses of soil pH, organic matter, total N, available P, and exchangeable K, a composite soil sample per treatment combinations will be collected after the conduct of the study. For the final analysis of soil pH, organic matter, total N, available P, and exchangeable K after harvesting.

Experimental Design and Layout

This study will be conducted in a Randomized Complete Block Design (RCBD). There are five treatments and three replications. The rates of NPK fertilizers will be based from the recommended rate of 40-40-60kg ha^{-1} of N, P_2O_5 and K_2O. The timing will be based from farmer's preference. The treatments as follows;

T1 = No fertilizer application (Control)

T2 = 40-40-60kg ha^{-1} of N, P_2O_5 & K_2O at 1 week after planting

T3 = 40-40-60kg ha^{-1} of N, P_2O_5 & K_2O at 1 month after planting

T4 = 20-20-30kg ha^{1} of N, P_2O_5 & K_2O at 1 week after planting and 20-20-30kg ha^{1} of N, P_2O_5 & K_2O at 1 month after planting

Land Preparation

The experimental area will be cleared from undesirable materials like branches of trees and weeds. The primary plow material has bolo, grab, and the secondary harrowing will use a Hand Rotavator Machine to pulverize the soil. The land is plowed twice at an interval of two (2) weeks and harrowing is done afterward. Ridges will be made uniformly at 30cm in width and 30cm in height.

Planting Materials Procurement and Preparation

Sweetpotato (NSIC Sp25) tip cuttings with lengths of 25–30 cm with 8 nodes will be gathered from healthy plants. A total of 519 cuttings for the whole experiment will be procured at Maguinda, Butuan City. A day before planting, it will be kept in a damp, shaded area close to the experimental site to avoid dehydration. Pre marked 1/2 the cutting. One cutting of sweet potato will be planted per hill on the ridges at a distance of 75 cm between rows and 25 cm between hills. Four nodes will be buried in the soil and the other four nodes including the shoots will be exposed at the surface of the soil.

Fertilizer Preparation and Application

Complete (16-16-16) and Muriate of Potash (MOP) are the fertilizer materials to be used in the study. The timing and rates of these two fertilizer materials will be based on the imposed treatments. All fertilizer materials regardless of the treatments will be applied in a band in each row.

Weeding Management

Hand weeding will be done two weeks before fertilizer application using bolo to control the weeds. Hand weeding operation will be done on each treatment plot and surroundings to maintain the cleanliness of the experimental area and to avoid the competition to the nutrients absorbed by the main crop against unwanted weeds.

Water Management

The sweetpotato planted will be watered daily during their first week.
It will be watered based on the soil moisture. Maintaining consistent soil moisture, avoiding overwatering to prevent root rot.

Pest and Disease Management

The pest and disease management of the sweetpotato will be done depending on the organisms that will attack and cause a disease on a plant. Phenomone will be applied into the field to prevent ground attack.

Harvest Management

Harvesting will be done 3-4 months after planting and will be using bolo to dig up the fleshy roots within the harvestable area. Extra care and attention will be observed to minimize damage of the fleshy roots. The roots will be cleaned and classified into marketable and non-marketable ones.

Data to be Gathered

A. Agronomic Characteristics

1. Length (cm) of the main vine- this will be obtained by measuring the main vine of the plant from the base to the tip of the vine using ten (10) sample plants per treatment plot within harvestable area. This will be done by carefully locating the specific vine of the particular sample where the lateral vines were connected. This will be collected during harvesting.

2. Number of primary lateral vines per plant- this will be recorded by counting the number of primary lateral vines from (10) sample plants in each treatment plot within the harvestable area. This will be collected during harvesting.

3. Fresh herbage yield- this will be determined by weighing the vines of all the harvested plants in each treatment plot within the harvestable area, excluding the border row in each side of the plot and 1 end plant in each row. This will be converted into tons per hectare using the formula:

$$\text{Herbage yield (t ha}^{-1}\text{)} = \frac{Fresh\ herbage\ yield\ (kg\ ha{-}1)}{Harvestable\ area\ (10.5\ m2)} \times \frac{10{,}000\ m2\ ha{-}1}{1{,}000\ kg\ ton}$$

B. Morphological Parameters

1. Leaf area index (LAI)- this will be obtained by measuring the length and width of all functional leaves within the 50 cm ×50 cm quadrat at 60 days after planting. The total leaf area within the quadrat will be divided by the effective ground area (cm^2) within the quadrat to get the leaf area index (LAI)

$$TLA = \text{Sum } (L \times W) \text{ CF } (0.497)$$

$$LAI = \frac{\text{Total Leaf Area (TLA)}}{\text{Area of the quadrant } (2{,}500 \text{ cm}^2)}$$

