FOLIAR NUTRITION IN SWEET POTATO (*Ipomoea batatas* (L.) Lam.) FOR VINE TOP AND TUBER YIELD

by

BHUPASAMUDRAM NEERAJA

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"FOLIAR NUTRITION IN SWEET POTATO (*Ipomoea batatas* (L.) Lam.) FOR VINE TOP AND TUBER YIELD"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

B. Neeraja

Place: Vellayani

Date: 15-07-2024

Bhupasamudram Neeraja

(2021-11-106)

CERTIFICATE

Certified that this thesis entitled **"FOLIAR NUTRITION IN SWEET POTATO (*Ipomoea batatas* (L.) Lam.) FOR VINE TOP AND TUBER YIELD"** is a record of bonafide research work done independently by **Ms. Bhupasamudram Neeraja (2021-11-106)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Place: Vellayani
Date : 15.07.2024

Dr. Renjan B.
Assistant Professor (Agronomy)
Farming Systems Research Station,
Sadanandapuram, Kollam-691 531

CERTIFICATE

We, the undersigned members of the advisory committee of Ms. Bhupasamudram Neeraja (2021-11-106), a candidate for the degree of Masters of science in Agriculture with major in Agronomy, agree that the thesis entitled **"FOLIAR NUTRITION IN SWEET POTATO (*Ipomoea batatas* (L.) Lam.) FOR VINE TOP AND TUBER YIELD"** may be submitted by Ms. Bhupasamudram Neeraja in partial fulfilment of the requirement of degree.

Dr. Renjan B.
(Major Advisor, Advisory Committee)
Assistant Professor (Agronomy)
Farming Systems Research Station,
Sadanandapuram, Kollam-691 531

Dr. Shalini Pillai P.
(Member, Advisory Committee)
Professor and Head
Department of Agronomy,
College of Agriculture, Vellayani,
Thiruvananthapuram- 695 522

Dr. Susha V.S.
(Member, Advisory Committee)
Assistant Professor (Agronomy)
Department of Agronomy,
College of Agriculture, Vellayani
Thiruvananthapuram- 695 522

Dr. Bindu B.
(Member, Advisory Committee)
Assistant Professor (Horticulture)
Farming Systems Research Station,
Sadanandapuram, Kollam-691 531

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

B:C ratio	Benefit cost ratio
CD (0.05)	Critical difference at 5 % level
CF	Crude fibre
cm	Centimeters
cm^2	Centimeter square
CP	Crude protein
DAP	Days after planting
DMP	Dry matter production
dsm^{-1}	Deci siemens per meter
EC	Electrical conductivity
fb	Followed by
Fe	Iron
Fig.	Figure
FYM	Farm yard manure
g	gram
g kg^{-1}	gram per kilogram
g $plant^{-1}$	gram per plant
HI	Harvest index
ha^{-1}	per hectare
K/K_2O	Potassium
i.e.,	that is
KAU	Kerala agricultural university
Kg ha^{-1}	Kilogram per hectare
LAI	Leaf area index
max	Maximum
mg g^{-1}	Milligram per gram

mg 100 g^{-1}	Milligram per hundred gram
min	Minimum
N	Nitrogen
Na	Sodium
NO_3	Nitrate
NS	Non-significant
P	Phosphorus
P_2O_5	Phosphoric acid
pH	Potenz hydrogen
$plant^{-1}$	per plant
RBD	Randomized block design
RDF	Recommended dose of fertilizers
SE (m) ±	Standard error mean
Temp.	Temperature
viz	namely
Zn	Zinc
T	Tonnes
L	Liter
et.al	And others
No	Numbers

LIST OF SYMBOLS

%	Per cent
@	at the rate
^{o}C	degree Celsius
₹	Indian rupee
*	note

Dedicated to……

family and friends

Introduction

1. INTRODUCTION

Sweet potato (*Ipomoea batatas* L. (Lam) is a major staple food crop, especially in developing countries. Sweet potato is being cultivated as a valuable source of human food, industrial raw material as well as animal feed in over 50 countries. Among the food crops, sweet potato is ranked as the fifth most important food crop (FAOSTAT, 2017) and is important for food security in tropical, subtropical and temperate regions of the world not only for its high dry matter per unit area per unit time but also as the cheapest source of minerals, vitamins and antioxidants. Owing to its vast utilization in domestic and industrial use, this crop was biofortified to combat malnutrition. Orange-fleshed and purple-fleshed sweet potato cultivars are being used for biofortification to improve the accessibility of diversified nutrition (Laurie *et al*., 2015).

According to Prakash *et al*. (2017), sweet potatoes are one of the key staple food crops in India for the underprivileged population. Sweet potatoes are grown in nearly every state in India, but only four states *viz,* West Bengal, Uttar Pradesh, Kerala, and Odisha account for 76 per cent of the country's total acreage and 79 per cent of its production. Even though Kerala has a smaller area dedicated to sweet potato farming than Odisha, the state nevertheless produced around 23 per cent of the nation's total sweet potatoes.

Sweet potato leaves are considered to be a leafy vegetable consumed by humans, which is currently widely used as food due to its high yield, drought tolerance, and ability to grow in different climates and farming systems (Yan *et al*., 2016). It contains essential minerals of Na, Mg, P, Ca, and K which ranged from 8.06−832.31, 220.2−910.5, 131.1−2639.8, 229.7−1958.1, and 479.3−4280.6 mg in 100 g^{-1} respectively, while the minerals Cu, Zn, Mn, and Fe ranged from of 0.7−1.9 mg, 1.2−3.2 mg, 1.7−10.9 mg, and 1.9−21.8 mg in 100 g^{-1} respectively (Sun *et al*., 2014). Leaves of sweet potato hold niacin (856−1498 μg 100 g^{-1}), vitamins B6 (120−329 μg 100 g^{-1}), B2 (248−254 μg 100 g^{-1}), C (62.7−81 mg/100 g), E (1.39−2.84 mg/100 g), and biotin (3−8 μg 100 g^{-1}) (Ishida *et al*., 2016).

Leaves of sweet potato have been recognized as a potent anti-cancer food source against various cancer cells, including HCT-116 colon cancer, HeLa cancer, MCF-7 breast cancer, prostate cancer, colorectal cancer and lung cancer (Lim *et al*., 2013; Vishnu *et al*., 2019) due to high content of anthocyanins and polyphenols (Kurata *et al*., 2007).

Sweet potato greens have antimicrobial properties that are said to be good for gut health, rich in vitamins, rich in dietary fibre and also help to boost immunity. Among the tropical tubers, sweet potato is the most nutritious in terms of macro and micronutrients contained in both the tuber and green leaves (John, 2011). Sweet potato has low glycemic index value of 54 which falls under low GI category and this makes it acceptable to health-conscious people (Olaoye and Oladipo 2022).

Sweet potato production as a dual-purpose food-security crop has been steady, but there is a scarcity of information on agronomic practices that may lead to optimum production of tuberous roots and shoots. In root and tuber crops as is the case with sweet potato, sink competition between vegetative growth and production of roots often manifests. The reduction in the vegetative growth of plants can increase the translocation of photoassimilates from the shoot to the storage roots and increase the sweet potato yield (Chen *et al*. 2014; Njiti *et al*. 2013).

Age at harvest is an important management factor that affects sweet potato fodder and tuberous root yield as well as quality (Frankow-Lindberg and Lindberg, 2003). Plants whose vines were harvested early days after planting produced significantly lower total tuberous roots than plants whose vines were not harvested (Ahmed *et al*., 2012).

Foliar sprays improve focused distribution, quick responsiveness, and the efficiency of nutrient uptake. Foliar sprays can alleviate nutritional deficiencies, increase plant vigour, and improve crop output when used properly. N affects the amount of biomass produced and distributed in sweet potato plants, as well as increased the yield of the stored roots that are harvested (Duan *et al*. 2019; Kakabouki *et al*. 2020).

A high nitrogen delivery can lead to lush vine and leaf development, which often reduces root yield. High N concentrations promote vine growth as opposed to root formation (Nedunchezhiyan *et al*., 2012).

The micronutrients play a critical role in respiration, photosynthesis, enzyme activation, natural hormone production, N metabolism, chloroplast development, and chlorophyll synthesis. Saif EI-deen *et al*. (2015) found that plants sprayed with a combination of micronutrients outperformed unsprayed ones in terms of performance. Applying a micronutrient mixture as a foliar spray often had substantially better results than the control, increasing marketable output and overall production (Hassan *et al*., 2005).

Keeping all these points, the present study was formulated to assess the effect of foliar nutrition on growth, vine top and tuber yield in sweet potato (*Ipomoea batatas* (L.) Lam.).

Review of literature

2. REVIEW OF LITERATURE

Sweet potato (*Ipomoea batatas* L. (Lam)) is a crucial staple crop in many developing nations, cultivated in over 50 countries for its diverse uses in human diets, industry, and animal feed. According to FAOSTAT (2017), it ranks as the fifth most significant food crop globally, particularly valued for its high yield per unit area and time, as well as its affordability and nutritional richness. It addresses malnutrition and enhances food security, especially in regions with limited resources.

Various agricultural techniques have been explored to improve sweet potato yield and quality. These include foliar application of urea, micronutrient mixtures, and the management of vine harvest intensity. This chapter aims to provide a comprehensive review of these practices, drawing from relevant literature on sweet potato cultivation and insights from research on other tuber crops. This chapter contributes to ongoing efforts to enhance sweet potato production and its role in global food security and sustainable agriculture by synthesizing existing knowledge and identifying areas for further investigation.

2.1 EFFECT OF MAJOR NUTRIENT- NITROGEN APPLICATION EFFECTS ON GROWTH AND YIELD ATTRIBUTES OF SWEET POTATO

2.1.1 Growth Characters of Sweet potato

Hartemink *et al*. (2000) conducted field study using varied levels of nitrogen fertilizer (ranging from 0 to 400 kg ha^{-1}) in split applications and reported that sweet potato vines utilized up to 156 kg N ha^{-1}. Despite the negative impact of nitrogen on yield, sweet potatoes displayed superior above-ground biomass production and higher nitrogen use efficiency.

Okpara *et al*. (2009) proved that application of nitrogen up to 120 kg N ha^{-1} registered increased leaf area index, heightened light absorption and greater shoot dry matter.

Trials conducted in Coimbatore, Tamil Nadu, demonstrated that application of 80 kg of nitrogen, 50 per cent administered as the basal and the remaining 50 per cent applied as foliar spray using 2 per cent urea at 30, 60, and 90 DAP, effectively improved foliage growth, leaf area, and vine length (John *et al*. 2011).

Du and Kong (2019) examined the impact of four nitrogen treatments on sweet potato yields: basal (100:0), 80:0, 40:40, and nitrogen omission. They found that basal application reduced yields by 20 % while split application increased yields by 16.6% to 19.0%. The study also proved that split application of nitrogen was more efficient in nitrogen utilization, displaying higher levels of agronomic use efficiency, recovery efficiency, physiological efficiency, and partial factor productivity.

As per Nongkhlaw *et al*. (2021), the application of 65 kg ha^{-1} of nitrogen resulted in the significant highest Photosynthetic Growth Efficiency (PGE) between 70 and 90 days after planting. Similarly, during the period from 50 to 70 DAP, a larger N dose led to a notable increase in Net Assimilation Rate (NAR), particularly evident at 65 kg ha^{-1}. Moreover, within the same timeframe and at a 65 kg ha^{-1} N dosage, Crop Growth Rate (CGR) showed an upward trend with increasing nitrogen levels.

Dong *et al*. (2022) investigated sweet potato plants treated with a modified Hoagland nutrient solution at different levels and found that N100 treatment encouraged the formation of cambium and promoted faster growth.

Kumar *et al*. (2023) reported that application of super-optimum nitrogen levels ie., 125% @ 62.5 kg ha^{-1} significantly improved growth attributes of Sree Arun and Sree Kanaka. They observed that, there were noticeable increases in vine length (257.5 cm), the number of branches per vine (8.17) significantly higher leaf count per vine (108.5) and a leaf area index of (5.46).

Lemma *et al*. (2023) revealed that the recommended nitrogen and phosphorus levels exhibited notably higher total nitrogen values, resulted in increased chlorophyll levels, photosynthetic rates, leaf expansion, total leaf count, and accumulation of dry matter. They also observed that higher agronomic use efficiency, nutrient absorption, and physiological use efficiency.

2.1.2 Yield attributes, yield and quality of sweet potato

Mulkey *et al*. (1994) reported that basal application of 50.4 kg N ha^{-1} enhanced the formation of storage roots and the yield of sweet potato. Their findings revealed that the basal nitrogen treatment resulted in increased storage roots per plant and the highest yield.

Hartemink *et al*. (2000) proved detrimental effect of high nitrogen fertilizers on both the marketable and non-marketable sweet potato yields. Marketable sweet potato yield was highest at 100 kg N ha^{-1} and lowest at 400 kg N ha^{-1}. Above-ground biomass was not significantly increased up to 200 kg N ha^{-1}, but higher applications yielded two times more vines up to 45.3 Mg ha^{-1}.

Ankumah *et al*. (2003) noted that early-maturing cultivars consistently outperformed their late-maturing counterparts, yielding significantly higher total and marketable yields. Furthermore, single nitrogen treatments led to substantially larger yields of storage roots compared to control conditions. They opined that late-maturing cultivars exhibited greater nitrogen recovery efficiency than early-maturing ones, while the latter demonstrated higher yields and physiological efficiencies and the physiological efficiency may serve as a more accurate predictor of yield than nitrogen recovery efficiency.

Application of humic acid-urea (HA-Urea) effectively stimulated the early-stage differentiation of storage roots and increased the number of storage roots per plant which resulted in a substantial increase in yield by 29.56%. HA-Urea application notably elevated the number of storage roots per plant by 14.01% and the average fresh weight per storage root by 13.7%. The synergistic enhancement in both biological yield and harvest index contributed to the overall improvement in yield facilitated by HA-Urea (Chen *et al*., 2017).

Fernandes *et al*. (2018) experimented and found that optimal root yield was observed when sweet potatoes were cultivated following legume and non-legume species, achieving N rates of 49.6 and 76.6 kg N ha^{-1}, respectively. The presence of legumes reduced the necessity for mineral nitrogen fertilizers by up to 35.2% when used as cover crops for sweet potatoes in tropical climates.

Relente *et al*. (2020) reported that significant increase in various parameters such as shoot-root ratio, weight and the number of marketable roots were enhanced when N levels increased. The harvest index of the plants remained consistent with applications of 40 and 80 kg N ha^{-1}. They also observed that elevating N levels from 0 to 160 kg ha^{-1} led to a higher content of total crude protein and total N in the leaves.

Nongkhlaw *et al*. (2021) found that the application of 65 kg ha^{-1} of nitrogen resulted in increased tuber yield and growth. Additionally, they observed that the highest harvest index value of 34.31% was reported when nitrogen was applied at a rate of 65 kg ha^{-1}, representing a significant improvement compared to the control.

According to Ribeiro *et al*. (2021), application of 50 kg ha^{-1} of nitrogen during the rainy season led to the greatest yield of fresh storage roots. However, in the dry season, while N fertilization boosted N uptake, it did not enhance root output. They opined that decreasing a plant's vegetative growth could improve the transfer of photoassimilates from the shoot to the storage roots, consequently increasing sweet potato yield.

Dong *et al*. (2022) observed that the application of nitrogen significantly boosted the proportion of initiated storage roots and promoted cambium development in immature adventitious roots of sweet potatoes. Application of nitrogen at a rate equivalent to 50 kg N ha^{-1} increased the length of both the first-order lateral root and the second-order lateral root by 78% and 73%, respectively.

The impact of nitrogen on two distinct sweet potato cultivars ie., Sree Arun and Sree Kanaka revealed that application of super-optimal nitrogen levels (125 per cent @ 62.5 kg ha^{-1}) led to the highest tuber yield (15.97 t ha^{-1}). When super-optimal nitrogen levels were applied, there was a significant increase in the quality parameters for crude protein (59.1 per cent) and crude fibre (2.49 per cent) (Kumar *et al*., 2023).

2.1.3 Growth characters of tuber crops other than sweet potato

Hartemink *et al*. (2000) emphasised detrimental effect of high dose of nitrogen fertilizers on both the marketable and non-marketable taro corm yields. High nitrogen treatments (400 kg ha^{-1}) resulted in the production of 26 Mg ha^{-1} more vines compared to the absolute control treatment. They also reported that less than 11 kg ha^{-1} of nitrogen was absorbed in the marketable corms, while more nitrogen was being absorbed in the non-marketable corms and higher dose of soil application leads to loss of tubers as non-marketable forms.

El-Sharkawy (2007) conducted an experiment involving three nitrogen sources viz., ammonium sulfate, ammonium nitrate, and urea followed by defoliation treatments (4, 5, 6 leaves plant^{-1}), along with a control in taro. The findings revealed that usage of ammonium sulfate as nitrogenous fertilizer resulted substantial enhancement in plant height by 15.56% to 26.85% and 15.15% to 33.51% and chlorophyll content by 6.74% and 6.98% respectively, across the two seasons.

Razaei *et al*. (2016) compared growth with and without the application of urea in lesser yam and observed that plants treated with nitrogen showed higher leaf count, total stem length, and dry weights of aerial parts compared to control plants. Although the number of main stems remained consistent at 120 DAP, it increased post-N treatment at 180 and 240 DAP. N-treated plants demonstrated a higher SPAD value (36.6) compared to control plants.

Thummanatsakun and Yampracha (2018) conducted an experiment utilizing different nitrogen levels in cassava plants revealed that increasing nitrogen levels up to 1500 µ mol L^{-1} resulted a substantial improvement in various parameters, including plant height (206.92 cm), SPAD values of both upper and lower leaves (34.64), fresh and dry leaf blade weights, stem+petiole weights and total weight.

An experiment in cassava with two varieties, revealed that highest moisture content (0.467%) and the lowest crude fibre content (14.13%) were achieved with the application of 160 kg N ha^{-1}. The highest crude fat content in cassava leaves (18.49%) was observed with 120 kg N ha^{-1}. Cassava variety Kello which treated with 160 kg N ha^{-1} exhibited the highest leaf nitrogen levels and the highest crude protein content in leaves (30.01 per cent) (Derara *et al*., 2020).

2.1.4 Yield and yield attributes of tuber crops other than sweet potato

El-Sharkawy (2007) proved that there was a significant increase in the fresh weight of corms per plant, ranging from 24.39% to 12.19% in taro as the nitrogen fertilizer level was raised to 80 kg N.

Comparative study between the application and without the application of urea revealed that at 180 DAP the N treatment resulted in reduced moisture content in the lesser yam tubers and by 240 DAP it was comparable to the control. The dry weight of the roots consistently exceeded that of the control at all observation times which indicated a positive influence of the nitrogen treatment on root development. The total nitrogen content of the seed tubers was 1.04%, whereas the nitrogen content of the leaves, stems, tubers, and roots under the N treatment for lesser yam surpassed that of the control (Razaei *et al*., 2016).

Thummanatsakun and Yampracha (2018) experimented by treating cassava plants with different nitrogen levels (500 µ mol L^{-1}, 1000 µ mol L^{-1} and 1500 µ mol L^{-1}) proved a substantial improvement in total fresh weights per plant (451 g, 749 g, and 900.62 g, respectively), total dry weights per plant (190.26 g, 279.00 g, and 321.86 g, respectively) and total nitrogen intake per plant (14.54 g, 23.14 g, and 27.70 g respectively).

Ahmed *et al*. (2018) conducted an experiment that resulted in a notable increase in colocasia tuber yield, the number of tubers per plant, weight of 1000 tubers, and tuber size (average length and diameter) and yield with the application of 60 kg N ha^{-1}.

2.2 EFFECT OF FOLIAR APPLICATION OF MICRONUTRIENT MIXTURE ON GROWTH CHARACTERS AND YIELD OF SWEET POTATO

2.2.1 Growth characters of sweet potato

EI-tohamy *et al*. (2014) found that foliar application of chelated form of micronutrients: Fe (1g L^{-1}), Zn (0.3 g L^{-1}), Mn (1g L^{-1}) and B (0.3 g L^{-1}) had a significant positive effect on vegetative growth like plant length (300 cm) and the number of branches (14). The foliar application of Fe was most effective in promoting plant length, while the B application resulted in the best overall outcomes. Moreover, treatments involving Fe, Mn, Zn, and B showed significant effects on the total dry matter production of sweet potato in all three cultivars examined.

Saif EI-deen *et al*. (2015) observed that foliar application of the micronutrient blend i.e., Zn-EDTA (13 per cent), Mn-EDTA (13 per cent) and Fe-EDTA (13 per cent) significantly increased plant height (146.6 cm), dry weight (131.36 g), and leaf area (1.028 m^{-2}) at a concentration of 50 ppm.

The foliar application of micronutrient blends (Fe, Zn, Mn and Cu) added as Fe-EDTA (6 per cent Fe), Zn-EDTA (15 per cent Zn), Mn-EDTA (12 per cent Mn) and $CuSO_4 .5H_2O$ (25.45 per cent Cu) of the mixture at varying concentrations (0, 10, 20 and 30 g 100 L-1 H_2O) resulted in enhanced plant growth. Furthermore, increasing the concentration of the foliar-applied microelement to 0.3 g L^{-1} significantly improved the fresh weight of vines, the number of branches per plant, and plant length compared to untreated control plants (Ali, 2019).

Arya (2019) proved that foliar application of 0.1 per cent micronutrients at 30 DAS resulted enhanced vine length (155.50 cm), shoot weight (612g) and specific leaf area (389.44 cm^2 g^{-1}).

Sharaf-Eldin *et al*. (2019) emphasized the influence of boron spray on sweet potato. Their findings revealed that repeated application of boron at concentrations of either 40 or 50 ppm led to improved vegetative growth parameters, increased leaf area index, enhanced absolute growth rate, and elevated net assimilation rate

2.2.2 Yield and yield attributes of sweet potato

According to Hassan *et al*. (2005) documented that the foliar application of a micronutrient blend (Zn, Fe and Mn each at 100ppm) outperformed the control, leading to a significant increase in overall yield by 30 per cent and marketable yield by 31.84 per cent and 12.57 per cent respectively, during the first and second seasons. Additionally, micronutrients notably boosted the total yield per plant in both seasons while reducing non-marketable yield by 8 per cent in the second season alone.

EI-tohamy *et al*. (2014) observed that foliar micronutrient application i.e., Fe (1 g L^{-1}), Zn (0.3 g L^{-1}), Mn (1 g L^{-1}) and B (0.3 g L^{-1}) significantly increased yield (35 t ha^{-1}), root count (5), root length (22 cm) and root diameter (7.5 cm). Foliar application of boron registered the highest yield. All the cultivars were positively responded to the application of Fe, Mn, Zn, and B significantly to the overall yield.

Saif EI-deen *et al*. (2015) noted that plants subjected to a micronutrient blend via foliar spraying outperformed untreated ones. The use of the micronutrient combination i.e., Zn-EDTA (13 per cent), Mn-EDTA (13 per cent) and Fe-EDTA (13 per cent) significantly boosted overall yield (22.74 t ha^{-1}), marketable yield (20.70 t ha^{-1}), individual weight (208 g), and diameter (5.4 cm). Additionally, the application of the micronutrient blend through foliar spraying resulted in a notable increase in nitrogen concentrations, particularly during the first growing season.

According to Singh *et al*. (2016) unlike lower concentrations, 30 ppm zinc led to the highest tuber yield. These treatments also resulted in maximum values for tuber length (19.82 cm), diameter (5.97 cm), overall yield (1102 g $plant^{-1}$) and the highest number of tubers per plant (4.18).

Sun *et al*. (2019) observed that the yield increased by 49.8 per cent, 27 per cent and 25.1 per cent for the Fe-Zn-AA (ascorbic acid) foliar treatment compared to the control.

The foliar spray solution up to 30 g per 100 L of micronutrient blends (Fe, Zn, Mn and Cu) added as Fe-EDTA (6 per cent Fe), Zn-EDTA (15 per cent Zn), Mn-EDTA (12 per cent

Mn) and $CuSO_4 .5H_2O$ (25.45 per cent Cu) boosted the total tuber yield and its attributes (Ali, 2019).

The studies of Arya (2019) indicated that micronutrients and growth regulators had a significant impact on yield. NPK as per POP along with foliar nutrition of micronutrient mixture (Fe+Zn+Mn+B @ 0.1 per cent each) + 500ppm cycocel at 30 DAS showed the most favourable outcomes for tuber characteristics like length, diameter, weight and yield. It was also noted that quality parameters like total sugar (34.48 mg g-1) and protein content (38.40mg g-1) were found to be higher in tubers.

Sharaf-Eldin *et al*. (2019) revealed that repeated application of boron at concentrations of either 40 or 50 ppm led to enhanced quality of tuberous roots and a yield registered as 26.4 t ha^{-1}.

2.2.3 Growth characters of tuber crops other than sweet potato

Ram and DY (2014) found that increasing the levels of the chelated micronutrient mixture (Fe + Zn + Mn + Cu) added as Fe-EDTA (6 per cent Fe), Zn EDTA (15 per cent Zn), Mn-EDTA (12 per cent Mn), and $CuSO_4.5H_2O$ (25.45 per cent Cu) up to 30 per cent concentration had significant augmenting effects on cassava plant height (145cm), leaf number (104), and branch number (3.82) per plant in both seasons.

Setiawan *et al*. (2017) investigated the effects of different levels of micronutrient fertilizer on the growth of cassava. The findings revealed that higher doses of fertilizer (40 kg ha^{-1}) resulted in an increase in leaf dry weight with a decrease in leaf count.

Studies in cassava indicated notable improvements in SPAD chlorophyll meter readings, visual evaluations of plant nutrient deficiencies, leaf area, harvest index, and plant height (108 cm) following the application of micronutrient foliar sprays 2 per cent $MnSO_4{\bullet}4H_2O$ + 2 per cent $ZnSO_4{\bullet}7H_2O$ + 0.5 per cent $CuSO_4{\bullet}5H_2O$ at 15 DAP and 30 DAP, (Janket *et al*., 2018).

The research conducted by Ramesh *et al*. (2019) showed the effects of secondary and micronutrients (Mg, S, Zn, B) via foliar spray on potato for augmenting the growth parameters. Significant improvements in plant height (23.55 cm, 28.43cm, and 33.89 cm at 45, 60, and 75 DAP respectively) were registered.

Kunlanit and Siritrakulsak (2023) concluded that fertilizer applications (15-15-15 at a rate of 313 kg ha^{-1}, 2 per cent Zn, 4 per cent Zn and 6 per cent Zn) resulted significant increase in plant height compared to the untreated control. Notably, the fertilization combined with 6 per cent Zn tended to promote taller plants consistently across all growth stages, particularly evident at 6-8 MAP.

2.2.4 Yield and yield attributes of other than sweet potato

The chelated micronutrient mixture (Fe + Zn + Mn + Cu) added as Fe-EDTA (6 per cent Fe), Zn EDTA (15 per cent Zn), Mn-EDTA (12 per cent Mn), and CuSO4.5H2O (25.45 per cent Cu) up to 30 per cent resulted in improved cassava plant yields. Micronutrient combinations positively influenced parameters such as dry matter percentage, starch content, and total sugar content. Application of micronutrient chelates led to enhanced tuber production (13.81 t ha^{-1}) and a significant 20 per cent increase in root weight (Ram and DY, 2014).

Setiawan *et al*. (2017) investigated the effects of different levels of micronutrient fertilizer (20 and 40 kg ha^{-1}) on the storage root development of cassava. The findings revealed that higher doses of fertilizer resulted in increased storage root quantity and weight. Furthermore, there was a significant improvement in storage root quantity and density, coupled with an enhancement in starch structure.

Janket *et al*. (2018) noticed foliar applications of zinc, manganese, and copper in cassava impacted a significant increase in yield ranging from 30.6 per cent to 75.7 per cent.

Foliar application of secondary and micronutrients (Mg, S, Zn, B) on potato revealed significant improvements in yield parameters like tuber number (4.84 per plant), and yield (22.52 t ha^{-1}). Among the treatments, it was observed that magnesium foliar application yielded the highest values, followed by zinc, boron, and sulfur. (Ramesh *et al*., 2019).

According to Kunlanit *et al*. (2022) the most favourable cassava production outcomes in terms of yield, quality, and financial returns could be achieved by incorporating 18.75 kg ha^{-1} of $ZnSO_4.7H_2O$ in addition to recommended NPK. This approach effectively addressed zinc deficiency in loamy sand soils, highlighting the critical role of zinc in rectifying soil deficiencies for successful cassava cultivation.

Silva *et al*. (2023) opined that the most effective zinc sulfate fertilization on cassava dosage was 2.5 grams per plant, resulted in increased yield. Additionally, the zinc content in the tuberous roots saw a significant rise of over 40 per cent, contributing to their nutritional quality. The zinc fertilization also enhanced major nutrient absorption by the plants.

2.3 GROWTH AND YIELD PERFORMANCE OF SWEETPOTATO THROUGH VINE HARVESTING

2.3.1 Growth characters of sweet potato

David *et al*. (1993) studied the effect of successive foliage topping (15 cm) on two sweet potato varieties and found that the vine removal did not impact the total dry matter accumulation.

Kahn *et al*. (1993) conducted an evaluation of early maturing sweet potato cultivars following vine removal of 20 per cent and found that all cultivars displayed significant recovery in Leaf Area Index (LAI) after the removal of vines.

Frankow-Lindberg and Lindberg (2003) opined that the frequency of harvesting vines had a more pronounced effect on tuber yield than on leaf and stem development. However, they found that with a 20-day interval between harvests and the removal of 50 per cent of the total vine biomass at each harvest, leaf production reached its peak.

Olorunnisomo (2007) studied pruning schedules for sweet potato vines with varying intervals (4, 6 and 8 weeks intervals) and found that more frequent pruning led to improvements in dry matter production and nutrient digestibility of the vine.

Ahmed *et al*. (2012) found that when sweet potato vines were harvested 45 and 75 days after planting the weight reduction was registered in the tune of 36 per cent and 75 per cent respectively.

Early pruning (at 4 weeks after planting) significantly decreased growth characters than later pruning (at 8 weeks after planting and 12 weeks after planting). A substantial increase in vine length per plant (7.61 per cent), number of leaves per plant (14.95 per cent) and fresh pruning weight per plant (42.60 per cent) registered when pruning was practiced at 12 weeks after planting (Aniekwe, 2014).

Suminarti and Novriani (2017) documented that the degree of defoliation (50 per cent and 100 per cent) influenced growth parameters, such as the number of branches (increasing by up to 21.88% and 16.71%), number of leaves (increasing by up to 2.60% and 17.11%), and leaf area (increasing by up to 23.10% and 23.45%) respectively.

Gupta *et al*. (2018) estimated that sweet potato vines offer substantial nutritional value, with protein levels ranging from 3.02 per cent to 7.38 per cent and magnesium content varying from 443.73 ppm to 471.84 ppm and opined that sweet potato can serve as an alternative feed source for ruminants.

Pratama *et al*. (2019) studied the varied levels of trimming of sweet potato vine and found that trimming increased the growth rate of primary branch length compared to the untrimmed treatment.

According to Netsail *et al*. (2019) the apical cutting resulted significantly in the longest vine length compared to different cutting positions like middle cutting and basal cutting.

Hasanah *et al*. (2021) examined the effects of potassium fertilizer as the first factor and pruning as the second factor in sweet potato and revealed that the foliar application of 0.7 per cent KCl and pruning up to two tendrils led to a notable increase in the vine length at 10-11 weeks after planting.

2.3.2 Yield and yield attributes of sweet potato

David *et al*. (1993) studied the effect of successive foliage topping (15 cm) on two sweet potato varieties and found that the vine removal did not impact the total yield of storage roots. Georgia Jet produced more foliage tops than TU-82-1892 and the highest production was observed when foliage cutting was delayed until 75 days after planting.

Kahn *et al*. (1993) evaluated combined effect of early maturing sweet potato cultivars and vine removal. Results revealed that there was an overall decline in total yield, with the most notable reduction observed at a 20 per cent vine removal rate. Notably, TU-82-155 exhibited an increase in marketable yield despite the vine removal process.

Kiozya *et al*. (2001) assessed the different leaf harvesting frequencies among different varieties on yield of sweet potato. The results revealed there were slight differences among varieties and harvesting frequencies, with the highest leaf vegetable production observed with three vine harvests at monthly intervals. Harvesting twice was found to be most advantageous for both leaf and root yields.

Frankow-Lindberg and Lindberg (2003) suggested that the frequency of vine harvests had a greater impact on tuber production compared to the growth of leaves and stems. Decreasing the interval between vine harvests and tuber harvesting more plants lead to reduction in tuber yields. Moreover, harvesting leaves at 120 days resulted in a significantly lower leaf yield, but higher tuber yield. Sweet potato leaves are estimated a high crude protein (25.5 to 29 per cent) content and a low fibre concentration compared to stems.

Sweet potato vine pruning experiment with varying intervals (4, 6 and 8 weeks intervals) showed that frequent pruning did not notably enhance overall biomass production, tuber yield, or fodder yield. Tuber yield was declined while vine yield experienced an increase with longer intervals between cuts. As the frequency of pruning increased, there was an observed rise in crude protein content alongside a decrease in fibre content (Olorunnisomo, 2007).

Dukuh (2011) noted that removing foliage before harvesting led to a decrease in issues such as weevil infestation, fungal decay, and tuber bruising during the harvesting and handling processes. Nevertheless, this defoliation practice was found to elevate tuber sprouting rates, escalating from 2.5 per cent for untreated tubers to 14.2 per cent for tubers that were defoliated 12 days before harvest.

Ahmed *et al*. (2012) observed that sweet potato was best for the production of herbage for fodder without sacrificing yield when planted on ridges and harvested 105 days later when the plant had finished around 60 per cent of its growth phase. However, for plants whose vines were harvested 105 days after planting, only around 11 per cent of the total fresh tuberous root weight was declined.

Aniekwe (2014) examined the effect of pruning interval (zero pruning, 4, 8 and 12 weeks after planting) and yield characteristics of two sweet potato varieties and found out that late pruning showed substantial improvements in root tuber weight per plant (64.58 per cent).

Munetsi (2015) proved that 25 per cent vine pruning led to enhanced length of storage roots, higher root diameter, vine weight and root weight. The study also pointed out that for maximizing yields of both storage roots and vines, utilize cuttings from the middle and apical stems, along with pruning levels set at 25 per cent and 50 per cent.

Suminarti and Novriani (2017) investigated the influence of defoliation and planting positions and found that there was no significant interaction effect between defoliation and planting position across all parameters. However, yield was impacted by planting position, with higher yield recorded at 60 ^{0} and 90 ^{0} planting. The 90 ^{0} planting position resulted in the highest tuber yield of 35.31 t ha^{-1}.

Okunade *et al*. (2019) investigated the impact of four pruning regimes (0, 6, 8 and 10 weeks after planting (WAP) on various sweet potato varieties, revealing significant differences in proximate composition. The Ex-Igbariam and King J varieties exhibited decreased root dry matter and carbohydrate contents, whereas the Mother's Delight variety showed improvements in both parameters. Additionally, the King J variety demonstrated increased root dry matter and carbohydrate contents, with late vine pruning proving to be more beneficial for crude protein content.

Pratama *et al*. (2019) experimented with multiple levels of trimming (without trimming, trimmed after tendrils reach 50 cm long, 75 cm long, and 100 cm long) and showed that compared to the untrimmed control, the treatment where trimming occurred after tendrils reached 75 cm resulted in an 11.14 per cent increase in the maximum number of tubers. It was also recorded that the wet weight of untrimmed sweet potato plants was significantly higher, reaching a 66.66 per cent increase compared to trimmed plants.

Pruning levels and cutting positions significantly influenced the storage root length, diameter, and weight of sweet potato plants. The apical cutting resulted in the longest average root length whereas middle cutting and 25 per cent pruning contributed to the highest average root diameter and weight. Adoption of middle and apical stem cuttings could enhance both storage root and vine yield (Netsail *et al*., 2019).

Indawan *et al*. (2020) observed a marginal increase in vine yields but a decrease in storage root yield due to vine harvesting. While comparing the pruning intensity, a single-time pruned sweet potato estimated starch yields ranged from 2.34 to 6.67 t ha^{-1} while those subjected to three pruning times experienced a reduction of more than 50 per cent.

Mark and Korpu (2020) established that the severity of apical shoot harvesting affects the tuber yields of sweet potatoes. The apical vine top at a length of 15 cm resulted in a higher total tuber yield. The comparison of two varieties regarding the vine top harvesting indicated that the SHABA variety showed significantly greater vegetative growth and tuber yield compared to SPK-004. Interaction between variety and severity of apical vine top harvesting at a length of 15 cm significantly influenced the weight of unmarketable, marketable and total tubers.

Sweet potato twice vine harvesting at 25 per cent and 50 per cent intensity levels, resulted in significantly higher forage and storage root yields, along with improved characteristics of sweet potatoes, compared to higher intensity vine harvesting (Samai *et al*., 2021).

Hasanah *et al*. (2021) examined the effects of potassium fertilizer and pruning and revealed that the combination of 7 g KCl plant^{-1} and pruning up to two tendrils led to a notable increase in the length of the tubers per sample. However, the highest tuber weight per plot was achieved by combining the treatment of pruning up to three tendrils with 14 g KCl plant^{-1}.

According to Anabire (2021) the varietal differential responses were there in removal of sensitive leaves (located in the top 10 cm) from the aerial sections of plants four times a week. Among the varieties tested, Georgia Jet consistently yielded the highest quantities of storage roots and leaves, regardless of leaf harvesting practices.

Gbaraneh and Wilson (2021) found that planting sweet potatoes on raised seedbeds and vine harvesting after 16 weeks (representing about 80 per cent of the plant's growth phase) yielded the highest shoot output suitable for fodder, without evident impacts on root tuber yield.

Samai *et al*. (2021) studied four levels of leaf harvest intensity under upland conditions and observed that the highest foliage yield (26.30 t ha^{-1}) resulted from harvesting leaves twice at 25 per cent and 50 per cent intensity, significantly contributed optimal forage and storage root yields. Conversely, the lowest leaf yield (1.11 t ha^{-1}) was observed with 100 per cent harvest intensity at 30 DAP.

Sahu *et al*. (2022) reported that vine topping 30 cm at 60 DAP combined with foliar application of cycocel 500 ppm at 60 and 80 DAP significantly enhanced both root tuber yield and starch content (9.05 per cent).

Abewoy *et al*. (2022) emphasised the importance of 50 per cent pruning of sweet potato vines to maximize both root and vine productivity. The kabode variety of sweet potato demonstrated the highest tuber yield (36.41 t ha^{-1}) when subjected to 50 per cent vine pruning, followed by the Alamura variety (32.50 t ha^{-1}). Conversely, when the Alamura variety was pruned at 75 per cent it exhibited the lowest root output (21.33 t ha^{-1}). The un-pruned Kabode variety yielded the lowest vine output at 11.09 t ha^{-1} at the time of crop harvest.

2.3.3 Growth characters of tuber crops other than sweet potato

El-Sharkawy (2007) observed that soil application of 40 kg ha^{-1} ammonium sulfate combined with defoliation of 4 or 6 leaves produced comparable taller plants in taro. Results also indicated that, defoliating six leaves resulted in a 12.52 per cent and 8.86 per cent increase in leaf area during two growing seasons compared to the control (no leaf harvest).

In cassava, Ecco *et al*. (2019) found that the least damage in terms of height occurred when the plants were subjected to defoliation at 205 DAP. The defoliation during the early stages (45 and 90 DAP) had an uneven impact on plant height; with the most significant decrease occurring at 90 DAP with 100 per cent defoliation. Plant height and diameter were inversely proportional to the degree of defoliation especially when subjected to 100 per cent defoliation at 90 DAS.

Utomo *et al*. (2019) opined that leaf-cutting frequency had a significant role in the production of dry matter content of cassava. Highest dry matter content was registered with 2 times cuttings (32.21 per cent), control (28.18 per cent) and with 4 cuttings (21.15per cent).

Iseki *et al*. (2022) showed that mutual shading among yam leaves impeded yam growth. They observed that during the period of maximal shoot growth, reducing the number of leaves by approximately 25 per cent improved light utilization. The correlation suggested that thinned plants produced more shoots per land area compared to control. However, thinning the leaves led to a reduction in shoot dry weight by 20-30 per cent.

2.3.4 Yield and yield attributes of tuber crops other than sweet potato

Sunitha *et al*. (2015) revealed that single pruning at 3 MAP did not affect the tuber yield in cassava when studied using three varieties (Sree Jaya, Sree Vijaya, and CE-347) while the pruning at 6 MAP reduced the tuber yield significantly. Single pruning at 3rd month resulted in maximum foliage yield closely followed by pruning twice at 3 MAP and 6 MAP respectively. It was also observed that even though stem yield was maximum with no pruning, but was on par with single pruning at 3 MAP.

Ecco *et al*. (2019) observed that when the cassava plants were subjected to 100 per cent defoliation at 132 DAS, led to low production of root biomass. An increase in the defoliation levels (0, 25, 50, 75 or 100 per cent of defoliation) induced a meaningful reduction in the deposition of starch in roots, showing a linear effect and decreasing according to the increase in defoliation. The defoliation at 90 and 135 DAP with high intensity of defoliation levels resulted in a greater root mass loss, and the starch content.

Utomo *et al*. (2019) estimated that leaf-cutting frequency had a significant role in the production of crude fibre in cassava. The crude fibre content in the control (19.17 per cent), with 2 cuttings (19.74 per cent), and with 4 cuttings (17.94 per cent), was recorded. Similarly, the crude protein content in the control, with 2 cuttings, and with 4 cuttings was measured at 22.05 per cent, 22.39 per cent and 23.56 per cent respectively. The study concluded that cassava leaves can be harvested after 5 months and recommended cutting them twice, at 5 and 9.5 months was suitable for cassava leaf production with optimal crude protein production.

Iseki *et al*. (2022) observed a significant average yield reduction of 37 per cent in tuber yields of white yam when subjected to defoliation. Defoliated plants showed a higher shoot growth rate, possibly due to the presence of newly formed leaves that assimilate nutrients more efficiently than older leaves. Defoliation after the initiation of tuber growth halted both tuber and shoot growth in white yam.

The above review hoarded the effect of foliar application of urea, micronutrient and vine top harvesting on growth, yield, physiological aspects, quality and economics in sweet potato and other tuber crops exemplify the importance of foliar nutrition and vine top harvesting without yield reduction and generate high income.

Materials and methods

3. MATERIALS AND METHODS

The current study entitled "Foliar nutrition in sweet potato (*Ipomoea batatas* (L) Lam.) for vine top and tuber yield" was carried out in the *Rabi* of 2022 at the Farming Systems Research Station (FSRS), Sadanandapuram, which is situated in the Kollam district of Kerala. The purpose of the study was to evaluate the impact of foliar nutrition on sweet potato (*Ipomoea batatas* (L) Lam) growth, vine top, and tuber yield.

3.1 EXPERIMENTAL SITE

3.1.1 Location

Experimental study was conducted at Farming Systems Research Station, Sadanandapuram, Kottarakkara, Kollam district. The field is located in latitude 8.59'03" N and longitude 76.48'29" E.

3.1.2 Climate during Crop Season

Warm humid tropical climate prevailed during crop season. The weather parameters *viz.*, temperature, evaporation, rainfall, and relative humidity were recorded daily during the growing period of crop. The mean weakly weather data that prevailed during the cropping period are presented in Appendix I, graphically represented in fig. 2, 3 and 4.

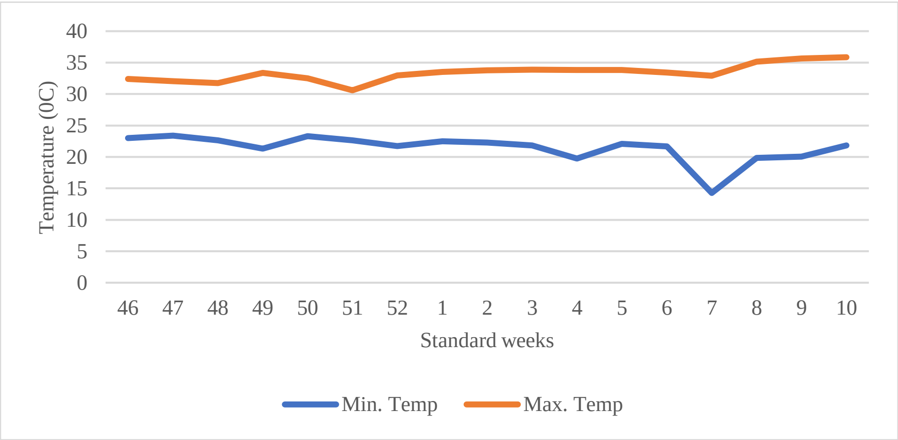

Fig 2. Temperature during the experimental period, ^{0}C

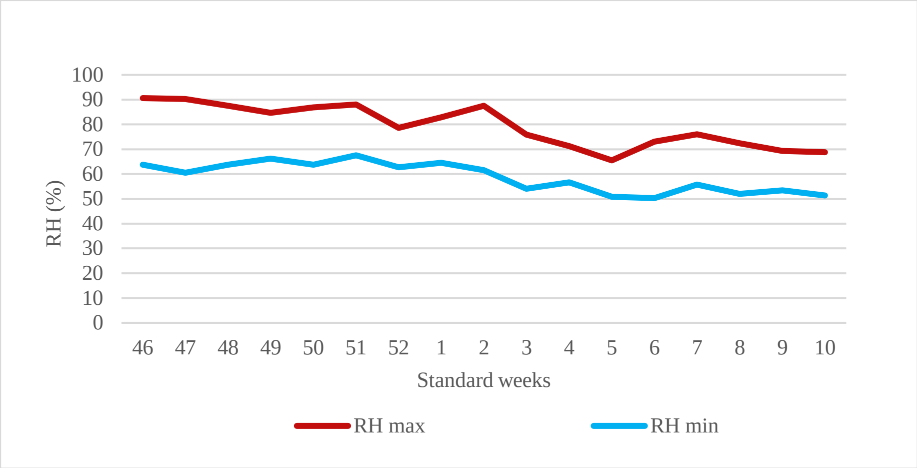

Fig 3. Relative humidity during the experimental period, %

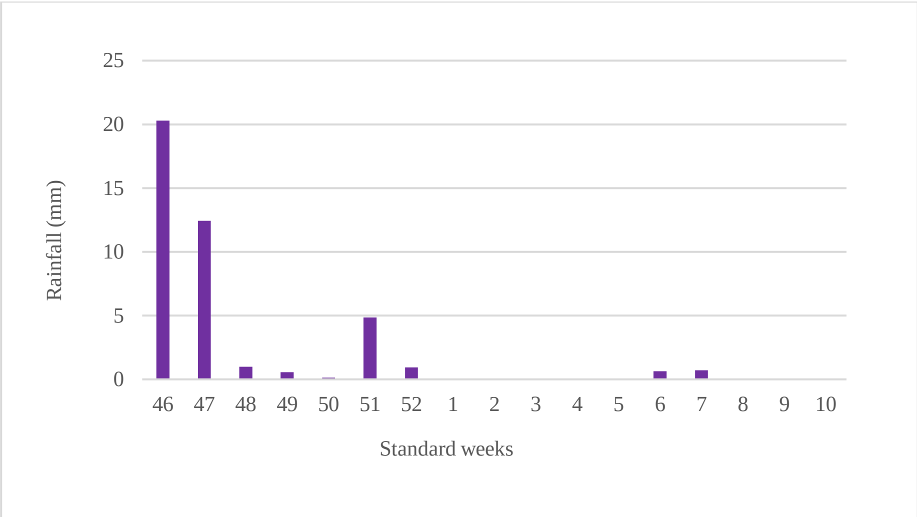

Fig 4. Rainfall during the experimental period, mm

3.1.3 Cropping Season

The crop was grown during *Rabi* of 2022 (November to February).

3.1.4 Soil

Assessment of the nutrient status of the soil was carried out before commencing the experiment. A composite soil sample was collected from a depth of 0 to 15 cm within the experimental block, and its chemical properties and physical composition were analyzed. Table. 1 shows the chemical and physical properties of the soil of the experimental area.

Table 1. Physio– chemical properties of experimental plot

Sl no.	Particulars	Value	Rating	Method of analysis
A.	Chemical characters			
1.	Soil pH	4.37	Strongly acidic	Blackman's Glass Electrode pH meter (Jackson, 1973)
2.	Electrical conductivity (d Sm^{-1} at 25^0 C)	0.19	Very low	Digital electrical conductivity meter (Jackson, 1973)
B.	Soil fraction (%)			By International Pipette Method (Piper, 1967)
1.	Coarse sand	64.32	Sandy clay loam	
2.	Silt	25.54		
3.	Clay	10.14		
4.	Textural class			
C.	Nutrient status			
1.	Available nitrogen (kg ha^{-1})	283.60	Medium	Alkaline Permanganate method (Subbiah and Asija, 1956)
2.	Available phosphorus (kg ha^{-1})	13.73	Medium	Dickman and Bray's molybdenum blue method using spectrophotometer (Jackson, 1973)
3.	Available potassium (kg ha^{-1})	152.40	Medium	Ammonium acetate method (Jackson, 1973)

3.1.5 Cropping History

The cropping history of experimental site for the past three years are summarized in Table 2.