Correction factor=0.497 (Cajefe, 2003)

C. Yield and Yield Components

1. **Weight of marketable and non-marketable roots per harvestable area (kg/plot)-** this will be obtained by sorting the marketable and non-marketable roots of sample hills per treatment plot within the harvestable area. Marketable storage roots were those that have 2.5 cm diameter x 6.5 cm long or not less than 40g weight by piece and were healthy and free from pests and diseases. Those that did not meet the criteria will be considered as non-marketable roots including those roots that are damaged by pests and diseases.
2. **Number of marketable and non-marketable roots per harvestable area-** this will be obtained by sorting and counting the number of the marketable and non-marketable roots per treatment plot within the harvestable area.
3. **Total Root yield ($t\ ha^{-1}$)-** This will be obtained by weighing all storage roots uprooted the harvestable area per treatment plot.

$$\text{Root yield } (\text{tha}^{-1}) = \frac{Root\ yield\ (kg\ plot{-}1)}{Harvestable\ area\ (10.5\ m2)}\ x = \frac{10{,}000\ m2\ ha{-}1}{1{,}000\ kg\ ton{-}1}$$

4. **Harvest Index (HI).** HI will be determined by taking the ratio of the economic yield (weight of roots) to the biological yield (weight of roots +herbage yield) on a fresh weight basis. All the sample plants per treatment per replication within the harvestable area were harvested to measure HI value and was calculated using the formula below:

$$HI = \frac{\text{Economic Yield (total root yield)}}{\text{Biological Yield (root yield + herbage yield)}}$$

D. Economic Analysis

Cost and Return Analysis- Net return is the income remaining after deducting all costs, both fixed and variable.

The formula will be:

$$NR = TR - TC$$

Where:

NR= Net Return

TR= Total Return

TC= Total Cost

Return on Investment- The ROI will be obtained by recording the total produce and will be calculated.

The formula will be:

$$ROI= (NR/FC) \times 100$$

Where:

ROI= Return on investment

NR= Net Return

FC= Fixed Cost

E. Agrometeorological Data

Data on total monthly rainfall (mm), average daily minimum and maximum temperatures (˚C) and relative humidity (%) one week before planting up to the time of harvesting will be taken from the records of the Department of Science and Technology (DOST) -CARAGA.

Statistical Analysis

The data will be computed and the analysis of variance (ANOVA) was analyzed using Statistical Tool for Agricultural Research (STAR) software. Comparison of means was done using Tukey's Honest Significant Difference (HSD) Test.

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APPENDICES

✔ **To compute how many fertilizers will be applied in plot (Full dose):**

Recommended rate: **40-40-60 kg/ha**

Amount of complete $= \left(\frac{\text{Recommended Rate}}{\text{Fertilizer Grade}} \times 100 \right)$

$= \frac{40 \text{ kg/ha}^{-1}}{16} \times 100$

$\mathbf{= 250 \text{ kg/ha}^{-1}}$

$250 \text{ kg/ha}^{-1} = \frac{x}{20m^2}$

$x = \frac{250 \text{ kg/ha}^{-1} \times (11.25 \text{ m}^2)}{10000 \text{ m}^2}$

$\mathbf{= 0.28 \text{ kg/ha}^{-1}}$ **or** $\boxed{\mathbf{280g \text{ plot}^{-1}}}$

Remaining 20;

Amount of MOP $= \left(\frac{\text{Recommended Rate}}{\text{Fertilizer Rate}} \times 100 \right)$

$= \frac{20 \text{ kg/ha}^{-1}}{60} \times 100$

$\mathbf{= 33.3 \text{ kg/ha}^{-1}}$

$33.3 \text{ kg/ha}^{-1} = \frac{x}{20m^2}$

$x = \frac{33.3 \text{ kg/ha}^{-1} \times (11.25 \text{ m}^2)}{10{,}000 m^2}$

$\mathbf{= 0.0375 \text{ kg/ha}^{1}}$ **or** $\boxed{\mathbf{37.5g \text{ plot}^{-1}}}$