Table 2. Cropping history of experimental plot

Year	*Kharif* season	*Rabi* season	*Summer* season
2020-2021	Brinjal	Snake gourd	Fallow
2021-2022	Bhindi	Amaranthus	Sesame
2022-2023	Bhindi	Cowpea	Sesame

3.2. MATERIALS

3.2.1 Crop variety

Sree Arun sweet potato variety recommended for cultivation by Kerala Agricultural university was used for the experiment. It was released in 2020 by CTCRI (Central Tuber Crop Research Institute) in Thiruvananthapuram, Kerala. It is a high yielding, early maturing sweet potato with creamy skin and flesh. It is suited to the upland and lowland conditions and it can be grown throughout Kerala. Average yield is 20-28 t ha^{-1}.

3.2.2 Source of seed

The required vine cuttings of Sree Arun for the experiment were procured from CTCRI, Sreekariyam, Thiruvananthapuram, Kerala.

3.2.3 Fertilizers and Manures

Well decomposed farmyard manure (FYM) analyzing 0.49 per cent N, 0.2 per cent P_2O_5 and 0.46 per cent K_2O was used as organic source. Fertilizers were applied in the form of urea (46 per cent N), mussooriephos (18 per cent P_2O_5), and muriate of potash (60 per cent K_2O). Sweet potato special micronutrient mixture was applied as foliar spray. Lime and chemical fertilizers were added as per the package of practices recommendation of Kerala Agricultural University (KAU, 2016).

3.3 METHODS

3.3.1 Layout of the experiment

Design	: Randomized Block Design
Treatments	: 4 x 3 = 12
Replications	: 3
Spacing	: 60 cm x 20 cm
Size of the plot	: 4.8 m x 3.0 m

Brief layout of experiment shown in fig. 1 and plate 1

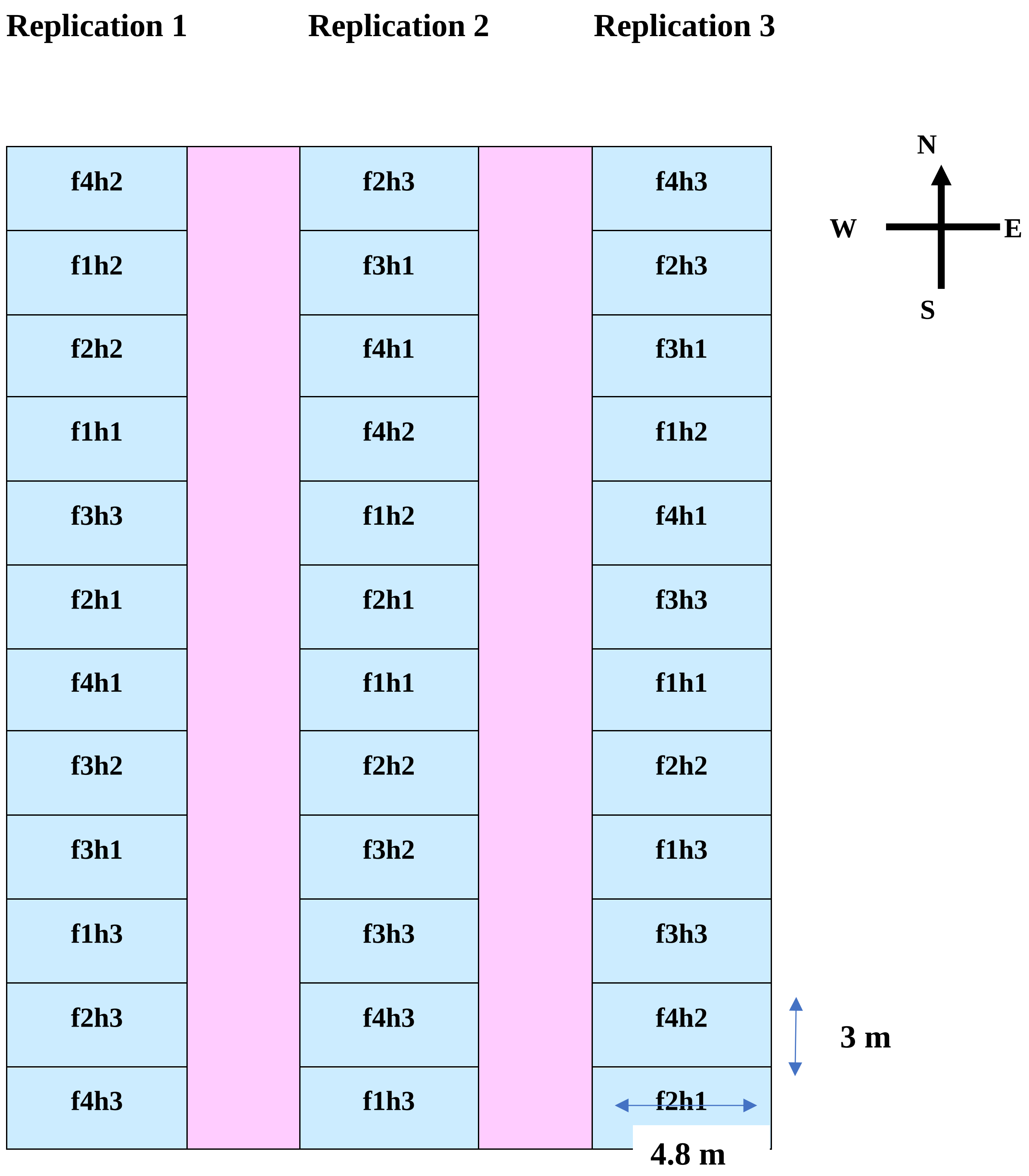

Fig.1 Layout of experiment

Plate 1. General view of the experimental field

3.3.2 Details of experiment

Factor A: Foliar nutrition management (f)

f_1: Urea 2 per cent spray at 20 and 35 DAP

f_2: Multi micronutrient 0.5 per cent spray at 20 and 35 DAP

f_3: Urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP

f_4: Control (water spray)

Factor B: Harvesting time of vine top (h)

h_1: 30 DAP

h_2: 45 DAP

h_3: Control (No leaf harvest)

Note: 15 cm top is harvested

Multi micronutrient fertilizer developed by CTCRI was used for foliar spray. It contains of Zn 2 per cent, Cu 0.6 per cent, B 0.2 per cent, Fe 0.5 per cent and Mn 0.25 per cent. The crop was raised as per POP recommendations (KAU, 2016).

Treatment combinations

f_1h_1- Urea 2 per cent spray at 20 and 35 DAP *fb* harvesting time of vine top at 30 DAP

f_1h_2 - Urea 2 per cent spray at 20 and 35 DAP *fb* harvesting time of vine top at 45 DAP

f_1h_3 - Urea 2 per cent spray at 20 and 35 DAP Control (No leaf harvest)

f_2h_1- Multi micronutrient 0.5 per cent spray at 20 and 35 DAP *fb* harvesting time of vine top at 30 DAP

f_2h_2 - Multi micronutrient 0.5 per cent spray at 20 and 35 DAP *fb* harvesting time of vine top at 45 DAP

f_2h_3 - Multi micronutrient 0.5 per cent spray at 20 and 35 DAP *fb* Control (No leaf harvest)

f_3h_1 - Urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP *fb* harvesting time of vine top at 30 DAP

f_3h_2 - Urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP *fb* harvesting time of vine top at 45 DAP

f_3h_3 - Urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP *fb* Control (No leaf harvest)

f_4h_1 - Control (water spray) *fb* harvesting time of vine top at 30 DAP

f_4h_2 - Control (water spray) *fb* harvesting time of vine top at 45 DAP

f_4h_3 - Control (water spray) *fb* Control (No leaf harvest)

3.3.3 CULTIVATION DETAILS

3.3.3.1 Crop Management

The crop was grown and managed as per the recommendations of the Package of Practices (KAU, 2016).

3.3.3.2 Land preparation and layout

The selected area was ploughed twice with cultivator, brought to fine tilth with rotavator. Ridges 25 cm in height were formed 60 cm apart.

3.3.3.3 Planting of vines

The sweet potato vines that were collected from CTCRI were planted on ridges maintaining an intra-row spacing of 20 cm.

Plate 2. Layout of the experiment

Plate 3. Planting of sweet potato vines in the field

3.3.3.4 Application of manures and fertilizers

Decomposed FYM @ 10 t ha^{-1} was applied to the plots at uniform rate. Chemical fertilizers were applied at the rate of 75: 50: 75 kg ha^{-1} N: P_2O_5: K_2O. Half of the dose of N (37.5 kg ha^{-1}), entire dose of P (50 kg ha^{-1}) and K (75 kg ha^{-1}) fertilizers were applied basally at time of planting. Half the dose of N (37.5 kg ha^{-1}) was top dressed 4 weeks after planting.

3.3.3.5 Irrigation

The plots were irrigated on alternate days from planting to 10 DAP (days after planting) and thereafter once in 7 days. Irrigation was stopped 3 weeks before harvesting. Final irrigation was given one day before harvesting.

3.3.3.6 Weed Management

Hand weeding was done twice a week up to 30 DAP.

3.3.3.7 Details of foliar nutrition

Urea (2 %) solution was prepared by dissolving 200 g of urea in 10 litres of water and multi micronutrient solution was prepared by adding 50 ml solution of multi micronutrient sweet potato special in 10 liters of water. 500 litres of water as spray volume, 5 kg urea and 1.25 litres multi micronutrient mixture were required for one hectare foliar application. (7.2 g of urea, 1.8 ml micronutrient sweet potato special with spray volume of 0.72 litres of water were used for 4.8 mx 3.0 m plot).

3.3.3.8 Details of vine harvest

The sweet potato vine tops were nipped up to 15 cm from the tip at 30 DAP and 45 DAP.

Plate 4. Foliar application of nutrients in sweet potato

Plate 5. Vine top harvesting at 30 DAP and 45 DAP

3.3.3.9 After Cultivation

Earthing up was done once in two weeks, and hand weeding was done twice a week up to 30 DAP.

3.3.3.10 Harvest

Harvesting was done 90th day by removing the vegetative parts above the ground tubers that were dug out from the soil. Marketable and nonmarketable tubers were separated and weighed the weight of tubers per each treatment separately to calculate the tuber yield and expressed in t ha^{-1}.

Plate 6. Tuber and vine harvesting operations

Plate 7. Best treatment (f_3h_2)

Plate 8. Control treatment (f_4h_3)

3.3.3.11 Pests and diseases incidence

At all phases of crop development, the occurrence of diseases and insect infestation were not observed.

3.4 OBSERVATIONS ON CROP

3.4.1 Growth Parameters

Five plants were randomly chosen and tagged from the net plot area of each treatment plot in order to record the observations on growth metrics, such as plant height, the number of branches per plant and leaf area.

3.4.1.1 Length of vine

Length of vine was measured from the ground level to the tip of the vine from the tagged plants at 15 DAP, 30 DAP, 45 DAP and at final harvest. The average was worked out and expressed in cm.

3.4.1.2 Number of Branches Per Plant

Number of branches was counted from each of the five tagged plants at 15 DAP, 30 DAP, 45 DAP and final harvest and the average was worked out.

3.4.1.3 Leaf Area and Leaf Area Index

Leaf area was found out using the leaf area meter. The leaf area index (LAI) was worked out by the following formula suggested by watson (1952). It was expressed in cm^2.

$$\text{Leaf area index } (cm^2) = \frac{\text{Leaf area per plant } (cm^2)}{\text{Land area occupied by the plant } (cm^2)}$$

3.4.1.4 Dry matter production per plant

Three sample plants were taken from per plot for each time of observation. The plant samples were dried at 70°C for a consistent weight before recording the dry weights. Dry matter production was expressed as g per plant.

3.4.1.5 Net assimilation rate

For calculating NAR, leaf area of individual plants had to be used. It was recorded by the formula given by Gregory (1926). It is expressed as gram of dry matter produced per square meter of leaf per day.

$$\text{NAR} = \frac{\text{Log L}_2 - \text{Log L}_1}{\text{L}_2 - \text{L}_1} \text{X} \frac{\text{w}_2 - \text{w}_1}{\text{t}_2 - \text{t}_1}$$

Where, L_1 and L_2 are total leaf area at time t_1 and t_2 respectively. W_1 and W_2 are total dry weight at time t_1 and t_2 respectively.

3.4.1.6 Crop growth rate

It is the absolute growth rate per unit land per unit time. It is expressed as g m^{-2} d^{-1} (gram of dry matter produced per day), given by Gardner *et al*. (2017).

$$CGR = \frac{(w_2 - w_1)}{(t_2 - t_1)}$$

Where w_1 is the whole plant dry weight m^{-2} recorded at time t_1, w_2 is the whole plant dry weight m^{-2} recorded at time t_2 (t_1 and t_2 are the interval of time).

3.4.2 YIELD AND YIELD ATTRIBUTES

3.4.2.1 Number of tubers per plant

At harvest, the tubers harvested from the observation plants were tagged for each plant. After calculation, the average number of tubers were reported in numbers.

3.4.2.2 Length of tuber

Among the collected tubers from the observation plants, two were picked at random, and their length was measured. The average length of the tuber was calculated and given in cm.

3.4.2.3 Girth of tuber

Among the collected tubers from observation plants, two were picked at random and their girth was measured at the middle and two ends of tuber. The average girth of tuber was calculated and given in cm.

3.4.2.4 Tuber bulking rate

It is the rate of increase in tuber weight per unit time and is an important measure of tuber growth. It is expressed in dry weight basis as g d^{-1} $plant^{-1}$.

$$TBR = \frac{(w_2 - w_1)}{(t_2 - t_1)}$$

Where w_1 and w_2 are the dry weight of tubers at time t_1 and t_2 respectively.

3.4.2.5 Vine top yield at each harvest

The vine tops were harvested up to 15 cm from selected plants as per treatment. The average was calculated and reported as the yield of vine top in kg ha^{-1}.

3.4.2.6 Vine yield at final harvest per hectare

The quantity of vines harvested was recorded from each treatment plot was recorded and expressed as vine yield in t ha^{-1}.

3.4.2.7 Tuber Yield per hectare

After harvesting tubers from net plot, tuber yield obtained from the net plot area of each treatment was measured and was expressed in t ha^{-1}.

3.4.2.8 Marketable tuber yield per hectare

After digging up tubers from net plots the fresh weight of marketable tubers was measured in tons per hectare. The non-bulked roots were discarded and tubers that could be sold to the market were considered.

3.4.2.9 Harvest index (HI)

By using formula given by Donald and Hamblin (1976), the harvest index was computed (fresh weight basis)

$$\text{Harvest Index} = \frac{\text{Economic Yield}}{\text{Biological Yield}}$$

3.4.3 PHYSIOLOGICAL PARAMETERS

3.4.3.1 Total Chlorophyll Content of harvested leaf (mg g^{-1})

Dimethyl Sulfoxide (DMSo) method suggested by Yoshida *et al*. (1976) was adopted for the determination of chlorophyll content in harvested leaves and expressed in mg g^{-1} fresh weight.

3.4.4 QUALITY PARAMETERS

3.4.4.1 Tuber

3.4.4.1.1 Starch content

Starch content of the tubers was estimated by the procedure as reported by the AOAC. (1990). The values were expressed as percentage on dry weight basis.

3.4.4.1.2 Crude Protein Content

Protein content of tuber was determined by multiplying the N content of the tubers estimated by the factor 6.25 and expressed as percentage using the micro – kjeldahl digestion and distillation method (Simpson *et al*., 1965).

3.4.4.1.3 Total sugars

Total sugars were determined as per the method described by Ranganna (1977). The results were expressed as percentage on fresh weight basis.

3.4.4.1.4 Beta carotene

Betacarotene was determined as per the method described by Sadasivam and Manickam (2008). The results were expressed as mg 100 g^{-1}.

3.4.4.2 Vine top

3.4.4.2.1 Nitrate Content

Nitrate Content in foliage was determined by using Spectrophotometry method (Nifras and Riyas, 2017) and expressed as mg 100 g^{-1}.

3.4.4.2.2 Crude protein content

Protein content of the tender leaves of harvested foliage was determined by multiplying the N content of the leaves with the factor 6.25 (Simpson *et al*., 1965).

3.4.4.2.3 Fibre content

Fibre content of leaves was estimated by using the Weende method (AOAC, 1990) and expressed as percentage.

3.4.4.2.4 Vitamin A content

Vitamin A content was estimated according to the method proposed by Srivastava and Kumar (1998) and expressed in IU (International units).

3.4.4.2.5 Vitamin C content

Vitamin C was determined as per the method described by Sadasivam and Manickam (2008). The results were expressed as mg 100 g^{-1}.

3.4.4.2.6 Fe, Zn, Cu, Mn content

Atomic Absorption Spectroscopy (Lindsay and Norvell, 1978) was adopted for the determination of total Fe, Zn, Cu, Mn content of foliage and expressed as mg 100g^{-1}.

3.4.5 Organoleptic evaluation

A panel of examiners comprised of 10 people conducted sensory analysis at the laboratory level. Judges were chosen from a group of staff, students and teachers. Based on nine-point hedonic scale (0-9), the main quality characteristics used to evaluate are appearance, color, taste, texture, flavour and overall acceptability (Srivastava and Kumar, 2002).

3.4.5.1 Vine top

An organoleptic test was performed to evaluate the cooked sweet potato vine top.

3.4.5.2 Tuber

An organoleptic test was performed to evaluate the cooked sweet potato tuber.

3.4.6 Soil analysis

3.4.6.1 Available NPK Analysis

After the harvest of crop, composite soil samples were drawn from each treatment plot, for the analysis of available N, P, K. For soil N, P, K analysis the soil sample was sieved through a 2 mm sieve.

3.4.6.1.1 Available N (kg ha^{-1})

Alkaline potassium permanganate method (Subbiah and Asija, 1956) was adopted for the determination of available N and was expressed in kg ha^{-1}.

3.4.6.1.2 Available P (kg ha^{-1})

Dickman and Bray molybdenum blue method (Jackson, 1973) was adopted for the determination of available P and expressed in kg ha^{-1}.

3.4.6.1.3 Available K (kg ha^{-1})

Flame photometry (Jackson, 1973) was adopted for the determination of available K and expressed in kg ha^{-1}.

3.4.7. Plant analysis

The vine and tubers of the observation plants at the harvest stage were analyzed for the total N, P and K content. The samples were shade dried initially for two days and then dried in a hot air oven at 65±5 °C to constant weight, ground and used for analysis. The required quantities of samples were weighed out accurately, and subjected to single acid digestion to determine the N content and di-acid digestion to determine the P and K content by adopting the following methods. Nutrient uptake was calculated as the result of the nutrient content expressed in kg ha^{-1}.

3.4.7.1 Total N uptake

Modified micro Kjeldahl method (Jackson, 1973) was adopted for the determination of total N content of vine and tubers.

3.4.7.2 Total P uptake

Total P content of vine and tubers were determined by vanadomolybdate phosphoric yellow color method (Jackson, 1973).

3.4.7.3 Total K uptake

Flame photometry (Jackson, 1973) was adopted for the determination of total K content of vine and tubers.

3.4 Economics

3.5.1 Net Income

Based on the current market pricing for various inputs and products, labour wage rates, and expressed in rupees per hectare, the cost of cultivation and gross income were calculated. Appendix II contains information on the cost of cultivation, the market price, and the price of other inputs. Net income was computed using the formula.

Net income (₹ ha^{-1}) = Gross income (₹ ha^{-1}) - Cost of cultivation (₹ ha^{-1})

3.5.2 Benefit Cost Ratio

The ratio of gross income to the cost of cultivation of the crop gave the B:C ratio. Benefit cost ratio was computed using the formula

$$\text{Benefit - cost ratio} = \frac{\text{Gross income (₹ ha}^{-1}\text{)}}{\text{Cost of cultivation (₹ ha}^{-1}\text{)}}$$

3.6 STATISTICAL ANALYSIS

The Department of Statistics at the College of Agriculture, Vellayani, created the General R-shiny based Analysis Platform Empowered by Statistics (GRAPES) software system, which was used to analyze the gathered data and calculate the critical difference. Every time a treatment was found to be significant, the F test was employed to assess the significance and key differences were calculated for comparison. A Pearson correlation analysis was performed using the grapes Agri 1 package in R to ascertain the relationship between tuber output, yield characteristics and growth.

Results

4. RESULTS

The experimental study was carried out to assess the effect of foliar nutrition on growth, vine top and tuber yield in sweet potato (*Ipomoea batatas* (L.) Lam.). The results of the current study were statistically evaluated and presented in this chapter.

4.1. GROWTH PARAMETERS

Growth parameters (vine length, number of branches plant^{-1}, leaf area plant^{-1}, leaf area index (LAI), dry matter production plant^{-1}, crop growth rate and net assimilation rate were not significantly influenced by foliar application of urea (2 per cent) and multi micronutrient (0.5 per cent) as well as the time of vine top harvesting and their interactions at 15 DAP, as the foliar nutrition application and vine top harvesting had taken place after 20 DAS.

4.1.1 Length of vine

Foliar application of urea (2 per cent) and multi micronutrient (0.5 per cent) as well as the time of vine top harvesting and their interactions on vine length are depicted in the Table 3.

At 15 DAP, foliar application of urea and multi micronutrient, time of vine top harvesting and their interactions had no significant effect on vine length.

The treatment f_1 (urea 2 percent spray at 20 and 35 DAP) resulted in vines at 30 DAP (69.66 cm), which was comparable to f_3 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP) (68.56 cm) and f_2 (multi micronutrient 0.5 percent spray at 20 and 35 DAP) (64.38 cm). When compared to the control (92.50 cm), significantly longer vines were found at 45 DAP f_2 (multi micronutrient 0.5 per cent spray at 20 and 35 DAP), (103.43 cm). Nonetheless, it was comparable with f_1 (urea 2 per cent spray at 20 and 35 DAP) (102.91 cm) and f_3 (urea 2 per cent spray at 20 DAP +multi micronutrient spray at 35 DAP) (98.42 cm). At the time of crop harvest, plants in treatment f_1 (urea 2 per cent spray at 20 and 35 DAP) showed significantly more vine length (128.69 cm) and it was on par with f_2 (multi micronutrient 0.5 per cent spray at 20 and 35 DAP) (128.22 cm) and f_3 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP) (124.71 cm). Control (f_4) registered the shortest vine lengths with 113.02 cm.

Throughout the observations, it was discovered that there was no significant relationship between the timing of vine top harvesting and its interaction with foliar nutrition in terms of plant height.

Table 3. Effect of foliar nutrition, harvesting time of vine top and its interaction on vine length of sweet potato, cm

Treatments	Vine length, cm			
	15 DAP	30 DAP	45 DAP	At harvesting
Factor A: Foliar nutrition management (F)				
f_1 – urea 2% spray at 20 and 35 DAP	30.39	69.66	102.91	128.69
f_2 – multi micronutrient 0.5 % spray at 20 and 35 DAP	29.06	64.38	103.43	128.22
f_3 – urea 2% spray at 20 DAP + multi micronutrient 0.5% spray at 35 DAP	28.67	68.56	98.42	124.71
f_4 – Control water spray	28.91	58.48	92.50	113.02
SE (m) ±	0.97	2.01	2.37	3.87
CD (0.05)	NS	5.93	6.98	11.43
Factor B: Harvesting time of vine top (H)				
h_1 – 30 DAP	29.12	65.77	100.13	123.98
h_2 – 45 DAP	29.83	66.34	101.08	125.57
h_3 – Control (No leaf harvest)	28.75	63.69	96.73	121.43
SE (m) ±	0.84	1.74	2.05	3.35
CD (0.05)	NS	NS	NS	NS
Interaction F x H				
f_1h_1 –	30.43	68.03	101.67	130.27
f_1h_2 –	30.77	74.30	106.30	127.47
f_1h_3 –	29.67	66.63	100.77	128.33
f_2h_1 –	29.33	68.63	106.23	123.97
f_2h_2 –	29.50	64.30	102.13	131.47
f_2h_3 –	28.35	60.20	101.93	129.23
f_3h_1 –	28.02	67.67	101.70	132.77
f_3h_2 –	29.67	70.10	99.37	125.30
f_3h_3 –	28.33	67.90	94.20	116.07
f_4h_1 –	28.69	58.73	90.93	108.93
f_4h_2 –	29.37	56.67	96.53	118.03
f_4h_3 –	28.67	60.03	90.03	112.10
SE (m) ±	1.68	3.48	4.10	6.71
CD (0.05)	NS	NS	NS	NS

4.1.2 Number of branches per plant

The data on effect of foliar application of urea (2 per cent) and multi micronutrient (0.5 per cent) as well as the time of vine top harvesting and their interactions on the number of branches are presented in the Table 4.

Foliar nutrition significantly improved number of branches. At 30 DAP, f_3 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP) recorded significantly higher number of branches (1.95) which was on par with f_1 (urea 2 per cent spray at 20 and 35 DAP) (1.94) and f_2 (multi micronutrient 0.5 per cent spray at 20 and 35 DAP) (1.93). During 45 DAP and at harvesting significantly higher number of branches were observed in f_3 (3.42 and 4.17 respectively).

There was a notable variation in the number of branches per plant considering the time of vine top harvest. Significantly more number of branches were observed in h_1 (vine top harvesting on 30 DAP) (3.18) and was comparable to h_2 (vine top harvesting on 45 DAP) (3.05) on 45 DAP. A substantially higher number of branches was seen during harvest by h_2 (vine top harvesting on 45 DAP) (3.78), which was comparable with h_1 (vine top harvesting on 30 DAP) (3.68). Significant lowest numbers of branches were observed in h_3 (no vine top harvest) at 45 DAP and at harvest.

Significant enhancements of number of branches were observed by the interaction effect of foliar nutrition and time of vine harvest. Observations at 45 DAP and at harvest showed higher number of branches (3.90 and 4.80 respectively) for f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine top harvest at 45 DAP). Comparable results were also observed in f_3h_1 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine top harvest at 30 DAP) (3.80 and 4.58 respectively) and f_1h_1 (urea 2 per cent spray at 20 and 35 DAP *fb* vine top harvest at 30 DAP) on 45 DAP (3.40).

Table 4. Effect of foliar nutrition, harvesting time of vine top and its interaction on number of branches of sweet potato plant^{-1}

Treatments	Number of branches per plant			
	15 DAP	30 DAP	45 DAP	At harvesting
Factor A: Foliar nutrition management (F)				
f_1 – urea 2% spray at 20 and 35 DAP	1.66	1.94	3.02	3.37
f_2 – multi micronutrient 0.5 % spray at 20 and 35 DAP	1.71	1.93	2.88	3.43
f_3 – urea 2% spray at 20 DAP + multi micronutrient 0.5% spray at 35 DAP	1.62	1.95	3.42	4.17
f_4 – Control water spray	1.62	1.39	2.42	2.98
SE (m) ±	0.09	0.10	0.11	0.08
CD (0.05)	NS	0.294	0.320	0.245
Factor B: Harvesting time of vine top (H)				
h_1 – 30 DAP	1.64	1.83	3.18	3.68
h_2 – 45 DAP	1.70	1.89	3.05	3.78
h_3 – Control (No leaf harvest)	1.58	1.69	2.58	2.99
SE (m) ±	0.07	0.09	0.09	0.07
CD (0.05)	NS	NS	0.277	0.212
Interaction F x H				
f_1h_1 –	1.63	2.03	3.40	3.43
f_1h_2 –	1.67	2.00	2.77	3.57
f_1h_3 –	1.57	1.80	2.90	3.11
f_2h_1 –	1.60	1.93	3.22	3.57
f_2h_2 –	1.93	1.97	3.03	3.67
f_2h_3 –	1.58	1.90	2.40	3.07
f_3h_1 –	1.68	2.07	3.80	4.58
f_3h_2 –	1.60	1.99	3.90	4.80
f_3h_3 –	1.57	1.80	2.57	3.13
f_4h_1 –	1.65	1.30	2.33	3.17
f_4h_2 –	1.61	1.60	2.50	3.10
f_4h_3 –	1.58	1.27	2.43	2.67
SE (m) ±	0.15	0.17	0.19	0.14
CD (0.05)	NS	NS	0.555	0.424

4.1.3 Leaf area per plant

The Table 5 shows the effect of foliar application of urea (2 per cent) and multi micronutrient (0.5 per cent) as well as the time of vine top harvesting and their interactions on leaf area per plant.

At 15 DAP, there is no significant difference in the leaf area per plant concerning foliar treatment, timing of vine top harvesting and their interaction effects.

Leaf area per plant was significantly enhanced by the foliar application at 30 DAP and 45 DAP. Urea 2 per cent spray at 20 DAP + multi-micronutrient spray at 35 DAP (f_3) resulted in larger leaves per plant (360.91 cm^2, 969.46 cm^2 respectively) and was comparable to f_1 (urea 2 per cent spray at 20 and 35 DAP) (353.57 cm^2, 931.24 cm^2 respectively) and f_2 (multi micronutrient 0.5 per cent spray at 20 and 35 DAP) (349.51 cm^2, 928.90 cm^2 respectively). During the harvest stage, f_3 (urea 2 percent spray at 20 DAP + multi-micronutrient spray at 35 DAP) showed the significant largest leaf area (907.05 cm^2). The treatment water spray control (f_4) had the lowest leaf area per plant in all observations.

There was a noticeable increment in leaf area with the time of vine top harvesting. The largest leaf area per plant was found in treatment h_2 (vine top harvesting on 45 DAP) (963.67 cm^2, 867.03 cm^2 respectively for 45 DAT and at harvest) whereas at harvest the leaf area was comparable with h_1 (vine top harvesting on 30 DAP) (839.97 cm^2) also. Lowest leaf area was registered for treatment with no vine top harvest (h_3).

With respect to the interaction at 45 DAP, f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine top harvest at 45 DAP) (1030.33 cm^2) had larger leaf area and were comparable to f_3h_1 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine top harvest at 30 DAP) (992.01 cm^2), f_1h_1 (urea 2 per cent spray at 20 and 35 DAP *fb* vine top harvest at 30 DAP) (963.36 cm2) and f_1h_2 (urea 2 per cent spray at 20 and 35 DAP *fb* vine top harvest at 45 DAP) (957.03 cm^2). At the harvest stage, f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine top harvest at 45 DAP) (972.02 cm^2) had larger leaf area per plant, on par with f_3h_1 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine top harvest at 30 DAP) (967.11 cm^2). No leaf harvest with water spray (f_4h_1) exhibited the lowest leaf area per plant.

Table 5. Effect of foliar nutrition, harvesting time of vine top and its interaction on leaf area of sweet potato, cm^2.

Treatments	Leaf area			
	15 DAP	30 DAP	45 DAP	At harvesting
Factor A: Foliar nutrition management (F)				
f_1 – urea 2% spray at 20 and 35 DAP	260.35	353.57	931.24	843.47
f_2 – multi micronutrient 0.5 % spray at 20 and 35 DAP	250.79	349.51	928.90	841.46
f_3 – urea 2% spray at 20 DAP + multi micronutrient 0.5% spray at 35 DAP	262.12	360.91	969.46	907.05
f_4 – Control water spray	223.57	334.26	817.45	721.146
SE (m) ±	10.19	5.93	15.45	16.84
CD (0.05)	NS	17.516	45.594	49.703
Factor B: Harvesting time of vine top (H)				
h_1 – 30 DAP	247.86	350.94	912.94	839.97
h_2 – 45 DAP	256.17	352.27	963.67	867.03
h_3 – Control (No leaf harvest)	243.59	345.47	866.18	777.84
SE (m) ±	8.83	5.14	13.38	14.58
CD (0.05)	NS	NS	39.486	43.044
Interaction F x H				
f_1h_1 –	263.37	357.36	963.36	849.02
f_1h_2 –	262.35	348.33	957.03	855.71
f_1h_3 –	255.33	355.02	873.33	825.67
f_2h_1 –	249.69	346.67	945.35	846.68
f_2h_2 –	239.33	349.68	930.67	856.04
f_2h_3 –	263.35	352.17	910.68	821.67
f_3h_1 –	249.02	367.02	992.01	967.11
f_3h_2 –	271.68	358.04	1030.33	972.02
f_3h_3 –	265.67	357.67	916.01	782.01
f_4h_1 –	229.36	332.72	751.01	697.05
f_4h_2 –	251.33	353.04	936.67	784.36
f_4h_3 –	190.01	317.01	866.18	682.03
SE (m) ±	17.67	10.28	26.75	29.17
CD (0.05)	NS	NS	78.97	86.089

4.1.4 Leaf area index

Data on the leaf area index of sweet potato as influenced by foliar application of nutrients, along with the timing of vine top harvesting and their interactions are depicted in Table 6.

At 15 DAP and 30 DAP there was no significant difference in the leaf area index concerning foliar treatment, timing of vine top harvesting and their interaction effects. At 45 DAP and at harvesting stage, foliar nutrition showed a significant improvement in leaf area index. The treatment f_3 (urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP) resulted in the highest leaf area index (5.10 and 5.73 respectively). Lowest leaf area index was observed in treatment control (f_4).

Time of vine top harvesting had significant influence on leaf area index at 45 DAP and at harvest. The treatment h_2 (vine top harvesting at 45 DAP) showed higher leaf area index (3.99 and 4.82 respectively at 45 DAP and at harvest) which was comparable with h_1 (vine top harvesting at 30 DAP) (3.97 and 4.80 respectively) at 45 DAP and harvesting stages. Lowest leaf area index was observed in treatment control h_3 (vine top harvesting).

Foliar nutrition and time of vine top harvesting had a significant impact on the leaf area index of sweet potato at 45 DAP. The treatment f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP *fb* vine harvesting at 45 DAP) showed the highest leaf area index (5.67), and was on par with f_3h_1 (urea 2 per cent spray at 20 + multi micronutrient 0.5 per cent spray at 35 DAP *fb* vine harvesting at 30 DAP) (5.63). The lowest leaf area index was observed in f_4h_1 (water spray *fb* vine harvesting at 30 DAP) (3.03).

Table 6. Effect of foliar nutrition, harvesting time of vine top and its interaction on leaf area index of sweet potato

Treatments	Leaf area index			
	15 DAP	30 DAP	45 DAP	At Harvesting
Factor A: Foliar nutrition management (F)				
f_1 – urea 2% spray at 20 and 35 DAP	0.64	3.17	3.81	4.63
f_2 – multi micronutrient 0.5 % spray at 20 and 35 DAP	0.60	3.11	3.16	4.26
f_3 – urea 2% spray at 20 DAP + multi micronutrient 0.5% spray at 35 DAP	0.61	3.48	5.10	5.73
f_4 – Control water spray	0.57	2.58	3.09	4.09
SE (m) ±	0.04	0.21	0.16	0.13
CD (0.05)	NS	NS	0.479	0.374
Factor B: Harvesting time of vine top (H)				
h_1 – 30 DAP	0.59	3.10	3.97	4.80
h_2 – 45 DAP	0.63	3.22	3.99	4.82
h_3 – Control (No leaf harvest)	0.59	2.94	3.40	4.41
SE (m) ±	0.03	0.18	0.14	0.11
CD (0.05)	NS	NS	0.415	0.324
Interaction F x H				
f_1h_1 –	0.62	3.20	4.04	4.75
f_1h_2 –	0.64	3.14	4.07	4.59
f_1h_3 –	0.65	3.17	3.33	4.54
f_2h_1 –	0.60	3.16	3.20	4.28
f_2h_2 –	0.63	3.13	3.11	4.34
f_2h_3 –	0.57	2.86	3.16	4.17
f_3h_1 –	0.61	3.47	5.63	6.10
f_3h_2 –	0.67	3.55	5.67	6.21
f_3h_3 –	0.56	3.42	4.01	4.87
f_4h_1 –	0.56	2.57	3.03	4.08
f_4h_2 –	0.57	2.87	3.14	4.13
f_4h_3 –	0.58	2.30	3.10	4.07
SE (m) ±	0.06	0.36	0.28	0.22
CD (0.05)	NS	NS	0.830	NS

4.1.5 Dry matter production per plant

The Table 7 shows the dry matter production per plant of sweet potato in response to foliar application of nutrients, timing of vine top harvesting and their interactions.

Foliar nutrition had a considerable impact on the amount of dry matter produced per plant except at 15 DAP. At 30 DAP significantly higher production of dry matter was observed in f_2 (multi micronutrient 0.5 per cent spray at 20 and 35 DAP) (12.90 g plant^{-1}) which was on par with f_1 (urea 2 per cent spray at 20 and 35 DAP) (12.79 g plant^{-1}) and f_3 (urea 2 per cent spray at 20 DAP + multi-micronutrient spray at 35 DAP) (12.65 g plant^{-1}). Control water spray (f_4) had the lowest dry matter production per plant.

At 45 DAP and harvest, f_3 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP) registered the highest dry matter output per plant (21.26 g plant^{-1}, 34.79 g plant^{-1} respectively) this was comparable to treatment f_2 (multi micronutrient 0.5 percent spray at 20 and 35 DAP) and f_1 (urea 2 per cent spray at 20 and 35 DAP). Control water spray (f_4) had the lowest dry matter production per plant.

Time of vine top harvesting had significant influence on dry matter production at harvest only. At harvesting stage higher dry matter production per plant was found in treatment h_1 (vine top harvesting on 30 DAP) (33.89 g plant^{-1}) which was on par with h_2 (vine top harvesting on 45 DAP) (33.11 g plant^{-1}). No leaf harvest (h_3) recorded the lowest dry matter output per plant.

Foliar nutrition and time of vine top harvesting had significant impact on dry matter production of sweet potato at harvest stage. Treatment f_3h_1 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine top harvest at 30 DAP) (37.34 g plant^{-1}) had the highest dry matter production per plant, on par with f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine top harvest at 45 DAP) (36.01 g plant^{-1}), f_1h_3 (urea 2 per cent spray at 20 DAP and 35 DAP with no vine top harvesting) (35.34 g plant^{-1}) and f_1h_1 (urea 2 per cent spray at 20 DAP and 35 DAP *fb* vine top harvest at 30 DAP) (34.51 g plant^{-1}). Treatment f_4h_3 (Control water spray with no vine top harvesting) recorded the lowest dry matter production per plant (23.67 g plant^{-1}).

Table 7. Effect of foliar nutrition, harvesting time of vine top and its interaction on dry matter production of sweet potato, g per plant.

Treatments	Dry matter production of sweet potato			
	15 DAP	30 DAP	45 DAP	At Harvesting
Factor A: Foliar nutrition management (F)				
f_1 – urea 2% spray at 20 and 35 DAP	2.50	12.79	19.96	34.29
f_2 – multi micronutrient 0.5 % spray at 20 and 35 DAP	2.81	12.90	20.06	33.13
f_3 – urea 2% spray at 20 DAP + multi micronutrient 0.5% spray at 35 DAP	3.13	12.65	21.26	34.79
f_4 – Control water spray	2.58	10.94	18.44	28.01
SE (m) ±	0.24	0.43	0.67	0.67
CD (0.05)	NS	1.281	1.987	1.985
Factor B: Harvesting time of vine top (H)				
h_1 – 30 DAP	2.66	11.82	19.28	33.89
h_2 – 45 DAP	2.89	13.09	20.25	33.11
h_3 – Control (No leaf harvest)	2.12	12.05	19.52	30.67
SE (m) ±	0.21	0.38	0.58	0.58
CD (0.05)	NS	NS	NS	1.719
Interaction F x H				
f_1h_1 –	2.73	12.33	18.23	34.51
f_1h_2 –	2.68	13.87	18.57	33.02
f_1h_3 –	2.09	12.17	20.09	35.34
f_2h_1 –	2.66	12.60	20.87	33.68
f_2h_2 –	2.74	13.87	20.33	33.05
f_2h_3 –	3.02	12.23	18.97	32.67
f_3h_1 –	3.03	12.03	20.67	37.34
f_3h_2 –	3.46	13.27	22.43	36.01
f_3h_3 –	2.89	12.67	20.69	31.03
f_4h_1 –	2.23	10.33	17.33	30.01
f_4h_2 –	2.66	11.37	19.67	30.33
f_4h_3 –	2.86	11.13	18.33	23.67
SE (m) ±	0.41	0.75	1.17	1.16
CD (0.05)	NS	NS	NS	3.438

4.1.6 Crop growth rate

The Table 8 shows the crop growth rate of sweet potato as influenced by foliar application of nutrients, timing of vine top harvesting and their interactions.

Foliar nutrition had significant influence on the crop growth rate of sweet potato

At 30-45 DAP and at 45 DAP to harvest stage foliar nutrition showed significant difference on crop growth rate with the higher crop growth rate in f_3 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP) (15.66 g m^{-2} d^{-1} and 14.80 g m^{-2} d^{-1} respectively) which was on par with f_1 (urea 2 per cent spray at 20 and 35 DAP) (15.54 g m^{-2} d^{-1}) and f_2 (multi micronutrient 0.5 per cent spray at 20 and 35 DAP) (15.14 g m^{-2} d^{-1}) at 30-45 DAP. Lowest crop growth rate was observed in control (f_4).

Time of vine top harvesting had significant influence on crop growth rate at 30-45 DAP. The treatment h_1 (vine top harvesting on 30 DAP) showed higher crop growth rate (15.57 g m^{-2} d^{-1}) and remained at par with h_2 (vine top harvesting at 45 DAP).

At 45 DAP to harvest stage, the treatment h_2 (vine top harvesting at 45 DAP) showed higher crop growth rate (14.14 g m^{-2} d^{-1}) and it was on par with h_1 (vine harvesting at 30 DAP) (13.90 g m^{-2} d^{-1}). The lowest crop growth rate was observed in control, h_3 (no leaf harvest).

Foliar nutrition and time of vine top harvesting had a significant impact on the crop growth rate of sweet potato at 45 DAP to harvest stage. Treatment f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine top harvesting at 45 DAP) showed higher crop growth rate (16.15 g m^{-2} d^{-1}) and it was on par with f_3h_1 (urea 2 percent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine top harvesting at 30 DAP) (16.11 g m^{-2} d^{-1}) and f_1h_1 (urea 2 per cent spray at 20 DAP and 35 DAP *fb* vine top harvest at 30 DAT) (14.63 g m^{-2} d^{-1}). The lowest crop growth rate was observed in f_4h_1 (water spray *fb* vine harvesting at 30 DAP) (10.89 g m^{-2} d^{-1}).

Table 8. Effect of foliar nutrition, harvesting time of vine top and its interaction on crop growth rate of sweet potato, g m^{-2} d^{-1}

Treatments	Crop growth rate of sweet potato		
	15-30 DAP	30-45 DAP	45 DAP to harvest
Factor A: Foliar nutrition management (F)			
f_1 – urea 2% spray at 20 and 35 DAP	8.61	15.54	13.76
f_2 – multi micronutrient 0.5 % spray at 20 and 35 DAP	8.21	15.14	13.24
f_3 – urea 2% spray at 20 DAP + multi micronutrient 0.5% spray at 35 DAP	8.47	15.66	14.80
f_4 – Control water spray	7.89	13.75	11.47
SE (m) ±	0.30	0.46	0.31
CD (0.05)	NS	1.345	0.910
Factor B: Harvesting time of vine top (H)			
h_1 – 30 DAP	7.99	15.57	13.90
h_2 – 45 DAP	8.62	15.31	14.14
h_3 – Control (No leaf harvest)	8.19	14.19	11.91
SE (m) ±	0.26	0.39	0.27
CD (0.05)	NS	1.165	0.788
Interaction F x H			
f_1h_1 –	8.51	15.86	14.63
f_1h_2 –	8.93	15.39	14.41
f_1h_3 –	8.40	15.39	12.24
f_2h_1 –	7.95	16.04	13.99
f_2h_2 –	8.46	15.36	13.80
f_2h_3 –	8.23	14.01	11.93
f_3h_1 –	7.97	16.77	16.11
f_3h_2 –	8.90	16.47	16.15
f_3h_3 –	8.53	13.73	12.13
f_4h_1 –	7.55	13.60	10.89
f_4h_2 –	8.18	14.02	12.18
f_4h_3 –	7.62	13.61	11.33
SE (m) ±	0.52	0.79	0.53
CD (0.05)	NS	NS	1.577

4.1.7 Net assimilation rate

Table 9 presents data on how the timing of vine top harvesting and foliar nutrition and their interactions affected the net assimilation rate of sweet potato.

Foliar nutrition, vine top harvesting and their interactions had significant influence in net assimilation rate of sweet potato

Significantly higher net assimilation rate were observed in f_3 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP) (0.030, 0.051 and 0.045 g m^{-2} d^{-1} for 15-30 DAP, 30 - 45 DAP and 45 DAP to harvest) and it was on par with f_1 (urea 2 per cent spray at 20 and 35 DAP) (0.027 and 0.043 g m^{-2} d^{-1} for 15-30 DAP, and 45 DAP to harvest respectively) and f_2 (multi micronutrient 0.5 per cent spray at 20 and 35 DAP) (0.026 g m^{-2} d^{-1} for 15-30 DAP). The lowest net assimilation rate was observed with water spray (f_4).

Time of vine top harvesting had significant influence on net assimilation rate at 30-45 DAP. The treatment h_1 (vine top harvesting at 30 DAP) showed higher net assimilation rate (0.046 g m^{-2} d^{-1}) and it was comparable with h_2 (vine top harvesting at 45 DAP) (0.044 g m^{-2} d^{-1}).

At 45 DAP to harvest stage, h_2 (vine top harvesting at 45 DAP) showed the higher net assimilation rate (0.042 g m^{-2} d^{-1}) and was on par with h_1 (vine top harvesting at 30 DAP) (0.041 g m^{-2} d^{-1}). The lowest net assimilation rate was observed in control h_3 (no leaf harvest).

Foliar nutrition and time of vine top harvesting had a significant impact on the net assimilation rate of sweet potato at 45 DAP to harvest stage. The treatment f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine harvesting at 45 DAP) showed higher net assimilation rate (0.051 g m^{-2} d^{-1}) and it was at par with f_3h_1 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine top harvesting at 30 DAP) (0.049 g m^{-2} d^{-1}) and f_1h_1 (urea 2 per cent spray at 20 DAP and 30 DAP *fb* vine top harvesting at 30 DAP) (0.045 g m^{-2} d^{-1}). The lowest net assimilation rate was observed in f_4h_1 (water spray *fb* vine top harvesting at 30 DAP) (0.031 g m^{-2} d^{-1}).

Table 9. Effect of foliar nutrition, harvesting time of vine top and its interaction on net assimilation rate of sweet potato, g m^{-2} d^{-1}

Treatments	Net assimilation rate		
	15-30 DAP	30-45 DAP	45 DAP to harvest
Factor A: Foliar nutrition management (F)			
f_1 – urea 2% spray at 20 and 35 DAP	0.027	0.043	0.043
f_2 – multi micronutrient 0.5 % spray at 20 and 35 DAP	0.026	0.042	0.039
f_3 – urea 2% spray at 20 DAP + multi micronutrient 0.5% spray at 35 DAP	0.030	0.051	0.045
f_4 – Control water spray	0.024	0.035	0.032
SE (m) ±	0.001	0.002	0.001
CD (0.05)	0.004	0.005	0.004
Factor B: Harvesting time of vine top (H)			
h_1 – 30 DAP	0.027	0.046	0.041
h_2 – 45 DAP	0.026	0.044	0.042
h_3 – Control (No leaf harvest)	0.028	0.039	0.037
SE (m) ±	0.001	0.001	0.001
CD (0.05)	NS	0.004	0.003
Interaction F x H			
f_1h_1 –	0.026	0.049	0.045
f_1h_2 –	0.026	0.042	0.043
f_1h_3 –	0.029	0.039	0.041
f_2h_1 –	0.028	0.049	0.039
f_2h_2 –	0.025	0.040	0.040
f_2h_3 –	0.025	0.038	0.038
f_3h_1 –	0.029	0.052	0.049
f_3h_2 –	0.032	0.055	0.051
f_3h_3 –	0.029	0.044	0.036
f_4h_1 –	0.023	0.033	0.031
f_4h_2 –	0.021	0.037	0.033
f_4h_3 –	0.027	0.034	0.032
SE (m) ±	0.002	0.003	0.002
CD (0.05)	NS	NS	0.006

4.3 YIELD AND YIELD ATTRIBUTES

The data on number of number tubers per plant, length of tuber, girth of tuber, tuber bulking rate, vine top yield, tuber yield, marketable tuber yield and vine yield at harvest are presented in the Tables 11 to 14.

The Table 10 shows the number of tubers per plant, length of tuber and girth of tuber of sweet potato for the effect of foliar application of nutrients, along with the timing of vine top harvesting and their interactions.

4.3.1 Number tubers per plant

Foliar nutrition had a significant role in improving the number of tubers per plant. Urea 2 per cent spray at 20 DAP + multi micronutrient 0.5% spray at 35 DAP (f_3) recorded the highest number of tubers per plant (4.34) and the lowest number of tubers per plant (2.35) was obtained with control water spray (f_4).

Vine top harvesting also had significant influence on the number of tubers per plant. Higher number of tubers per plant (3.53) was obtained in vine top harvesting at 45 DAP (h_2) and it was on par with the vine top harvesting at 30 DAP *i.e.*, h_1 (3.36). The lowest number of tubers per plant (2.84) was registered with no vine harvest (h_3).

Combined effect of foliar nutrition and time of vine top harvesting was significant on the number of tubers of sweet potato at harvest stage. Treatment f_3h_2 (urea 2 percent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine top harvesting at 45 DAP) showed the highest number of tubers (4.79 $plant^{-1}$) and it was on par with f_3h_1 (urea 2 percent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine harvesting at 30 DAP) (4.72 $plant^{-1}$). Lowest number of tubers was observed in f_4h_1 (water spray *fb* vine top harvesting at 30 DAP) (2.27 $plant^{-1}$).