✔ **To compute how many fertilizers will be applied in each row (Full dose):**

$x = \frac{\text{Amount of NPK}}{\text{No. of row per plot}}$

$= \frac{280g \text{ plot}^{-1}}{4}$

$= \frac{70g}{\text{No. of hill per row}}$

$= \frac{70g}{9}$

$\boxed{\mathbf{x = 7.78g/row}}$

$x = \frac{\text{Amount of MOP}}{\text{No. of row per plot}}$

$= \frac{37.5g \text{ plot}^{-1}}{4}$

$= \frac{9.38g}{\text{No. of hill per row}}$

$= \frac{9.38g}{9}$

$\boxed{\mathbf{x = 1.04g/row}}$

✔ **To compute how many fertilizers will be applied in plot (Half dose):**

Recommended rate: 40-40-60 kg/ha

$$\text{Amount of complete} = \frac{\text{Recommended Rate}}{\text{Fertilizer Grade}} \times 100$$

$$= \frac{40\ kg/ha^{-1}}{16} \times 100$$

$$= 250\ kg/ha^{-1}/2$$

$$\mathbf{= 125\ kg/ha^{-1}}$$

$$125\ kg/ha\text{-}1 = \frac{x}{20m^2}$$

$$x = \frac{125\ kg/ha^{-1} \times (11.25m^2)}{10000\ m^2}$$

$$=0.141\ kg/ha^{-1} \text{ or } \boxed{\mathbf{141g\ plot^{-1}}}$$

Remaining 20;

$$\text{Amount of MOP} = \frac{\text{Recommended Rate x 100}}{\text{Fertilizer Rate}}$$

$$= \frac{20\ kg/ha^{-1}}{60} \times 100$$

$$= 33.3\ kg/ha^{-1}/2$$

$$\mathbf{=16.65\ kg/ha^{-1}}$$

$$16.65\ kg/ha^{-1} = \frac{x}{20m^2}$$

$$x = \frac{16.65\ kg/ha^{-1} \times (11.25m^2)}{10{,}000m^2}$$

$$=0.0187\ kg/ha^{-2} \text{ or } \boxed{\mathbf{18.7g\ plot^{-1}}}$$

✔ **To compute how many fertilizers will be applied in each row (half dose):**

$$x = \frac{\text{Amount of NPK}}{\text{No. of row per plot}}$$

$$= \frac{141g\ plot^{-1}}{4}$$

$$= \frac{35.25g}{\text{No. of hill/row}}$$

$$= \frac{35.25g}{9}$$

$$\boxed{\mathbf{x = 3.92g/row}}$$

$$x = \frac{\text{Amount of MOP}}{\text{No. of row per plot}}$$

$$= \frac{18.7g\ plot^{-1}}{4}$$

$$= \frac{4.675g}{\text{No. of hill per row}}$$

$$= \frac{4.675g}{9}$$

$$\boxed{\mathbf{x =0.52g/row}}$$

✔ **To compute how many rows and hills per plot:**

No. of Row = (length of plot -2 border length)/Row Spacing

No. of Column = (width of plot – 2 border width)/hill spacing

Length of plot- = 4m

Width of plot = 5m

Row spacing = 75cm (0.75m)

Border length = 0.125m

Border width = 0.375m

Solution:

NR = 4m-(2x0.125m)/0.75m

= (3.75m-0.25m)/0.75m

= 3.5/ 0.75m

= 4.8 row

NC = 5m – (2x0.375m) / 0.25m

= (3m-0.75m) / 0.25 m

= 2.25 / 0.25

= 9 hill

= 9x4.8 = 43.2 cuttings of sweet potato per plot

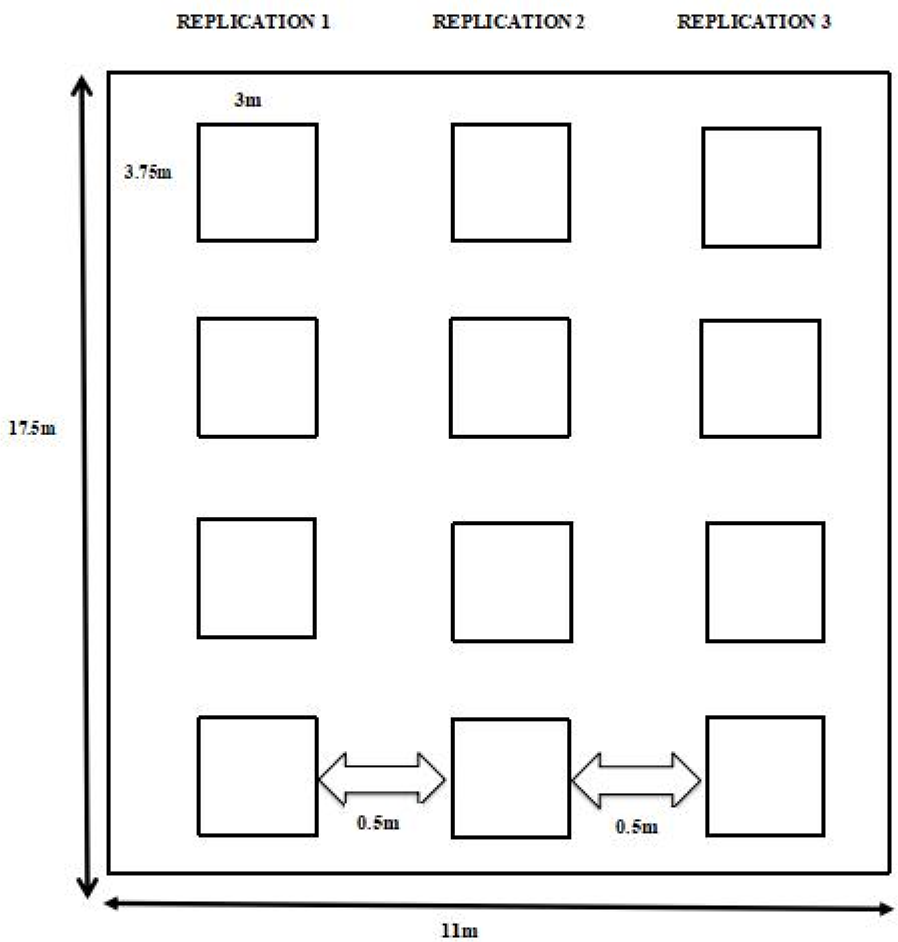
✔ **To compute how many cuttings will be use in the whole experiment:**