4.3.2 Length of tuber

Length of tuber was observed to increase significantly by foliar nutrition, vine top harvesting and their interaction effect. Urea 2 per cent spray at 20 DAP + multi micronutrient 0.5% spray at 35 DAP (f_3) recorded the longest tubers (15.22 cm) and the shortest tubers were obtained with control water spray (f_4) (9.03 cm).

Longer tubers (12.48 cm) were obtained with vine top harvesting at 45 DAP (h_2) and it was on par with the vine top harvesting at 30 DAP *i.e.*, h_1 (11.93 cm). The shortest tubers (10.81 cm) were obtained with no leaf harvest (h_3).

Foliar nutrition and time of vine top harvesting had a significant impact on the length of tuber of sweet potato at harvest stage. Treatment f_3h_2 (urea 2 percent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine harvesting at 45 DAP) showed longer tubers (16.57 cm) and it was on par with f_3h_3 (urea 2 percent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* no vine harvesting) (16.45 cm). Lowest length of tuber was observed in f_4h_1 (water spray *fb* vine harvesting at 30 DAP) (8.67 cm).

4.3.3 Girth of tuber

Foliar nutrition, vine top harvesting and their interaction effect had significant role in increasing tuber girth.

Urea 2 per cent spray at 20 DAP + multi micronutrient 0.5% spray at 35 DAP (f_3) recorded significantly the highest tuber girth (13.93 cm). The lowest tuber girth was obtained with control water spray (f_4) (9.94 cm).

Vine top harvesting at 45 DAP (h_2) resulted in higher tuber girth (12.60 cm) and was on par with the vine top harvesting time at 30 DAP *i.e.*, h_1 (12.07 cm). The lowest tuber girth (10.37 cm) was obtained with no vine top harvest (h_3).

Interaction between foliar nutrition and time of vine top harvesting had a significant impact on enhancing tuber girth of sweet potato. Treatment f_3h_2 (urea 2 percent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine harvesting at 45 DAP) showed the higher tuber girth (15.62 cm) and was comparable with f_3h_1 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* no vine harvesting) (15.27 cm). Lowest tuber girth was observed in f_4h_1 (water spray *fb* vine harvesting at 30 DAP) (9.73 cm).

Table 10. Effect of foliar nutrition, harvesting time of vine top and its interaction on yield parameters of sweet potato

Treatments	Number of tubers plant^{-1}	Length of tuber (cm)	Girth of tuber (cm)
Factor A : Foliar nutrition management (F)			
f_1 – urea 2% spray at 20 and 35 DAP	3.13	11.29	11.58
f_2 – multi micronutrient 0.5 % spray at 20 and 35 DAP	3.14	11.42	11.27
f_3 – urea 2% spray at 20 DAP + multi micronutrient 0.5% spray at 35 DAP	4.34	15.22	13.93
f_4 – Control water spray	2.35	9.03	9.94
SE (m) ±	0.10	0.36	0.39
CD (0.05)	0.308	1.050	1.150
Factor B: Harvesting time of vine top (H)			
h_1 – 30 DAP	3.36	11.93	12.07
h_2 – 45 DAP	3.53	12.48	12.60
h_3 – Control (No leaf harvest)	2.84	10.81	10.37
SE (m) ±	0.09	0.31	0.34
CD (0.05)	0.267	0.910	0.996
Interaction F x H			
f_1h_1 –	3.33	11.27	12.01
f_1h_2 –	3.43	11.67	12.37
f_1h_3 –	2.63	10.93	10.37
f_2h_1 –	3.11	11.32	11.27
f_2h_2 –	3.47	12.62	12.30
f_2h_3 –	2.87	10.31	10.23
f_3h_1 –	4.72	16.45	15.27
f_3h_2 –	4.79	16.57	15.62
f_3h_3 –	3.51	12.63	10.91
f_4h_1 –	2.27	8.67	9.73
f_4h_2 –	2.42	9.07	10.13
f_4h_3 –	2.37	9.36	9.97
SE (m) ±	0.18	0.62	0.68
CD (0.05)	0.534	1.819	1.992

4.3.4 Tuber bulking rate

Tuber bulking rate of sweet potato as influenced by foliar application of nutrients, timing of vine top harvesting and their interaction are depicted in the Table 11.

Foliar nutrition, timing of vine top harvesting and their interaction had significant role in enhancing tuber bulking rate of sweet potato

At 30-45 DAP stage showed higher tuber bulking rate for f_3 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP) (1.89 g d^{-1} $plant^{-1}$) and was comparable with f_2 (multi micronutrient 0.5 per cent spray at 20 and 35 DAP) (1.53 g d^{-1} $plant^{-1}$).

At 45 DAP- harvest stage foliar nutrition recorded the highest tuber bulking rate for f_3 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP) (3.40 g d^{-1} $plant^{-1}$). Lowest tuber bulking rate observed in water spray (f_4) (2.08 g d^{-1} $plant^{-1}$)

Time of vine top harvesting had significant influence on tuber bulking rate at 45 DAP to harvest stage. Higher tuber bulking rate was observed in treatment h_2 (vine top harvesting at 45 DAP) (2.93 g d^{-1} $plant^{-1}$) it was on par with the vine top harvesting at 30 DAP *i.e.*, h_1 (2.69 g d^{-1} $plant^{-1}$). Lowest tuber bulking rate was observed in control h_3 (no vine top harvest) (2.41 g d^{-1} $plant^{-1}$).

Combination effect of foliar nutrition and time of vine top harvesting was significant on the tuber bulking rate of sweet potato at harvest stage. The treatment f_3h_2 (urea 2 percent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine harvesting at 45 DAP) showed higher tuber bulking rate (3.67 g d^{-1} $plant^{-1}$) which was comparable with f_3h_1 (urea 2 percent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine harvesting at 30 DAP) (3.61 g d^{-1} $plant^{-1}$). The lowest tuber bulking rate was observed in f_4h_1 (water spray *fb* vine harvesting at 30 DAP) (1.82 g d^{-1} $plant^{-1}$).

Table 11. Effect of foliar nutrition and vine top harvesting time and their interactions on tuber bulking rate, g d^{-1} $plant^{-1}$

Treatments	Tuber bulking rate		
	15-30 DAP	30-45 DAP	45 DAP to harvest
Factor A: Foliar nutrition management (F)			
f_1 – urea 2% spray at 20 and 35 DAP	0.24	1.46	2.66
f_2 – multi micronutrient 0.5 % spray at 20 and 35 DAP	0.25	1.53	2.57
f_3 – urea 2% spray at 20 DAP + multi micronutrient 0.5% spray at 35 DAP	0.26	1.89	3.40
f_4 – Control water spray	0.23	1.26	2.08
SE (m) ±	0.01	0.13	0.10
CD (0.05)	NS	0.391	0.297
Factor B: vine top harvesting time (H)			
h_1 – 30 DAP	0.23	1.56	2.69
h_2 – 45 DAP	0.25	1.71	2.93
h_3 – Control (No leaf harvest)	0.25	1.35	2.41
SE (m) ±	0.01	0.12	0.09
CD (0.05)	NS	NS	0.257
Interaction F x H			
f_1h_1 –	0.21	1.53	2.53
f_1h_2 –	0.23	1.58	2.93
f_1h_3 –	0.27	1.27	2.51
f_2h_1 –	0.24	1.44	2.78
f_2h_2 –	0.26	1.69	2.90
f_2h_3 –	0.25	1.46	2.01
f_3h_1 –	0.24	2.03	3.61
f_3h_2 –	0.28	2.29	3.67
f_3h_3 –	0.26	1.35	2.92
f_4h_1 –	0.23	1.23	1.82
f_4h_2 –	0.22	1.26	2.23
f_4h_3 –	0.25	1.30	2.18
SE (m) ±	0.02	0.23	0.17
CD (0.05)	NS	NS	0.514

4.3.5 Vine top yield

Vine top and tuber yield of sweet potato for the effect of foliar application of nutrients, along with the timing of vine top harvesting and their interactions are described in the Table 12.

Foliar nutrition and its interaction with timing of vine top harvesting had significant role in augmenting vine top yield. Significantly the highest vine top yield of sweet potato was observed with foliar application of urea 2 per cent spray at 20 DAP + multi micronutrient 0.5% spray at 35 DAP (f_3) (1178.8 kg ha^{-1}). The lowest was registered with control water spray (f_4) (853.5 kg ha^{-1}). Vine top harvesting at 30 DAP (h_1) and at 45 DAP were non-significant.

Interaction effect of foliar nutrition and time of vine top harvesting was significant on vine top yield. Treatment f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine harvesting at 45 DAP) revealed the highest vine top yield) (1226.7 kg ha^{-1}). Lowest vine top yield was observed in f_4h_2 (water spray *fb* vine harvesting at 45 DAP) (822.7 kg ha^{-1}).

4.3.6 Tuber yield

Tuber yield of sweet potato increased with foliar application of nutrients, timing of vine top harvesting and their interactions.

Foliar application of 2 per cent urea at 20 DAP + multi micronutrient 0.5% spray at 35 DAP (f_3) recorded the highest tuber yield (21.48 t ha^{-1}) and the lowest tuber yield was obtained with water spray control (f_4) (17.33 t ha^{-1}).

Significantly higher tuber yield (19.66 t ha^{-1}) was obtained with vine top harvesting at 45 DAP (h_2) and it was on par with the yield of vine top harvesting at 30 DAP *i.e.*, h_1 (19.46 t ha^{-1}). The lowest tuber yield (18.65 t ha^{-1}) was obtained with no vine top harvesting (h_3).

Interaction of foliar nutrition and vine top harvesting time significantly enhanced tuber yield. The treatment f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP *fb* vine top harvesting time at 45 DAP) recorded significantly higher tuber yield (22.13 t ha^{-1}) and it was comparable with f_3h_1 (urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP *fb* vine top harvesting time at 30 DAP) (21.97 t ha^{-1}). The lowest tuber yield was registered in f_4h_1 (water spray *fb* vine top harvesting at 30 DAP (17.10 t ha^{-1}).

Table 12. Effect of foliar nutrition, harvesting time of vine top and its interaction on vine top yield and tuber yield.

Treatments	Vine top yield (kg ha^{-1})	Tuber yield (t ha^{-1})
Factor A : Foliar nutrition management (F)		
f_1 – urea 2% spray at 20 and 35 DAP	1051.7	19.02
f_2 – multi micronutrient 0.5 % spray at 20 and 35 DAP	944.0	19.19
f_3 – urea 2% spray at 20 DAP + multi micronutrient 0.5% spray at 35 DAP	1178.8	21.48
f_4 – Control water spray	853.5	17.33
SE (m) ±	15.6	0.1
CD (0.05)	47.73	0.47
Factor B: Harvesting time of vine top (H)		
h_1 – 30 DAP	998.3	19.46
h_2 – 45 DAP	1015.7	19.66
h_3 – Control (No leaf harvest)	0	18.65
SE (m) ±	11.0	0.1
CD (0.05)	NS	0.41
Interaction F x H		
f_1h_1 –	1016.7	19.37
f_1h_2 –	1086.7	19.53
f_1h_3 –	0.00	18.17
f_2h_1 –	961.3	19.40
f_2h_2 –	926.7	19.83
f_2h_3 –	0.00	18.33
f_3h_1 –	1131.0	21.97
f_3h_2 –	1226.7	22.13
f_3h_3 –	0.00	20.33
f_4h_1 –	884.3	17.10
f_4h_2 –	822.7	17.13
f_4h_3 –	0.00	17.77
SE (m) ±	22.0	0.3
CD (0.05)	67.49	0.82

4.3.7 Marketable tuber yield

The Table 13 shows the effect of foliar application of nutrients, the timing of vine top harvesting and their interactions on marketable tuber yield and vine yield at final harvesting.

Foliar application of nutrients, timing of vine top harvesting and their interaction had significant influence on marketable tuber yield. Foliar application of 2 per cent urea at 20 DAP + multi micronutrient 0.5% spray at 35 DAP (f_3) recorded the highest marketable tuber yield (17.28 t ha^{-1}) and the lowest marketable tuber yield was obtained in control water spray (f_4) (11.22 t ha^{-1}).

Significantly higher marketable tuber yield (15.20 t ha^{-1}) was obtained by leaf harvesting time at 45 DAP (h_2). The lowest marketable tuber yield (12.64 t ha^{-1}) was obtained with no vine top harvest (h_3).

The treatment f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP *fb* leaf harvesting time at 45 DAP) recorded higher marketable tuber yield (19.48 t ha^{-1}) and it was on par with f_3h_1 (urea 2 per cent spray at 20 DAP + multi micronutrient 0.5% spray at 35 DAP *fb* leaf harvesting time 30 DAP) (18.30 t ha^{-1}). The lowest marketable tuber yield was recorded by the treatment f_4h_1 (water spray control *fb* leaf harvesting time at 30 DAP (10.77 t ha^{-1}).

4.3.8 Vine yield at final harvest

Foliar application of nutrients, timing of vine top harvesting and their interaction had significant influence on vine yield at final harvest.

Urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP (f_3) recorded the highest vine yield (36.27 t ha^{-1}). The lowest vine yield was obtained with control water spray (f_4) (30.50 t ha^{-1}).

Vine top harvesting at 45 DAP (h_2) registered the higher vine yield (34.11 t ha^{-1}) and it was on par with vine top harvesting at 30 DAP (h_1) (33.86 t ha^{-1}). The lowest vine yield (30.66 t ha^{-1}) was obtained with no leaf harvest (h_3).

Interaction between foliar nutrition and time of vine top harvesting significantly boosted vine yield at harvest. The treatment f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP *fb* leaf harvesting time 45 DAP) registered higher vine yield (38.57 t ha^{-1}) and it was comparable with vine yield of f_3h_1 (urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP *fb* leaf harvesting time 30 DAP (38.28 t ha^{-1}). The lowest vine yield was recorded with f_4h_3 (water spray control *fb* no vine top harvesting) (28.16 t ha^{-1}).

Table 13. Effect of foliar nutrition, harvesting time of vine top and its interaction on marketable tuber yield and vine yield, t ha^{-1}.

Treatments	Marketable tuber yield	Vine yield
Factor A : Foliar nutrition management (F)		
f_1 – urea 2% spray at 20 and 35 DAP	13.38	32.21
f_2 – multi micronutrient 0.5 % spray at 20 and 35 DAP	13.80	32.51
f_3 – urea 2% spray at 20 DAP + multi micronutrient 0.5% spray at 35 DAP	17.28	36.27
f_4 – Control water spray	11.22	30.50
SE (m) ±	0.38	0.48
CD (0.05)	1.131	1.416
Factor B: Harvesting time of vine top (H)		
h_1 – 30 DAP	13.92	33.86
h_2 – 45 DAP	15.20	34.11
h_3 – Control (No leaf harvest)	12.64	30.67
SE (m) ±	0.33	0.42
CD (0.05)	0.979	1.226
Interaction F x H		
f_1h_1 –	13.53	32.33
f_1h_2 –	14.37	32.98
f_1h_3 –	12.23	31.32
f_2h_1 –	13.07	33.67
f_2h_2 –	15.50	32.70
f_2h_3 –	12.83	31.18
f_3h_1 –	18.30	38.28
f_3h_2 –	19.48	38.57
f_3h_3 –	14.07	31.97
f_4h_1 –	10.77	31.14
f_4h_2 –	11.47	32.19
f_4h_3 –	11.43	28.16
SE (m) ±	0.66	0.83
CD (0.05)	1.959	2.453

4.3 PHYSIOLOGICAL PARAMETERS

4.3.1 Total chlorophyll content

The Table 14 shows the total chlorophyll content of harvested vine top of sweet potato as influenced by foliar application of nutrients, along with the timing of vine top harvesting and their interaction.

Foliar application of urea 2 per cent at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP (f_3) recorded significantly higher chlorophyll content of leaf (3.40 mg g^{-1}) and it were on par with f_1 (urea 2 per cent spray at 20 and 35 DAP) (3.35 mg g^{-1}) and f_2 (multi micronutrient 0.5 per cent spray at 20 and 35 DAP) (3.24 mg g^{-1}). The lowest chlorophyll content of leaf (2.16 mg g^{-1}) was obtained with control water spray (f_4).

Significantly higher chlorophyll content of leaf (3.21 mg g^{-1}) was obtained by h_2 (vine top harvesting time at 45 DAP) and it was comparable with leaf harvesting time at 30 DAP (h_1) (3.16 mg g^{-1}). The lowest chlorophyll content of leaf (2.73 mg g^{-1}) was obtained with no vine top harvest (h_3).

Interaction effect of foliar nutrition and time of vine top harvesting on chlorophyll content of leaf was non-significant.

Table 14. Effect of foliar nutrition, vine top harvesting and their interactions on chlorophyll content of leaf

Treatments	Chlorophyll content of leaf mg g^{-1}
Factor A: Foliar nutrition management (F)	
f_1 – urea 2% spray at 20 and 35 DAP	3.34
f_2 – multi micronutrient 0.5 % spray at 20 and 35 DAP	3.35
f_3 – urea 2% spray at 20 DAP + multi micronutrient 0.5% spray at 35 DAP	3.71
f_4 – Control water spray	2.14
SE (m) ±	0.13
CD (0.05)	0.391
Factor B: Harvesting time of vine top (H)	
h_1 – 30 DAP	3.24
h_2 – 45 DAP	3.27
h_3 – Control (No vine top harvest)*	2.89
SE (m) ±	0.12
CD (0.05)	NS
Interaction F x H	
f_1h_1 –	3.35
f_1h_2 –	3.44
f_1h_3 –	3.22
f_2h_1 –	3.56
f_2h_2 –	3.55
f_2h_3 –	2.94
f_3h_1 –	3.94
f_3h_2 –	3.97
f_3h_3 –	3.23
f_4h_1 –	2.10
f_4h_2 –	2.11
f_4h_3 –	2.19
SE (m) ±	0.23
CD (0.05)	NS
*Control (No vine top harvest): Sample collected on 45 DAP (chlorophyll content-fresh weight basis)	

4.4 QUALITY PARAMETERS

Results on effect of quality parameters of tuber and vine top are presented below.

4.4.1 Tuber

Table 15 shows the starch content, crude protein content, total sugars and beta carotene content of sweet potato tuber for the effect of foliar application of nutrients, along with the timing of vine top harvesting and their interactions.

4.4.1.1 Starch content

Foliar nutrition, time of vine top harvest and their interaction had significant influence on starch content in sweet potato. The maximum starch content (23.40 per cent) was reported with application of urea 2 per cent spray at 20 DAP and a multi-micronutrient 0.5 per cent spray at 35 DAP (f_3) and it is on par with f_1 (urea 2 per cent spray at 20 and 35 DAP) (22.67 per cent). Control water spray (f_4) registered the lowest starch content of the tuber (20.96 per cent).

The time of vine top harvesting at 45 DAP (h_2) yielded higher starch content (22.87 per cent), which is comparable to h_1 (vine top harvesting at 30 DAP) (22.78 per cent). The lowest starch content (21.52 per cent) was observed with no vine top harvest (h_3).

Interaction between foliar nutrition and time of vine top harvesting significantly enhanced the starch content of tuber. The treatment f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP *fb* leaf harvesting time at 45 DAP) recorded significantly higher starch content of tuber (24.47 per cent) and it were on par with the starch content of tuber of f_3h_1 (urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP *fb* leaf harvesting at 30 DAP) (24.31 per cent), f_1h_2 (urea 2 per cent spray at 20 and 35 DAP *fb* leaf harvesting time at 45 DAP) (23.12 per cent) and f_1h_1 (urea 2 per cent spray at 20 and 35 DAP *fb* vine harvesting time at 30 DAP) (23.09 per cent). The lowest starch content of tuber recorded by the treatment f_4h_1 (control water spray *fb* leaf harvesting time at 30 DAP (20.69 per cent).

Table 15. Effect of foliar nutrition, time of vine top harvesting and its interaction on quality parameters of sweet potato tubers

Treatments	Starch content (%)	Crude protein content (%)	Total sugars (%)	Beta carotene content (mg 100 g^{-1})
Factor A: Foliar nutrition management (F)				
f_1 – urea 2% spray at 20 and 35 DAP	22.67	4.24	4.02	0.52
f_2 – multi micronutrient 0.5 % spray at 20 and 35 DAP	22.52	4.37	4.01	0.51
f_3 – urea 2% spray at 20 DAP + multi micronutrient 0.5% spray at 35 DAP	23.40	5.17	4.71	0.53
f_4 – Control water spray	20.96	3.45	2.96	0.44
SE (m) ±	0.28	0.14	0.17	0.01
CD (0.05)	0.823	0.421	0.510	0.038
Factor B: Harvesting time of vine top (H)				
h_1 – 30 DAP	22.78	4.40	4.11	0.51
h_2 – 45 DAP	22.87	4.64	4.16	0.52
h_3 – Control (No leaf harvest)	21.52	3.88	3.51	0.47
SE (m) ±	0.24	0.12	0.15	0.01
CD (0.05)	0.712	0.365	0.441	0.033
Interaction F x H				
f_1h_1 –	23.09	4.23	4.24	0.53
f_1h_2 –	23.12	4.70	4.13	0.52
f_1h_3 –	21.81	3.78	3.67	0.49
f_2h_1 –	23.02	4.40	4.07	0.51
f_2h_2 –	22.86	4.44	4.10	0.53
f_2h_3 –	21.68	4.26	3.86	0.48
f_3h_1 –	24.31	5.62	5.22	0.55
f_3h_2 –	24.47	5.77	5.45	0.56
f_3h_3 –	21.42	4.10	3.46	0.47
f_4h_1 –	20.69	3.33	2.90	0.43
f_4h_2 –	21.02	3.63	2.95	0.45
f_4h_3 –	21.18	3.39	3.03	0.44
SE (m) ±	0.48	0.25	0.29	0.02
CD (0.05)	1.425	0.729	0.883	NS
*Starch, crude protein, betacarotene content-dry weight basis. Total sugars content-fresh weight basis				

4.4.1.2. Crude protein content

Crude protein content in sweet potato tubers were significantly influenced by foliar nutrition, time of vine top harvest and their interaction.

The highest amount of crude protein in the tuber (5.17 per cent) was recorded with foliar application of urea 2 per cent spray at 20 DAP and a multi-micronutrient 0.5 per cent spray at 35 DAP (f_3). Control water spray (f_4) produced the lowest crude protein content (3.45 per cent) of tuber.

The vine top harvesting at 45 DAP (h_2) yielded greater crude protein content of the tuber (4.64 per cent), which was comparable to h_1 (vine top harvesting at 30 DAP) (4.40 per cent). When there was no leaf harvest, the crude protein level was at its lowest (3.88 per cent) (h_3).

Interaction between foliar nutrition and time of vine top harvesting significantly affected the crude protein content of tuber. The treatment f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP *fb* leaf harvesting time at 45 DAP) recorded higher crude protein content of tuber (5.77 per cent) and it was on par with the crude protein content of tuber f_3h_1 (urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP *fb* leaf harvesting time 30 DAP) (5.62 per cent). The lowest crude protein content of tuber was recorded by the treatment f_4h_1 (control water spray *fb* leaf harvesting time at 30 DAP (3.33 per cent),

4.4.1.3. Total sugars

Total sugar content of sweet potato tuber was significantly influenced by foliar nutrition, time of vine top harvest and their interaction.

The highest total sugar content of the tuber (4.71 per cent) was recorded with foliar application of urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP (f_3). The control water spray (f_4) resulted in the lowest total sugar content in tuber (2.96 per cent).

Vine top harvesting at 45 DAP (h_2) yielded higher total sugar content (4.16 per cent), which was comparable to h_1 (vine top harvesting period at 30 DAP) (4.11 per cent). The lowest total sugars content (3.51 per cent) was registered in no vine top harvesting (h_3)

Interaction between foliar nutrition and vine top harvesting significantly affected the total sugar content of tuber. The treatment f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP *fb* leaf harvesting time at 45 DAP) recorded significantly higher total sugar content of tuber (5.45 per cent) and it was on par with the total sugar content of f_3h_1 (urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP *fb* leaf harvesting time 30 DAP) (5.22 per cent). The lowest total sugar content of tuber was recorded by the treatment f_4h_1 *i,e.*, control water spray *fb* vine top harvesting time at 30 DAP (2.90 per cent).

4.4.1.4. Beta carotene content

Beta carotene content of tuber was influenced significantly by foliar application of nutrient and time of vine top harvest. Interaction effect was not significant.

Urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP (f_3) recorded higher beta carotene content of tuber (0.53 mg 100 g^{-1}) and it were on par with multi micronutrient 0.5 per cent spray at 20 and 35 DAP (f_2) (0.51 mg 100 g^{-1}) and f_1 (urea 2 per cent spray at 20 and 35 DAP) (0.52 mg 100 g^{-1}). The lowest beta carotene content of tuber (0.44 mg 100 g^{-1}) was obtained with control water spray (f_4).

Beta carotene content of tuber (0.52 mg 100 g^{-1}) was higher with vine top harvesting at 45 DAP (h_2) and it was on par with h_1 (vine harvesting time at 30 DAP) (0.51 mg 100 g^{-1}). The lowest beta carotene content of tuber (0.47 mg 100 g^{-1}) was obtained with no vine top harvest (h_3).

4.4.2 Vine top

The results on the nitrate, crude protein, fibre, vitamin A and vitamin C contents in vine top of sweet potato are presented below.

4.4.2.1. Nitrate content

Table 16 shows the nitrate content, crude protein content and fibre content of sweet potato vine top in response to foliar application of nutrients, timing of vine top harvesting and their interactions.

Significantly the lowest nitrate content of vine top (666.89 mg $100g^{-1}$) was obtained with control water spray (f_4). Urea 2 per cent spray at 20 and 35 DAP (f_1) recorded higher nitrate content of vine top (898.69 mg $100g^{-1}$) and it was on par with urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP (f_3) (890.33 mg $100g^{-1}$).

There is no significant effect for harvesting time of vine top on nitrate content of vine top.

Interaction between foliar nutrition and leaf harvesting time significantly affected the nitrate content of vine top. Lower nitrate content (659.67 mg $100g^{-1}$) of vine top was recorded by the treatment f_4h_1 *i,e.*, control water spray *fb* vine top harvesting at 30 DAP and remained comparable with f_4h_2 (control water spray *fb* vine top harvesting at 45 DAP) (663.67 mg $100g^{-1}$) and f_4h_3 (control water spray *fb* with no vine top harvest) (677.33 mg $100g^{-1}$).

The treatment f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP *fb* leaf harvesting time at 45 DAP) recorded higher nitrate content of vine top (964.28 mg $100g^{-1}$) and it was on par with f_3h_1 (urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP *fb* leaf harvesting time 30 DAP) (941.69 mg $100g^{-1}$), f_1h_1 (urea 2 per cent spray at 20 and 35 DAP *fb* leaf harvesting time at 30 DAP) (931.33 mg $100g^{-1}$) and f_1h_2 (urea 2 per cent spray at 20 and 35 DAP *fb* leaf harvesting time at 45 DAP) (914.69 mg $100g^{-1}$).

4.4.2.2. Crude protein content

Crude protein content of sweet potato vine was significantly influenced by foliar nutrition, time of vine top harvest and their interaction.

Foliar application of urea 2 per cent at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP (f_3) recorded significantly the highest crude protein content of vine top (23.60 %). The lowest crude protein content of vine top (20.45 %) was obtained with control water spray (f_4).

The Vine top harvesting at 30 DAP (h_1) yielded higher crude protein content (22.68 %), which was comparable to h_2 (vine top harvesting at 45 DAP) (22.32 %). The lowest crude protein content (21.15 %) was obtained with control water spray (f_4).

Interaction between foliar nutrition and vine top harvesting time significantly affected the crude protein content of vine top. The treatment f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP *fb* vine top harvesting at 45 DAP) recorded higher crude protein content of vine top (25.16 %) and it was on par with f_3h_1 (urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP *fb* vine top harvesting at 30 DAP) (25.01 %). The lowest crude protein content of vine top was recorded by the treatment f_4h_1 *i,e.*, control water spray *fb* leaf harvesting time at 30 DAP (20.20 %).

4.4.2.3. Fibre content

Fibre content of sweet potato vine was significantly influenced by foliar nutrition, time of vine top harvest and their interaction.

Foliar application of urea 2 per cent spray at 20 DAP and 35 DAP (f_1) recorded significantly the lowest fibre content in vine top (4.74 %). The highest fibre content of vine top (6.64 %) was obtained with control water spray (f_4).

Significantly the lowest fibre content of vine top (4.83 %) was obtained by vine top harvesting at 45 DAP (h_2). The highest fibre content of vine top (6.59 %) was obtained with no leaf harvest (h_3).

Interaction between foliar nutrition and vine top harvesting significantly decreased the fibre content of vine top. The treatment f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP *fb* vine top harvesting at 45 DAP) recorded significantly the lowest fibre content (4.09 per cent). The higher fibre content of vine top was recorded by the treatment f_4h_3 (control water spray *fb* no leaf harvesting (7.66 per cent) and it was on par with (f_2h_3) multi micronutrient 0.5 per cent spray at 20 and 35 DAP *fb* no vine top harvesting (7.07 per cent).

Table 16. Effect of foliar nutrition, time of vine top harvesting and its interaction on quality parameters of sweet potato vine top

Treatments	Nitrate content mg $100g^{-1}$)	Crude protein content (%)	Fibre content (%)
Factor A: Foliar nutrition management (F)			
f_1 – urea 2% spray at 20 and 35 DAP	898.69	22.10	4.74
f_2 – multi micronutrient 0.5 % spray at 20 and 35 DAP	769.12	22.05	5.63
f_3 – urea 2% spray at 20 DAP + multi micronutrient 0.5% spray at 35 DAP	890.33	23.60	4.82
f_4 – Control water spray	666.89	20.45	6.64
SE (m) ±	20.51	0.41	0.15
CD (0.05)	60.544	1.220	0.457
Factor B: Leaf harvesting time (H)			
h_1 – 30 DAP	826.76	22.68	4.95
h_2 – 45 DAP	821.74	22.32	4.83
h_3 – Control (No leaf harvest)*	770.27	21.15	6.59
SE (m) ±	17.76	0.36	0.13
CD (0.05)	NS	1.056	0.396
Interaction F x H			
f_1h_1 –	931.33	22.86	4.32
f_1h_2 –	914.69	22.30	4.51
f_1h_3 –	850.05	21.14	5.40
f_2h_1 –	774.36	22.64	4.55
f_2h_2 –	744.33	21.27	5.26
f_2h_3 –	788.67	22.24	7.07
f_3h_1 –	941.69	25.01	4.12
f_3h_2 –	964.28	25.16	4.09
f_3h_3 –	765.01	20.61	6.25
f_4h_1 –	659.67	20.20	6.82
f_4h_2 –	663.67	20.54	5.44
f_4h_3 –	677.33	20.60	7.66
SE (m) ±	35.52	0.72	0.27
CD (0.05)	104.865	2.112	0.792
*Control (No vine top harvest): Sample collected on 45 DAT (nitrate, crude protein and fibre content-dry weight basis)			

4.4.2.4. Vitamin A

Foliar nutrition and its interaction influenced the vitamin A and vitamin C content of vine top of sweet potato (Table 17). The time of vine top harvested did not affect the vitamin A content of the vine top.

Urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP (f_3) recorded significantly the highest vitamin A content of vine top (3243.13 IU). The lowest vitamin A content of vine top (3011.57 IU) was obtained with control water spray (f_4).

Interaction between foliar nutrition and leaf harvesting time significantly affected the vitamin A content of vine top. The treatment f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP *fb* vine top harvesting at 45 DAP) recorded significantly higher vitamin A content in vine top (3290.33 IU) and it was comparable with f_3h_1 (urea 2 per cent spray at 20 DAP + multi micronutrient 0.5% spray at 35 DAP *fb* vine top harvest at 30 DAP) (3232.37 IU) and f_2h_2 (multi micronutrient 0.5 % spray at 20 and 35 DAP *fb* vine top harvest at 45 DAP) (3222.33 IU). The lowest vitamin A content of vine top (2966.02 IU) was recorded by the treatment f_4h_1 (control water spray *fb* leaf harvesting time at 30 DAP.

4.4.2.5. Vitamin C

Foliar nutrition and time of vine top harvesting influenced the vitamin C content of vine top of sweet potato.

Foliar application of 2 per cent urea at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP (f_3) recorded higher vitamin C content of vine top (9.84 mg 100 g^{-1}) and it were on par with f_1 (urea 2 per cent spray at 20 and 35 DAP) (9.61 mg 100 g^{-1}) and f_2 (multi micronutrient 0.5 per cent spray at 20 and 35 DAP) (9.40 mg 100 g^{-1}). The lowest vitamin C content of vine top (8.67 mg 100 g^{-1}) was obtained with control water spray (f_4).

Vitamin C content of vine top (9.75 mg 100 g^{-1}) was significantly higher with vine top harvesting at 45 DAP (h_2) and it was on par with h_1 (vine top harvesting at 30 DAP) (9.58 mg 100 g^{-1}). The lowest vitamin C content of vine top (8.81 mg 100 g^{-1}) was obtained with no vine top harvest (h_3).

There was no significant effect for interaction of foliar nutrition and time of vine top harvesting on vitamin C content.

Table 17. Effect of foliar nutrition, harvesting time of vine top and interaction on Vitamin A and C

Treatments	Vitamin C (mg $100g^{-1}$)	Vitamin A (IU)
Factor A: Foliar nutrition management (F)		
f_1 – urea 2% spray at 20 and 35 DAP	9.61	3121.36
f_2 – multi micronutrient 0.5 % spray at 20 and 35 DAP	9.40	3170.92
f_3 – urea 2% spray at 20 DAP + multi micronutrient 0.5% spray at 35 DAP	9.84	3243.13
f_4 – Control water spray	8.67	3011.57
SE (m) ±	0.27	15.46
CD (0.05)	0.795	45.638
Factor B: Harvesting time of vine top (H)		
h_1 – 30 DAP	9.58	3132.53
h_2 – 45 DAP	9.75	3159.09
h_3 – Control (No leaf harvest)	8.81	3118.61
SE (m) ±	0.23	13.39
CD (0.05)	0.688	NS
Interaction F x H		
f_1h_1 –	9.84	3168.36
f_1h_2 –	9.98	3085.67
f_1h_3 –	9.01	3110.06
f_2h_1 –	9.86	3163.37
f_2h_2 –	9.33	3222.33
f_2h_3 –	9.02	3127.04
f_3h_1 –	10.17	3232.37
f_3h_2 –	10.67	3290.33
f_3h_3 –	8.70	3206.67
f_4h_1 –	8.43	2966.02
f_4h_2 –	9.02	3038.03
f_4h_3 –	8.50	3030.67
SE (m) ±	0.47	26.78
CD (0.05)	NS	79.047
*Control (No vine top harvest): Sample collected on 45 DAP (vitamin A and C- dry weight basis)		

4.4.2.6 NPK uptake in plants

Table 18 shows the NPK uptake of sweet potato as influenced by foliar application of nutrients, timing of vine top harvesting and their interactions.

Foliar nutrition, time of vine top harvesting and its interaction had significant effect on NPK uptake. Significantly higher NPK uptake were observed with foliar application of urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP (f_3) (53.36, 10.53, 55.04 kg ha^{-1} NPK respectively) and it was comparable with f_1 (urea 2 per cent spray at 20 and 35 DAP) (52.21, 51.94 kg ha^{-1} NPK respectively) in case of nitrogen and potassium. The lowest NPK uptake was registered with control water spray (f_4) (35.51, 5.73, 43.03 94 kg ha^{-1} NPK respectively).

The vine top harvesting time showed significant effect on uptake of phosphorus and potassium. The vine top harvesting at 45 DAP (h_2) showed higher uptake of phosphorus and potassium (8.73 kg P_2O_5 ha^{-1}, 49.85 kg K_2O ha^{-1} respectively), which is comparable to h_1 (vine top harvesting at 30 DAP) (8.67 kg P_2O_5 ha^{-1}, 49.79 kg K_2O ha^{-1} respectively). The lowest uptake (7.30 kg P_2O_5 ha^{-1}, 46.08 kg K_2O ha^{-1} respectively) was observed with no vine top harvest (h_3).

Interaction effect of foliar nutrition and time of vine top harvesting was significant on uptake of phosphorus. Treatment f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine harvesting at 45 DAP) revealed higher uptake on phosphorus (11.83 kg ha^{-1}) and it was on par with f_3h_1 (urea 2 per cent spray at 20 DAP + multi micronutrient 0.5per cent spray at 35 DAP *fb* vine top harvest at 30 DAP) (11.67 kg ha^{-1}). The lowest phosphorus uptake was observed in f_4h_1 (water spray *fb* vine harvesting at 30 DAP) (5.49 kg ha^{-1}).

Table 18. Effect of foliar nutrition, time of vine top harvesting and its interaction on plant uptake of NPK at harvest of sweet potato, kg ha^{-1}

Treatments	Nutrient uptake		
	Nitrogen	Phosphorus	Potassium
Factor A: Foliar nutrition management (F)			
f_1 – urea 2% spray at 20 and 35 DAP	52.21	8.57	51.94
f_2 – multi micronutrient 0.5 % spray at 20 and 35 DAP	43.57	8.11	44.28
f_3 – urea 2% spray at 20 DAP + multi micronutrient 0.5% spray at 35 DAP	53.36	10.53	55.04
f_4 – Control water spray	35.51	5.73	43.03
SE (m) ±	1.12	0.34	1.05
CD (0.05)	3.320	1.011	3.094
Factor B: Harvesting time of vine top (H)			
h_1 – 30 DAP	46.64	8.67	49.79
h_2 – 45 DAP	46.78	8.73	49.85
h_3 – Control (No leaf harvest)	45.07	7.30	46.08
SE (m) ±	0.97	0.29	0.91
CD (0.05)	NS	0.875	2.680
Interaction F x H			
f_1h_1 –	53.37	9.10	54.13
f_1h_2 –	52.83	8.67	52.60
f_1h_3 –	50.43	7.93	49.08
f_2h_1 –	43.33	8.43	44.57
f_2h_2 –	42.03	8.67	44.70
f_2h_3 –	45.33	7.23	43.59
f_3h_1 –	55.54	11.67	57.39
f_3h_2 –	56.33	11.83	58.83
f_3h_3 –	48.20	8.10	48.80
f_4h_1 –	34.30	5.49	43.07
f_4h_2 –	35.93	5.77	43.27
f_4h_3 –	36.30	5.93	42.77
SE (m) ±	1.95	0.58	1.82
CD (0.05)	NS	1.750	NS

4.4.2.7. Zinc content

Table 19 shows the Zn, Fe, Cu and Mn content of sweet potato in response to foliar application of nutrients, timing of vine top harvesting and their interaction.

Foliar nutrition and time of vine top harvest had significant influence on zinc content in vine top. Higher zinc content (4.24 mg $100g^{-1}$) was observed with application of multi-micronutrient 0.5 per cent spray at 20 DAP and 35 DAP (f_2) and it was on par with urea 2 per cent spray at 20 DAP and a multi-micronutrient 0.5 per cent spray at 35 DAP (f3) and f_1 (urea 2 per cent spray at 20 and 35 DAP) (4.18 and 3.97 mg 100 g^{-1} respectively). Control water spray (f_4) registered the lowest zinc content of the vine top (2.42 mg $100g^{-1}$).

The vine top harvesting at 30 DAP (h_1) yielded higher zinc content (3.98 mg $100g^{-1}$) and was comparable to h_2 (vine top harvesting at 45 DAP) (3.86 mg $100g^{-1}$). The lowest zinc content (3.27 mg $100g^{-1}$) was observed with no vine top harvest (h_3).

There was no significant difference in zinc content of vine top with interaction of foliar nutrition and time of vine top harvesting.

4.4.2.8. Iron content

Only foliar nutrition had significant influence on iron content in vine top. Higher iron content (41.05 mg $100g^{-1}$) was noted with application of multi-micronutrient 0.5 per cent spray at 20 DAP and 35 DAP (f_2) and it was on par with urea 2 per cent spray at 20 DAP and a multi-micronutrient 0.5 per cent spray at 35 DAP (f3) (40.56 mg $100g^{-1}$). Control water spray (f_4) registered the lowest iron content in vine top (27.84 mg $100g^{-1}$).

There was no significant effect for harvesting time of vine top and interaction between foliar nutrition and time of vine top harvesting on iron content of vine top.

4.4.2.9. Copper content

Foliar nutrition and time of vine top harvest had significant influence on copper content in vine top.

Higher copper content (1.47 mg $100g^{-1}$) was observed with application of urea 2 per cent spray at 20 DAP and a multi-micronutrient 0.5 per cent spray at 35 DAP (f3) and it was comparable with (f_2) multi-micronutrient 0.5 per cent spray at 20 DAP and 35 DAP and f_1 (urea 2 per cent spray at 20 and 35 DAP) (1.33 and 1.31 mg $100g^{-1}$ respectively). Control water spray (f_4) registered the lowest copper content in the vine top (0.82 mg $100g^{-1}$).

Vine top harvesting at 45 DAP (h_2) yielded higher copper content (1.32 mg $100g^{-1}$), which was comparable to h_1 (vine top harvesting at 30 DAP) (1.26 mg $100g^{-1}$). The lowest copper content (1.11 mg $100g^{-1}$) was observed with no vine top harvest (h_3).

There was no significant difference in the effect of interaction of foliar nutrition and time of vine top harvesting on copper content of vine top.

4.4.2.10. Manganese content

Foliar nutrition, time of vine top harvest and their interaction had significant influence on manganese content in vine top. The highest manganese content (7.96 mg $100g^{-1}$) was reported with application of urea 2 per cent spray at 20 DAP and a multi-micronutrient 0.5 per cent spray at 35 DAP (f_3). Control water spray (f_4) registered the lowest manganese content of the vine top (4.29 mg $100g^{-1}$).

The vine top harvesting at 30 DAP (h_1) yielded higher manganese content (6.86 mg $100g^{-1}$), which was comparable to h_2 (vine top harvesting at 45 DAP) (6.82 mg $100g^{-1}$). The lowest manganese content (6.19 mg $100g^{-1}$) was observed with no vine top harvest (h_3).

Interaction between foliar nutrition and leaf harvesting time significantly affected the manganese content of vine top. The treatment f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP *fb* vine top harvesting at 45 DAP) recorded significantly higher manganese content in vine top (8.73 mg $100g^{-1}$) and it was comparable with f_3h_1 (urea 2 per cent spray at 20 DAP + multi micronutrient 0.5% spray at 35 DAP *fb* vine top harvest at 30 DAP) (8.47 mg $100g^{-1}$). The lowest manganese content of vine top was recorded by the treatment f_4h_1 (control water spray *fb* leaf harvesting time at 30 DAP (4.07 mg $100g^{-1}$).

Table 19. Effect of foliar nutrition, time of vine top harvesting and its interaction on uptake of micronutrient content of sweet potato, mg $100g^{-1}$

Treatments	Zinc	Iron	Copper	Manganese
Factor A: Foliar nutrition management (F)				
f_1 – urea 2% spray at 20 and 35 DAP	3.97	37.22	1.31	6.92
f_2 – multi micronutrient 0.5 % spray at 20 and 35 DAP	4.24	41.05	1.33	7.31
f_3 – urea 2% spray at 20 DAP + multi micronutrient 0.5% spray at 35 DAP	4.18	40.56	1.47	7.96
f_4 – Control water spray	2.42	27.84	0.82	4.29
SE (m) ±	0.12	0.98	0.06	0.18
CD (0.05)	0.362	2.902	0.169	0.520
Factor B: Harvesting time of vine top (H)				
h_1 – 30 DAP	3.98	37.84	1.26	6.86
h_2 – 45 DAP	3.86	37.29	1.32	6.82
h_3 – Control (No leaf harvest)	3.27	34.88	1.11	6.19
SE (m) ±	0.11	0.85	0.05	0.15
CD (0.05)	0.314	NS	0.146	0.450
Interaction F x H				
f_1h_1 –	4.47	37.50	1.31	7.63
f_1h_2 –	4.17	37.83	1.37	6.70
f_1h_3 –	3.29	36.33	1.24	6.43
f_2h_1 –	4.56	43.60	1.41	7.27
f_2h_2 –	4.27	40.13	1.40	7.53
f_2h_3 –	3.89	39.42	1.17	7.13
f_3h_1 –	4.48	43.27	1.60	8.47
f_3h_2 –	4.54	43.48	1.66	8.73
f_3h_3 –	3.51	34.93	1.13	6.69
f_4h_1 –	2.40	26.98	0.72	4.07
f_4h_2 –	2.48	27.71	0.85	4.32
f_4h_3 –	2.39	28.83	0.88	4.50
SE (m) ±	0.21	1.70	0.09	0.31
CD (0.05)	NS	NS	NS	0.900
*Zinc, iron, manganese and copper content-dry weight basis				

4.4.2.11. NPK in soil after the experiment

NPK content of soil after the experiment are depicted in Table 20.

Foliar application of nutrients and its interaction effect showed significant effect on NPK content in soil after the experiment,

The highest NPK status was recorded with f_3 (foliar application of 2 per cent urea at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP (234.25, 13.74, 130.58 kg ha^{-1} NPK respectively) it was comparable with f_1 (urea 2 per cent spray at 20 and 35 DAP) (233.81, 12.69 kg ha^{-1}) for nitrogen and phosphorus. The lowest NPK status was registered with f_4 (control water spray) (207.85, 10.86, 107.07 kg ha^{-1} NPK respectively).

The time of vine top harvesting did not affect the NPK status in soil after the experiment significantly.

Interaction effect of foliar nutrition and time of vine top harvesting was significant with respect to NPK content in soil after the experiment. Treatment f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine harvesting at 45 DAP) registered highest NPK status (246.27, 15.01, 137.03 kg ha^{-1} NPK respectively) and it were on par with f_3h_1 (urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP *fb* vine top harvest at 30 DAP) (240.37 kg N ha^{-1}), f_1h_3 (urea 2 per cent spray at 20 and 35 DAP *fb* no vine top harvesting) (235.47 kg N ha^{-1}), f_1h_2 (urea 2 per cent spray at 20 and 35 DAP *fb* vine harvesting at 45 DAP) (233.30 kg N ha^{-1}), f_1h_1 (urea 2 per cent spray at 20 and 35 DAP *fb* vine harvesting at 30 DAP) (232.67 kg N ha^{-1}). Phosphorus and potassium were on par with f_3h_1 (urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP *fb* vine top harvest at 30 DAP) (14.75 and 134.25 kg ha^{-1}). Lowest NPK was observed with f_4h_1 (water spray *fb* vine harvesting at 30 DAP) (203.33, 10.02, 102.40 kg NPK ha^{-1}).

Table 20. Effect of foliar nutrition, time of vine top harvesting and its interaction on NPK in the soil after harvest of sweet potato, kg ha^{-1}

Treatments	NPK present in the soil after harvest		
	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
Factor A: Foliar nutrition management (F)			
f_1 – urea 2% spray at 20 and 35 DAP	233.81	12.69	121.58
f_2 – multi micronutrient 0.5 % spray at 20 and 35 DAP	215.10	12.41	121.10
f_3 – urea 2% spray at 20 DAP + multi micronutrient 0.5% spray at 35 DAP	234.25	13.74	130.58
f_4 – Control water spray	207.85	10.86	107.07
SE (m) ±	3.11	0.37	1.50
CD (0.05)	9.173	1.078	4.430
Factor B: Harvesting time of vine top (H)			
h_1 – 30 DAP	222.79	12.45	120.21
h_2 – 45 DAP	226.20	12.83	121.37
h_3 – Control (No leaf harvest)	219.27	11.99	118.67
SE (m) ±	2.69	0.32	1.30
CD (0.05)	NS	NS	NS
Interaction F x H			
f_1h_1 –	232.67	12.73	120.53
f_1h_2 –	233.30	12.65	122.87
f_1h_3 –	235.47	12.69	121.33
f_2h_1 –	214.77	12.30	123.67
f_2h_2 –	216.40	12.33	118.30
f_2h_3 –	214.13	12.60	121.33
f_3h_1 –	240.37	14.75	134.25
f_3h_2 –	246.27	15.01	137.03
f_3h_3 –	216.10	11.47	120.50
f_4h_1 –	203.33	10.02	102.40
f_4h_2 –	208.83	11.33	107.30
f_4h_3 –	211.38	11.23	111.50
SE (m) ±	5.38	0.63	2.59
CD (0.05)	15.889	1.868	7.672

4.4.2.12. Organoleptic evaluation

4.4.2.12.1. Tuber

Organoleptic observations of tuber are tabulated as Table 21.

The f_3h_2 (foliar application of urea 2 per cent at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine harvesting at 45 DAP) registered the highest overall tuber acceptability (score: 19.53) and the lowest over all tuber acceptability with f_4h_2 (control water spray *fb* vine harvesting at 45 DAP) (score: 17.04).

Table 21. Effect of foliar nutrition and time of vine top harvesting on organoleptic evaluation of sweet potato tuber.