x = No. of cuttings per plot x no. of treatment

= 43.2x12

x = 518.4 cuttings in the whole experiment

Figure 1. Experimental area illustrating the different treatments in each replication



Total Area=L x W

=17.5m x 11m

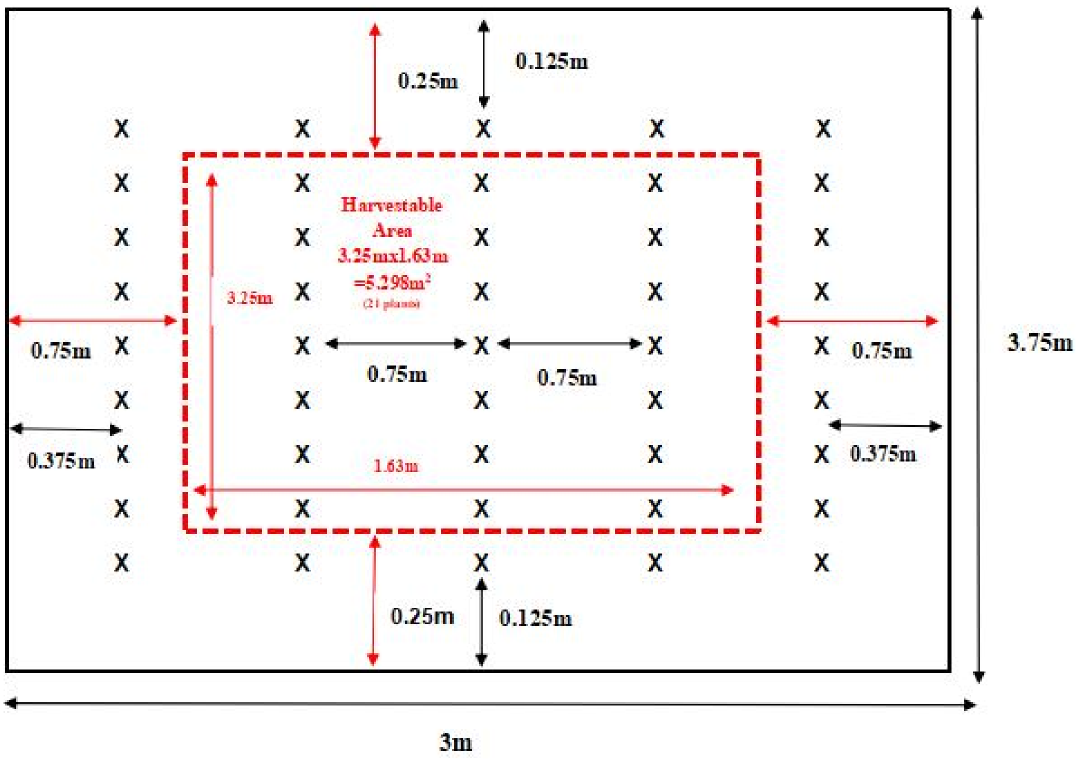
=192.5m^2

Plot size: 3.75m x 3m

Spacing between replication: 0.5m

Spacing between plot: 0.5m

Figure 2. Harvestable area (5.298m^2) at 75cm x 25 cm plant spacing



Plot size: 3.75m x 5m

Row spacing: 0.75m

Hill spacing : 0.25m

Border effect per plot: 0.375m x 0.125m