Treatments	**Appearance**	**Colour**	**Flavour**	**Texture**	**Taste**	**Overall acceptability**
Interaction FXH						
f_1h_1	3.20	3.10	3.50	3.40	4.30	17.50
f_1h_2	3.40	3.09	3.30	3.60	4.24	17.63
f_1h_3	3.50	3.13	3.43	3.27	4.40	17.73
f_2h_1	3.20	3.12	3.28	3.48	4.26	17.34
f_2h_2	3.60	3.08	3.46	3.30	4.38	17.82
f_2h_3	3.30	3.16	3.27	3.53	4.40	17.66
f_3h_1	3.70	3.26	3.78	3.83	4.68	19.25
f_3h_2	3.80	3.30	3.86	3.72	4.85	19.53
f_3h_3	3.50	3.27	3.69	3.54	4.71	18.71
f_4h_1	3.20	3.05	3.20	3.20	4.08	16.73
f_4h_2	3.30	3.17	3.21	3.26	4.10	17.04
f_4h_3	3.35	3.20	3.25	3.31	4.20	17.31

4.4.2.12.2. Vine top

Vine tops were cooked in water and organoleptic observations of vine top are tabulated as Table 22.

The f_3h_2 (foliar application of urea 2 per cent at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine harvesting at 45 DAP) registered the highest overall vine top acceptability (score: 11.71) and the lowest overall tuber acceptability with f_4h_2 (control water spray *fb* vine harvesting at 45 DAP) (score: 9.85).

Table 22. Effect of foliar nutrition and harvesting time of vine top on organoleptic evaluation of sweet potato vine top.

Treatments	Appearance	Colour	Flavour	Texture	Taste	Overall acceptability
Interaction FXH						
f_1h_1	2.50	2.20	1.30	2.40	2.10	10.50
f_1h_2	2.70	2.43	1.20	2.26	2.20	10.79
f_1h_3	2.20	2.70	1.34	2.30	2.06	10.60
f_2h_1	2.60	2.50	1.10	2.30	2.18	10.68
f_2h_2	2.30	2.30	1.40	2.10	2.15	10.25
f_2h_3	2.80	2.40	1.20	2.08	2.00	10.48
f_3h_1	2.50	2.20	1.50	2.43	2.40	11.03
f_3h_2	2.70	2.30	1.70	2.56	2.45	11.71
f_3h_3	2.40	2.24	1.50	2.40	2.32	10.86
f_4h_1	2.45	2.10	1.20	2.10	2.00	9.85
f_4h_2	2.40	2.10	1.10	2.18	2.10	9.88
f_4h_3	2.20	2.20	1.23	2.20	2.17	10.00

4.4.2.13. Net income and B:C ratio

The data on net income and B:C ratio were represented in Table 23. Foliar application and vine top harvesting time in sweet potatoes improved net income and the B:C ratio. The treatment f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine harvesting at 45 DAP) resulted in higher net income (₹ 581440 ha^{-1}) and B:C ratio (2.44). The lowest net income was observed in f_4h_1 (water spray *fb* vine harvesting at 30 DAP) (₹143166 ha^{-1}) and B:C ratio (1.35).

Table 23. Effect of foliar nutrition and harvesting time of vine top on net income and B:C ratio

Treatments	Net income (₹ ha^{-1})	B:C ratio
Interaction FXH		
f_1h_1	282589	1.70
f_1h_2	325289	1.81
f_1h_3	210423	1.52
f_2h_1	258786	1.64
f_2h_2	379940	1.94
f_2h_3	240173	1.60
f_3h_1	521483	2.29
f_3h_2	581440	2.44
f_3h_3	301673	1.75
f_4h_1	143166	1.35
f_4h_2	178153	1.44
f_4h_3	170923	1.43

4.5 Correlation studies

Correlation studies was carried out between tuber yield and yield parameters (number of tubers per plant, tuber length, tuber girth and vine yield). There was a positive correlation between yield and all of the characteristics indicated above.

Table 24. Correlation matrix between tuber yield and yield parameters.

Yield parameters	Tuber yield	Number of tubers	Tuber length	Tuber girth	Vine yield
Tuber yield	1	0.98376	0.977395	0.923951	0.846202
no. of tubers	0.98376	1	0.983533	0.966615	0.904898
Tuber length	0.977395	0.983533	1	0.950406	0.89457
Tuber girth	0.923951	0.966615	0.950406	1	0.924881
Vine yield	0.846202	0.904898	0.89457	0.924881	1

Discussion

5. DISCUSSION

The field experiment was conducted from November 2022 to March 2023 at the Farming Systems Research Station in Sadanandapuram, Kottarakkara, Kollam. The design used was a randomized block design with twelve treatments that were duplicated three times.

5.1 EFFECT OF FOLIAR NUTRITION ON THE GROWTH AND TUBER YIELD OF SWEET POTATO

5.1.1 Growth parameters

Foliar application of 2 per cent urea and micronutrient mixture 0.5 per cent at growth stages had a significant impact on the growth parameters of sweet potato. At 30 DAP, 45 DAP and at harvest stage, the plants were observed to be taller when sprayed with combination of urea 2 per cent at 20 DAP + multi micronutrient mixture 0.5 per cent at 35 DAP i.e., f_3 and spraying with urea 2 per cent at 20 and 35 DAP (f_1) and spraying with multi micronutrient mixture 0.5 per cent at 20 and 35 DAP (f_2) which were on par. Further the number of branches at 30, 45 DAP and at harvest the higher number of branches were observed when sprayed with combination of urea 2 per cent at 20 DAP + multi micronutrient mixture 0.5 per cent at 35 DAP i.e., f_3 and urea 2 per cent spray at 20 and 35 DAP i.e., f_1 treatment is on par. The treatments f_1 (urea 2 percent at 20 and 35 DAP) and f_3 (urea 2 per cent at 20 DAP + multi micronutrient 0.5 per cent at 35 DAP) showed positive effect but there was no considerable effect when plant sprayed with only multi micronutrient mixture 0.5 percent at 20 and 35 DAP. Although f_1 and f_3 showed increased vine length and number of branches over others due to the reason that these treatments received additional application of urea and micronutrient mixture through foliar spray combining urea with micronutrients can have synergistic effects on plant growth. micronutrients such as iron and manganese are involved in photosynthesis and enzyme activities, which can enhance the utilization of nitrogen provided by urea for better growth and yield. By ensuring that sweet potato plants have access to both essential macronutrients and micronutrients, can promote overall plant health and vigour. The importance of N application on enhancing the vine length and number of branches above the super optimal 62.5 kg ha^{-1}were also emphasised by Kumar *et al*. (2023). According to John *et al*. (2011), applying 80 kg N 50 per cent as basal and 50 per cent as foliar in the form of 2 per cent urea at 30, 60, and 90 days after planting increased the vine length and foliage growth in sweet potato. According to Saif EI-deen *et al*. (2015), the results demonstrated that the plants sprayed with a combination of micronutrients performed better than the unsprayed ones. In sweet potatoes, a topically applied combination of micronutrients greatly lengthens the vine. Ali (2019) found that increasing the concentration of foliar applied microelements mixture up to 30 g 100 L^{-1} constantly and significantly increased fresh weight of vines and number of branches per plant as well as plant length compared with untreated control plants.

Leaf area and leaf area index were higher with f_3 (urea 2 percent at 20 DAP + multi micronutrient mixture 0.5 per cent at 35 DAP) and was on par with f_1(urea 2 per cent at 20 and 35 DAP). This could be due to increased length of vine and number of branches brought on by foliar application of urea and micronutrient mixture. The results were in agreement with Kumar *et al*. (2023), concluded that nitrogen application up to 62.5 kg ha^{-1} increased leaf area index. The results showed that the plants sprayed with a mixture of micronutrients performed better than the unsprayed ones. The study of Saif EI-deen *et al*. (2015) also agreed that combination of micronutrients applied topically significantly enhanced leaf area in sweet potato. Higher nitrogen application levels led to a considerable increase in leaf area and fresh herbage, according to Relente *et al*. (2020).

Dry matter production at 30 DAP was found to be higher in f_2 (multi micronutrient mixture 0.5 per cent at 20 and 35 DAP) and was on par with f_3. At 45 DAP, f_3 attained higher dry matter production and was on par with f_2 and at harvest stage f_3 attained highest dry matter production, f_2 and f_1 are on par. This might be due to the direct delivery of vital nutrients to the leaves; foliar application of urea and micronutrient combinations provides a focused strategy to improve sweet potato dry matter production and leaf growth. This approach also promotes photosynthetic efficiency, stress tolerance, and nutrition use efficiency. As per Lemma *et al*. (2023) reported that the plots that were treated, with the recommended nitrogen showed significantly higher total N values. This is due to optimum N fertilizer concentrations can enhance N uptake, which in turn benefits higher levels of photosynthetic rate, leaf expansion, total number of leaves, and dry matter accumulation in sweet potato. The findings of Relente *et al*. (2020) also agreeing present study that higher nitrogen application levels considerably enhanced fresh herbage, biomass, and dry matter yield.

At 30 to 45 DAP and 45 DAP to harvest, the net assimilation rate and crop growth rate were found to be greater with f_3 and were on par with f_1 and f_2. This may be due to urea, being a source of nitrogen, plays a crucial role in chlorophyll synthesis, which is essential for photosynthesis. Micronutrients such as iron, manganese, zinc, and boron are also vital for various enzymes involved in photosynthesis. Foliar application ensures immediate availability of these nutrients, promoting higher chlorophyll content and photosynthetic activity. Increased photosynthesis leads to higher rates of carbon assimilation, thereby increasing the net assimilation rate. Increased availability of nutrients as nitrogen and micronutrients supports optimal functioning of meristematic tissues, promoting cell division and expansion, which contribute to higher crop growth rates. Nongkhlaw *et al*. (2021) reported that when 65 kg ha^{-1} of N was applied to the sweet potato crop, NAR (0.127 g m^2 d^{-1}) and CGR (24.56 g m^2 d^{-1}) increased and were significantly greater than other treatments (65 kg ha^{-1}). According to Sharaf-Eldin et al. (2019), repeatedly spraying boron at 40 or 50 ppm increased the vegetative growth, leaf area index, absolute growth rate, and net assimilation rate.

5.1.2 Yield and Yield Attributes

Urea 2 per cent at 20 DAP *fb* multi micronutrient mixture 0.5 per cent at 35 DAP showed the highest number of tubers per plant this may be due to urea's nitrogen boosts plant photosynthesis, generating more carbohydrates for subterranean tuber growth. Micronutrients like zinc, iron, manganese, and boron are crucial for plant physiological functions. Foliar application ensures easy access to these components, promoting healthy growth and tuber formation. Chen *et al*. (2017) also reported that foliar application of humic acid-urea efficiently enhanced storage root differentiation at the early growth stage and increased the number of storage roots per plant. Humic acid-urea greatly boosted the number of storage roots per plant by 14.01 per cent and the average fresh weight per storage root by 13.7 per cent. The studies of EI-tohamy *et al*. (2014) also harmonized that micronutrient treatment enhanced the number of storage roots.

Tuber length and tuber girth were observed to be the highest with f_3 (urea 2 per cent at 20 DAP + multi micronutrient mixture 0.5 per cent at 35 DAP) it could be because urea offers a readily available source of nitrogen, which is a crucial nutrient for plant growth and tuber development. Micronutrients such as boron, zinc, and manganese play essential roles in various physiological processes, including cell elongation and division, which are necessary for tuber enlargement. Some micronutrients play a role in regulating hormonal balance within the plant. Hormones like auxins and cytokinins are involved in cell division and elongation processes, which directly influence tuber growth. Dong *et al*. (2022), also observed that the administration of N at 100 mg L^{-1} significantly boosted the percentage of initiated storage roots and promoted cambium development. The length of the first-order and second-order lateral roots grew by 78 per cent and 73 per cent, respectively, upon nitrogen application at a rate of 50 kg N ha^{-1}. The present study also in conformity with the findings of Saif EI-deen *et al*. (2015) and Singh *et al*. (2016).

Tuber bulking rate was the highest with f_3 (urea 2 percent at 20 DAP + multi micronutrient mixture 0.5 per cent at 35 DAP). Nitrogen is a key component of amino acids, proteins, and enzymes involved in various metabolic processes, including cell division and expansion. Adequate nitrogen supply through foliar spraying can promote rapid tuber bulking by facilitating the synthesis of structural and storage proteins necessary for tuber enlargement. The multi-micronutrient mixture supplements essential micronutrients such as boron, zinc, manganese, and iron. Ensuring adequate levels of these micronutrients through foliar spraying can optimize metabolic pathways associated with tuber bulking, thereby promoting faster bulking rates. Micronutrients play a crucial role in mitigating environmental stresses that may inhibit tuber bulking. By enhancing the plant's tolerance to stress, foliar application of micronutrients can minimize growth limitations and allow for uninterrupted tuber development, resulting in faster bulking rates.

Vine top yield and vine yield were the highest with treatment f_3 (urea 2 percent at 20 DAP + multi micronutrient mixture 0.5 per cent at 35 DAP). It might be due to urea provides a readily available source of nitrogen, a vital nutrient for plant growth. Nitrogen is a key component of chlorophyll, essential for photosynthesis, and plays a crucial role in overall plant vigor and biomass production. Increased nitrogen availability through foliar spraying can stimulate vegetative growth, leading to greater vine development and ultimately higher vine yield. Micronutrients play essential roles as cofactors for enzymes involved in nutrient uptake and utilization. By ensuring optimal nutrient uptake and utilization efficiency, the foliar spray can enhance overall plant growth and development, including vine yield. In conformity with the present study, Ali (2019) also observed that vine fresh weight increased significantly with the foliar-applied microelements mixture.

Tuber yield was the highest with urea 2 percent at 20 DAP + multi micronutrient mixture 0.5 per cent at 35 DAP i.e., f_3. Perhaps because urea offers nitrogen, which is essential for chlorophyll synthesis and photosynthesis. Increased nitrogen availability can boost photosynthetic activity, leading to greater production of carbohydrates. These carbohydrates are essential for tuber growth and development. Micronutrients like boron are involved in cell division and differentiation processes, which are crucial for tuber initiation and development and micronutrients can also influence hormonal balance within the plant, including auxins and cytokinins, which are involved in tuberization processes. By regulating hormone levels, foliar spraying can promote tuber formation and enlargement, ultimately increasing tuber yield. John *et al*. (2011) also emphasised the importance of foliar application of 2% urea at 30 DAP for the significant production of tubers in sweet potato. The results also supported by the findings of Hassan *et al*. (2005); Du and Kong (2019).

Marketable tuber yield was the highest by foliar spraying with urea 2 percent at 20 DAP + multi micronutrient mixture 0.5 per cent at 35 DAP (f_3). While foliar spraying primarily targets above-ground plant parts, some nutrients may also be translocated to the roots. Enhanced root growth and function could improve nutrient and water uptake, supporting overall plant health and the production of more marketable tubers. Urea provides a readily available source of nitrogen, which is essential for plant growth and tuber development. Micronutrients included in the mixture, such as boron, zinc, and manganese, also play critical roles in various metabolic processes necessary for optimal tuber formation. Ensuring an adequate supply of these nutrients through foliar spraying can enhance tuber yield and quality, resulting in more marketable tubers. The studies of Hartemink *et al*. (2000) and Saif EI-deen *et al*. (2015) were also documented the importance of nitrogen and foliar application of micronutrients for enhancing the marketable tubers yield in sweet potato and were agreement with present study.

5.1.3 Physiological parameters

The highest total chlorophyll content of the harvested leaf is with f_3 (urea 2 percent at 20 DAP + multi micronutrient mixture 0.5 per cent at 35 DAP). Lowest chlorophyll content observed with f_4 (control water spray). This is due to urea is a rich source of nitrogen, which is a primary component of chlorophyll molecules. Chlorophyll synthesis requires nitrogen, and urea provides an easily absorbable form of nitrogen for the plant. Increased nitrogen availability can lead to enhanced chlorophyll production. Micronutrients like iron, magnesium, manganese, and zinc are essential cofactors for enzymes involved in chlorophyll synthesis. The presence of these micronutrients in the spray can facilitate the activation of enzymes responsible for chlorophyll production, thereby increasing chlorophyll content in leaves. The findings of Lemma *et al*. (2023) were also in agreement with this present study that higher nitrogen fertilizer concentrations lead to improve the nitrogen uptake, resulted in higher levels of chlorophyll, photosynthetic rates, leaf expansion, and total leaf count.

5.1.4 Quality parameters

Starch content in tuber was the highest with urea 2 percent at 20 DAP + multi micronutrient mixture 0.5 per cent at 35 DAP (f_3). Treatment with control water spray f_4 had low starch content. This is due to nitrogen being a major component of chlorophyll, which is crucial for photosynthesis, the process by which plants produce sugars and starches. Adequate nitrogen supply can enhance photosynthesis and subsequently increase the production of carbohydrates, including starch, in sweet potatoes. Micronutrients such as zinc, iron, manganese, and copper play essential roles as cofactors for various enzymes involved in carbohydrate metabolism. They facilitate enzymatic reactions necessary for starch synthesis. A foliar spray containing micronutrients can ensure that these cofactors are readily available for the enzymes, optimizing their activity and consequently enhancing starch production.

Crude protein content in tuber was highest with urea 2 percent at 20 DAP + multi micronutrient mixture 0.5 per cent at 35 DAP (f_3). Treatment with control water spray f4 is having low crude protein content. This might be due to the multi-micronutrient spray complements the urea by providing essential trace elements required for optimal plant growth and protein synthesis. These micronutrients act as cofactors for enzymes involved in nitrogen metabolism and protein synthesis, thereby enhancing the efficiency of nitrogen utilization and protein accumulation in sweet potato tubers. Relente *et al*. (2020) and Kumar *et al*. (2023) were also proved that super-optimal application of nitrogen levels resulted a significant increase in the quality parameters for crude protein, which agreed with the current study.

Total sugars were the highest with urea 2 percent at 20 DAP + multi micronutrient mixture 0.5 per cent at 35 DAP (f_3). This may be due to Nitrogen and micronutrients play essential roles in promoting overall plant growth and development. Optimal plant growth leads to increased leaf area and photosynthetic activity, resulting in higher sugar production. Additionally, balanced nutrition provided by foliar spraying supports the efficient allocation of assimilates towards sugar accumulation in the tubers.

Betacarone was higher with urea 2 percent at 20 DAP + multi micronutrient mixture 0.5 per cent at 35 DAP (f_3) and it were on par with f_1 (urea 2 per cent spray at 20 and 35 DAP) and f_2 (multi micronutrient 0.5 per cent spray at 20 and 35 DAP). This might be due to foliar spraying of urea and micronutrients can potentially enhanced beta-carotene content in sweet potatoes, the effectiveness of this approach may vary depending on factors such as the concentration and timing of application, environmental conditions and sweet potato cultivar. Findings of Gemechu (2019) revealed that nitrogen fertilizer application significantly elevates beta-carotene content and were in agreement with present study.

Nitrate content in vine top was higher in f_1 (urea 2 per cent spray at 20 and 35 DAP) and it was on par with urea 2 percent at 20 DAP + multi micronutrient mixture 0.5 per cent at

35 DAP (f_3). Treatment with control water spray f_4 was having low nitrate content. The highest nitrate content in vine top was due to foliar spraying of urea ensures rapid uptake of nitrogen by the plant leaves. Once absorbed, nitrogen undergoes assimilation processes within the plant, leading to the formation of nitrate and other nitrogen-containing compounds. Thus, foliar spraying of urea can contribute to increased nitrate levels in the vine tops of sweet potatoes. Micronutrients such as molybdenum and iron are involved in nitrogen metabolism pathways, including nitrate assimilation and reduction. By supplying these micronutrients, foliar spraying can enhance the efficiency of nitrogen utilization and nitrate accumulation in the vine tops of sweet potatoes. Research work of Saif EI-deen *et al*. (2015) and Relente *et al*. (2020) were also in tune with findings of present study. However the enhancement of nitrate content was with in the safe limit for human consumption.

Crude protein content was the highest with treatment f_1 (urea 2 per cent spray at 20 and 35 DAP) it was on par with urea 2 percent at 20 DAP + multi micronutrient mixture 0.5 per cent at 35 DAP (f_3). Treatment with control water spray (f_4) has low crude protein content. High crude protein content in vine top is due to higher level of nitrogen supplied by the foliar application of urea, which is a fundamental component of amino acids - the building blocks of proteins. Nitrogen is assimilated by the plant and incorporated into amino acids, leading to the synthesis of proteins. Adequate nitrogen supply through foliar spraying can enhance the overall protein content in the vine tops of sweet potatoes. By supplying micronutrients through foliar spraying can enhance the activity of enzymes responsible for protein synthesis, consequently increasing the crude protein content in sweet potato vine tops.

Fibre content in vine top was the highest for control water spray (f_4). The lowest fibre content in vine top was with urea 2 per cent spray at 20 and 35 DAP. This might be due to increased nitrogen availability can promote vegetative growth, potentially leading to reduced fibre content in plant tissues. This is because nitrogen is often allocated towards growth and protein synthesis rather than fibre formation. Optimizing the availability of micronutrients can enhance overall plant health and nutrient uptake efficiency. While there is not a direct link between micronutrients and fibre content, their presence can ensure proper nutrient assimilation and utilization, potentially indirectly affecting fibre levels. Foliar spraying of urea and micronutrients should ideally be timed during the vegetative phase. This ensures that the nutrients are taken up and utilized effectively. Application during this period can stimulate vine growth while potentially reducing the allocation of resources toward fibre deposition.

Vitamin A and vitamin C were the highest with urea 2 percent at 20 DAP + multi micronutrient mixture 0.5 per cent at 35 DAP (f_3). The lowest vitamin A and vitamin C were with control water spray (f_4). This may be due to urea provides a readily available source of nitrogen, which is essential for chlorophyll synthesis and overall plant growth. Chlorophyll is crucial for photosynthesis and it's also a precursor to vitamin A. By promoting chlorophyll production through urea application, the plant can potentially enhance its capacity to synthesize and accumulate vitamin A. The micronutrient mixture provides essential trace elements required for various enzymatic reactions and metabolic processes in plants. These micronutrients, including iron, zinc, manganese, and copper, play vital roles as cofactors for enzymes involved in the synthesis and metabolism of vitamins. Adequate levels of these micronutrients can optimize the enzymatic pathways responsible for vitamin A and vitamin C biosynthesis. Zinc is involved in the synthesis of ascorbic acid (vitamin C) and its regulation within plant tissues. By supplying adequate levels of micronutrients, leads to enhanced vitamin A and vitamin C content in sweet potato vine tops.

Zinc and iron content were higher with multi micronutrient mixture 0.5 per cent at 20 and 35 DAP (f_2) and it was on par with f_3 and f_1. The lowest zinc and iron content were with treatment control water spray (f_4). This might be due to nitrogen is essential for various metabolic processes, including the synthesis of enzymes involved in nutrient uptake and assimilation. By supplying nitrogen through urea, foliar spraying can potentially improve the efficiency of zinc and iron uptake by sweet potato plants. Foliar spraying provides a direct route for nutrients to be absorbed by the plant leaves and translocated to various plant tissues, including the vine tops. The application of a micronutrient mixture containing zinc and iron ensures that these essential nutrients are readily available for uptake by the plants.

Copper and manganese were the highest with urea 2 percent at 20 DAP + multi micronutrient mixture 0.5 per cent at 35 DAP (f_3). This could be because one of the metabolic processes for which nitrogen is essential is the creation of enzymes involved in the intake and assimilation of nutrients. By supplying nitrogen through urea, foliar spraying can improve the efficiency of sweet potato plants' uptake of copper and manganese. Due to the relative immobility of copper and manganese inside the plant, foliar spraying enables the direct administration of these micronutrients to the younger, actively growing plant sections, like the vine tops, where nutrient uptake and utilization are more effective.

While considering the anti-nutritional factors in sweet potato, Antia *et al*., (2006) observed that the leaves of sweet potato embrace low levels of tannins (0.21 mg 100 g), cyanide

(30.24 mg 100 g), and phytic acid (1.44 mg 100 g). However, the oxalate content in the leaves is unusually elevated (308 mg/100 g), which could make them toxic to humans, when consumed in uncooked form. When leaves are cooked properly before eating, their overall oxalate level is much decreased (Akwaowo et al., 2000). Considering the leaves provide an adequate number of vitamins, minerals, and other nutrients, sweet potato vines can be included in the diet of humans once it is subjected to proper cooking.

NPK uptake in plant was higher with urea 2 percent at 20 DAP + multi micronutrient mixture 0.5 per cent at 35 DAP (f_3) it was comparable with f_1 in case of nitrogen and potassium. The NPK uptake was lowest with treatment control water spray (f_4). This could be due to micronutrients often act as cofactors or activators for enzymes involved in nutrient uptake and metabolism. For instance, zinc plays a crucial role in the synthesis of auxins, which are plant hormones involved in root development and nutrient uptake. By supplying the necessary micronutrients along with urea, you can ensure that the sweet potato plants can efficiently take up and utilize NPK nutrients from the soil.

5.2 EFFECT OF HARVESTING TIME OF VINE TOP ON GROWTH AND TUBER YIELD OF SWEET POTATO

5.2.1 Growth parameters

Number of branches were higher at h_1 (harvesting time of vine top at 30 DAP) at 45 DAP and comparable with h_2 (harvesting time of vine top at 45 DAP). At the harvest stage, the number of branches were greater at h_2 (harvesting time of vine top at 45 DAP) and h_1 was on par with it. When the vine tops were harvested, it stimulated the growth of lateral branches from the leaf nodes along the remaining vine. Sweet potato plants can produce new shoots from dormant buds located in the leaf axils. Vine top harvesting allows for better penetration of sunlight into the lower parts of the plant canopy. Increased light exposure to the lower branches stimulates their growth and development. Removing the apical dominance vine top harvesting encourages the activation and growth of these dormant buds, resulting in the formation of additional branches. Suminarti and Novriani (2017) studies on the impact of defoliation is supporting the present findings.

Leaf area was higher at 45 DAP and harvest stage by vine top harvesting at 45 DAP (h_2). In case of harvest stage h_2 was on par with h_1. It is due to by removing the terminal ends of the vines, the plant redirects its energy from vertical growth (vine extension) to lateral growth (side shoots). This energy redirection encourages the development of more leaves along the lateral branches, contributing to an increase in leaf area. With a larger leaf area, sweet potato plants have more surface area available for photosynthesis and nutrient assimilation. This can result in improved nutrient uptake and utilization by the plants, leading to better growth and potentially higher yields.

Leaf area index was higher with h_1 (vine top harvesting at 30 DAP) at 45 DAP and at harvest stage. At the harvest stage, h_1 (vine top harvesting at 30 DAP) was on par with h_2 (vine top harvesting at 45 DAP). It might be due to stimulation of production of more lateral branches, and number of leaves after the cutting of vines. Sweet potato being a hardy and fast growing crop, after the vine top harvesting, it could well recovered the leaf area and could intercept more sunlight. This additional light availability stimulates further leaf expansion and canopy development, ultimately leading to a higher LAI. A larger leaf area provides more surface area for photosynthesis and nutrient uptake. This can result in better nutrient assimilation by the plants, leading to increased leaf growth and ultimately a higher LAI.

Dry matter production was higher with vine top harvesting at 30 DAP (h_1) at harvest stage and it was on par with h_2 (vine top harvesting at 45 DAP). When the vines were harvested, the apical growth stimulated and develops more branches; leaves resulted in better accumulation of photosynthates. Plant redirects its energy towards root development instead of vine growth. This can lead to increased root biomass, which is the primary storage organ for carbohydrates in sweet potatoes. More extensive root systems can result in greater nutrient and water uptake, supporting increased dry matter production. The present study agreement with findings of Krishnaveni *et al.* (2014) that pinching of leaves helped to increase in dry matter production.

Net assimilation rate and crop growth rate were higher with vine top harvesting at 30 DAP (h_1) at 30-45 DAP it was on par with h_2 (vine top harvesting at 45 DAP). At the harvest stage net assimilation rate and crop growth rate were higher with vine top harvesting at 45 DAP (h_2) it was on par with h_1 (vine top harvesting at 30 DAP). The increase in net assimilation rate due to removing excessive vine growth reduces the shading effect within the canopy, allowing more sunlight to reach the remaining leaves. Increased light availability stimulates photosynthesis, leading to higher rates of assimilation and consequently a higher net assimilation rate. With reduced competition for resources such as water and nutrients due to vine top harvesting, the plant can allocate more resources towards photosynthesis and growth. This can result in improved nutrient uptake efficiency, supporting higher rates of assimilation and contributing to an increased net assimilation rate. The increase in crop growth rate might be due to vine top harvesting promotes a more balanced allocation of resources between above-ground and below-ground parts of the plant. This balanced allocation supports overall plant growth and development, contributing to an increased crop growth rate.

5.2.2 Yield parameters

Number of tubers were more with treatment h_2 (vine top harvesting at 45 DAP) it was on par with h_1 (vine top harvesting at 30 DAP). Lowest number of tubers observed in control. The greater number of tubers may be due to vine top harvesting at an appropriate stage of plant growth can coincide with the optimal timing for tuber initiation. By allowing the plant to reach an advanced developmental stage before vine top harvesting, more nodes along the remaining vines may have the potential to produce tubers, thereby increasing the number of tubers per plant. Vine top harvesting in sweet potato plants can promote resource reallocation, enhance photosynthesis and reduce competition among plant parts all of which contribute to an increased number of tubers per plant.

Length of tuber and girth of tuber were higher with h_2 (vine top harvesting at 45 DAP) it was on par with h_1 vine top harvesting at 30 DAP. The increase in length and girth of tuber due to vine top harvesting can improve light penetration and air circulation within the canopy, leading to increased photosynthetic activity in the remaining leaves. The additional assimilates produced through enhanced photosynthesis can support the growth and enlargement of tubers, resulting in increased length and girth. Likewise Munetsi (2015) also noted that the length of storage roots, their diameter, and the weight of vines were greatly affected by both the cutting position and the level of pruning.

Tuber bulking rate was higher with h_2 (vine top harvesting at 45 DAP) at 45 DAP to harvest stage and it was comparable with h_1 (vine top harvesting at 30 DAP). The increase in tuber bulking rate might be due to vine top harvesting promotes a more balanced allocation of resources between vegetative growth and tuber development. This optimization of plant architecture could lead to a better leaf-to-tuber ratio, allowing the plant to utilize assimilates more efficiently for tuber bulking while maintaining sufficient leaf area for photosynthesis. By removing the vine tops, the plant reallocates resources such as carbohydrates and nutrients to the development of tubers. This redirection of resources towards tuber formation promotes rapid bulking of the storage roots, leading to an increased tuber bulking rate.

The highest vine yield observed in treatment h_1 with vine top harvesting at 30 DAP. The lowest vine yield obtained by h_2 (vine top harvesting at 45 DAP). The increase in vine yield due to when the vine tops are harvested, it encourages lateral growth of the remaining vines. This lateral growth leads to the development of more branches and foliage, ultimately resulting in a greater overall vine yield. Vine top harvesting in sweet potato plants can increase vine yield by enhancing nutrient allocation, improving light penetration, and reducing disease pressure.

Tuber yield was higher with h_2 (vine top harvesting at 45 DAP) it was on par with h_1 (vine top harvesting at 30 DAP). The lowest tuber yield was obtained by control. The tuber yield increased due to removing excess vine growth reduces competition among plant parts for resources such as water, nutrients, and space. With fewer vines to support, there is less competition for resources, allowing more resources to be allocated towards tuber growth and ultimately increasing tuber yield. Vine top harvesting redirects the plant's energy towards root development, which includes the development of tubers. A well-developed root system can support increased tuber growth and yield by enhancing nutrient and water uptake. The findings of Abewoy *et al*. (2022) were also supporting with the present study that sweet potato with 50 per cent pruning of vine yielded the best root yield.

Marketable tuber yield was highest with h_2 (vine top harvesting at 45 DAP). The lowest tuber yield was obtained by control. The increase in marketable tubers is due to removing excess vine growth redirects the plant's energy away from unnecessary vine growth and towards tuber development. This optimization of energy resources results in more robust and sizable tubers suitable for the market.

5.2.3 Physiological parameters

Highest total chlorophyll content of harvested leaf was with treatment h_2 (vine top harvesting at 45 DAP). Lowest chlorophyll content with h_3 (no vine harvesting). This might be due to pruning opens up the canopy, allowing more sunlight to penetrate through to the leaves. Chlorophyll is essential for photosynthesis, the process by which plants convert light energy into chemical energy. Increased light exposure can stimulate chlorophyll synthesis and enhance photosynthetic activity, leading to higher chlorophyll content in the leaves.

5.2.4 Quality parameters

Starch and crude protein content in the tuber were higher with treatment h_2 (vine top harvesting at 45 DAP) and they were on par with h_1 (vine top harvesting at 30 DAP). This could be because of pruning vine tops reduces the overall vegetative growth of the plant. With fewer leaves and stems to support, the plant can focus more energy and resources on root development and starch accumulation. This shift in resource allocation towards storage roots, can lead to an increase in starch content in sweet potato storage roots. Pruning vine tops can stimulate root growth and enhance nutrient uptake from the soil. Increased nutrient availability, particularly nitrogen, can promote the synthesis of proteins in the storage roots, leading to higher crude protein content. The results of Sahu *et al*. (2022) also showed that topping increased the starch content.

Total sugars and beta carotene content were higher with treatment h_2 (vine top harvesting at 45 DAP) and they were on par with h_1 (vine top harvesting at 30 DAP). The lowest total sugar and beta-carotene were with h_3 (no vine top harvesting). Pruning vine tops of sweet potato plants results in decreased shading within the canopy, allowing more light to reach the lower leaves. This increased light exposure facilitates photosynthesis, leading to higher levels of both sugars and beta-carotene in the tubers. Moreover, pruning induces mild stress in the plants, prompting physiological responses that encourage the accumulation of secondary metabolites such as sugars and carotenoids. These compounds play important roles, with sugars acting as osmolytes to aid in stress tolerance and beta-carotene serving as antioxidants to protect against oxidative damage.

Crude protein content in vine top was higher with h_1 (vine top harvesting at 30 DAP) it was comparable with h_2 (vine top harvesting at 45 DAP). The lowest crude protein content in vine top was with h_3 (no vine top harvesting). This might be due to pruning of vine tops in sweet potato plants has the potential to stimulate new growth and branching in the remaining vine tops. This fresh growth typically exhibits higher protein concentrations compared to older tissues, as it is actively growing and metabolically active. Additionally, pruning can enhance the plant's utilization of available nitrogen, a crucial building block of proteins. By optimizing nitrogen availability and utilization, pruning can facilitate increased protein content in the vine tops. The research work of Frankow-Lindberg and Lindberg (2003) were also emphasised that removal of vine enhanced the crude protein. Sweet potato leaves were noted to have a high crude protein content and a low fibre concentration compared to stems. Therefore, removing sweet potato leaves from the vines could potentially increase the crude protein content while decreasing fibrous components.

Fibre content in the vine top was highest with control treatment h_3 (no vine top harvesting). The lowest fibre content in the vine top was with h_2 (vine top harvesting at 45 DAP). This could be because of pruning of vine tops in sweet potato plants involves the removal of older, mature tissues that typically have higher fibre content. By selectively eliminating the vine, reduces the overall fibre content in the remaining vine tops. Furthermore, pruning encourages the growth of new shoots and branches in the remaining vine tops. These fresh growths generally possess lower levels of fibre compared to the older tissues, thus contributing to an overall decrease in fibre content. The results of Olorunnisomo (2007) also agreed that, as the frequency of pruning increased, there was an observed rise in crude protein content alongside a decrease in fibre content.

Vitamin C content in vine top was higher with treatment h_2 (vine top harvesting at 45 DAP) it was on par with h_1 (vine top harvesting at 30 DAP). The increase in vitamin C content is due to pruning encourages the growth of fresh shoots and foliage in the remaining vine tops, which are characterized by their heightened metabolic activity and increased nutrient uptake. This fosters the synthesis and accumulation of vitamin C within these younger tissues. Furthermore, pruning reallocates essential nutrients like nitrogen and micronutrients from pruned foliage to the remaining parts of the plant. These nutrients play crucial roles as cofactors in the production pathways of vitamin C, thereby supporting its synthesis in the vine tops. Additionally, by reducing shading within the canopy, pruning allows more sunlight to reach the remaining vine tops. This enhanced light exposure stimulates photosynthesis, leading to greater production of vitamin C as a byproduct of the photosynthetic process.

Zinc and manganese were higher with h_1 (vine top harvesting at 30 DAP) and they were comparable with h_2 (vine top harvesting at 45 DAP). The lowest was with h_3 (no vine top harvesting). Pruning in sweet potato plants enables the transfer of nutrients, such as zinc and manganese, from pruned foliage to the remaining parts of the plant. This redistribution promotes the accumulation of these micronutrients specifically in the vine tops. Additionally, pruning stimulates the growth of new shoots and foliage in the remaining vine tops, which exhibit heightened metabolic activity and increased nutrient uptake rates. This results in enhanced absorption and retention of zinc and manganese.

Copper content in sweet potato vine top was higher with h_2 (vine top harvesting at 45 DAP) and it was comparable with h_1 (vine top harvesting at 30 DAP). The increase in copper content is due to pruning promotes the growth of new shoots and foliage in the remaining vine tops. Younger tissues tend to have higher metabolic activity and nutrient uptake rates, which can lead to increased absorption and accumulation of copper.

The higher phosphorus and potassium uptake in plants was with h_2 (vine top harvesting at 45 DAP) and it was comparable with h_1 (vine top harvesting at 30 DAP). This might be due to pruning being effective in regulating resource distribution within plants. By trimming excess foliage, plants can redirect their energy and nutrients toward root and tuber growth, where NPK absorption primarily occurs. This reallocation enhances nutrient uptake efficiency. Additionally, pruning reduces overcrowding among vines, which otherwise compete for water, light, and nutrients, including NPK. This reduction in competition ensures that each plant can access resources more effectively, leading to improved NPK uptake by the remaining vines.

5.3 INTERACTION EFFECT OF FOLIAR NUTRITION AND VINE TOP HARVESTING TIME ON GROWTH AND YIELD PARAMETERS

5.3.1 Growth parameters

Plant growth and yield were significantly affected by the foliar nutrition and time of vine harvesting. At 45 DAP the number of branches were significantly increased by foliar nutrition and vine top harvesting in the treatments (Fig 5). The higher number of branches were observed in the treatment f_3h_2 (urea 2 per cent at 20 DAP + multi micronutrient mixture 0.5 per cent at 35 DAP *fb* vine top harvesting at 45 DAP) it were on par with f_3h_1 (urea 2 per cent at 20 DAP + multi micronutrient mixture 0.5 per cent at 35 DAP *fb* harvesting time of vine top at 30 DAP) and f_1h_1 (urea 2 per cent spray at 20 and 35 DAP *fb* vine top harvesting at 30 DAP). By combining foliar nutrition with vine top harvesting, number of branches in sweet potato would enhance which leading to the increased foliage density, better ground cover, and potentially higher yields. Additionally, increased branching can also contribute to improved soil coverage and weed suppression, further benefiting sweet potato cultivation.

Leaf area was significantly affected by foliar nutrition and harvesting time of vine top (Fig 6). At 45 DAP and harvest stage leaf area was higher with f_3h_2 (urea 2 per cent at 20 DAP + multi micronutrient mixture 0.5 per cent at 35 DAP *fb* vine top harvesting at 45 DAP). At 45 DAP it was on par with f_3h_1 (urea 2 per cent at 20 DAP + multi micronutrient mixture 0.5 per cent at 35 DAP *fb* harvesting time of vine top at 30 DAP), f_1h_1 (urea 2 per cent spray at 20 and 35 DAP *fb* vine top harvesting at 30 DAP) and f_1h_2 (urea 2 per cent spray at 20 and 35 DAP *fb* vine top harvesting at 45 DAP). At harvest stage f_3h_2 was on par with only f_3h_1 (urea 2 percent at 20 DAP + multi micronutrient mixture 0.5 per cent at 35 DAP *fb* harvesting time of vine top at 30 DAP). This is due to foliar application urea and micronutrients can influence hormonal balance within the plant, promoting cell division and elongation, which are essential processes for leaf expansion. Pruning of vines removes excessive vegetative growth, redirecting the plant's resources towards new growth, including leaf expansion.

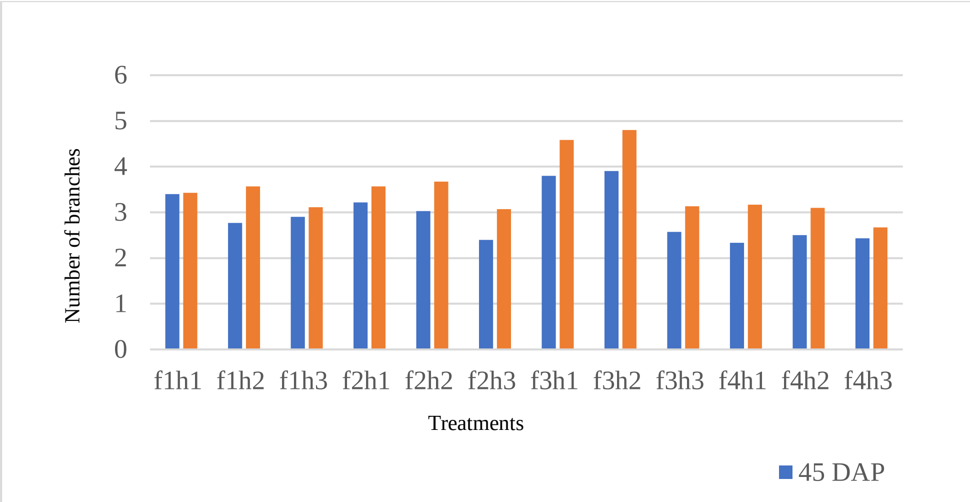

Fig. 5 Interaction effects of foliar nutrition and time of vine harvesting on number of branches

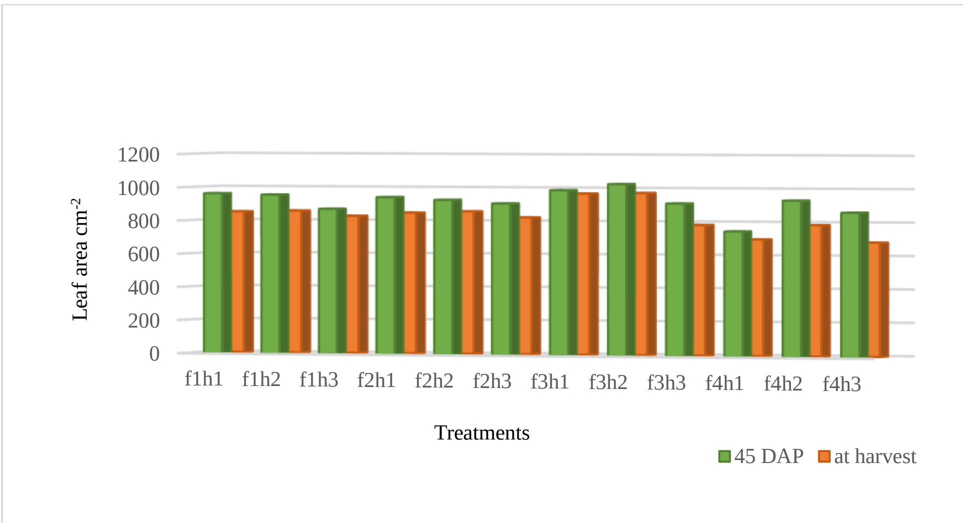

Fig 6. Interaction effects of foliar nutrition and harvesting time of vine top on leaf area, cm^{-2}

Leaf area index was higher with f_3h_2 (urea 2 per cent at 20 DAP + multi micronutrient mixture 0.5 per cent at 35 DAP *fb* harvesting time of vine top at 45 DAP) at 45 DAP, it was on par with f_3h_1 (urea 2 per cent at 20 DAP + multi micronutrient mixture 0.5 per cent at 35 DAP *fb* harvesting time of vine top at 30 DAP). This may be due to the foliar application ensures the direct absorption of nutrients through the leaves, bypassing potential soil nutrient limitations. This can lead to more efficient nutrient uptake, allowing the plant to allocate resources towards leaf growth and increasing LAI. Pruning removes diseased or pest-infested foliage, which can negatively impact overall plant health and reduce LAI. By eliminating these compromised leaves, pruning helps maintain a healthy canopy, allowing unaffected leaves to thrive and contribute to higher LAI.

Dry matter yield was higher with f_3h_1 (urea 2 per cent at 20 DAP + multi micronutrient mixture 0.5 per cent at 35 DAP *fb* harvesting time of vine top at 30 DAP) it was on par with f_3h_2 (urea 2 per cent at 20 DAP + multi micronutrient mixture 0.5 per cent at 35 DAP *fb* harvesting time of vine top at 45 DAP), f_1h_3 (urea 2 per cent spray at 20 and 35 DAP *fb* no leaf harvesting) and f_1h_1 (urea 2 per cent spray at 20 and 35 DAP *fb* vine top harvesting at 30 DAP). This is due to urea provides a readily available source of nitrogen, a crucial nutrient for plant growth and the synthesis of proteins, enzymes, and chlorophyll. Micronutrients such as iron, manganese, zinc, and boron are essential for various physiological processes, including photosynthesis and enzyme activation. Foliar application ensures that these nutrients are directly available to the plants, promoting optimal growth and maximizing dry matter yield. Vine pruning removes excess vegetative growth, reducing competition for resources such as water, nutrients, and sunlight. This helps alleviate stress on the plants, allowing them to allocate more energy towards growth and tuber development, ultimately increasing dry matter yield.

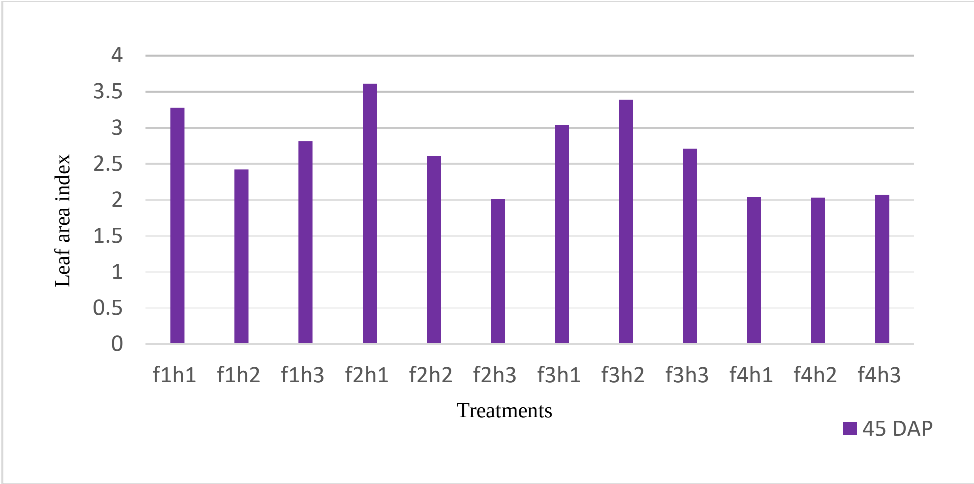

Fig 7. Interaction effects of foliar nutrition and harvesting time of vine top on leaf area index

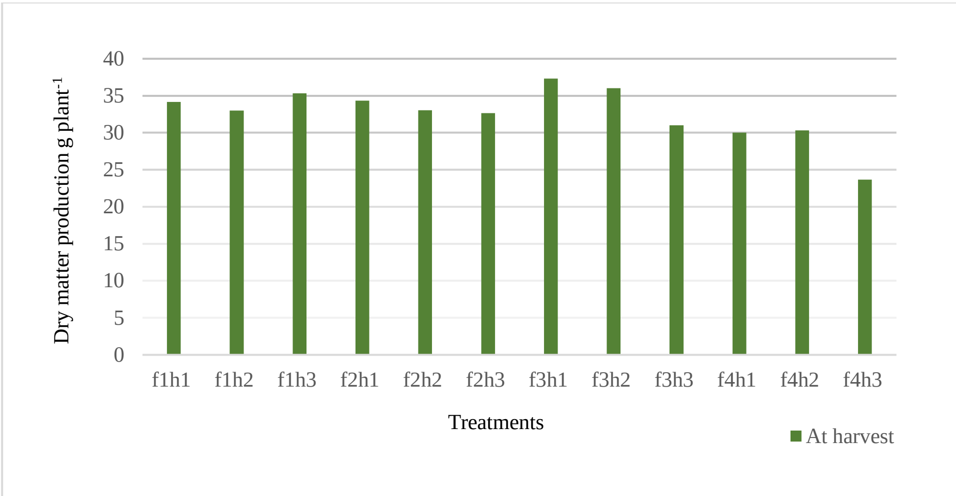

Fig 8. Interaction effects of foliar nutrition and harvesting time of vine top on dry matter production g plant^{-1}

Net assimilation rate and crop growth rate were higher at 45 DAP to harvest stage with treatment f_3h_2 (urea 2 per cent at 20 DAP + multi micronutrient mixture 0.5 per cent at 35 DAP *fb* harvesting time of vine top at 45 DAP) it was on par with f_3h_1 (urea 2 per cent at 20 DAP + multi micronutrient mixture 0.5 per cent at 35 DAP *fb* harvesting time of vine top at 30 DAP) and f_1h_1 (urea 2 per cent spray at 20 DAP and 30 DAP *fb* vine top harvesting at 30 DAP). This is due to Foliar application of nutrients can stimulate root development, leading to a more extensive root system. This improves nutrient and water uptake efficiency, facilitating greater resource acquisition and utilization by the plant. Enhanced root growth supports higher NAR and CGR by providing the necessary substrates for metabolic processes and biomass accumulation. Pruning removes diseased or pest-infested foliage, reducing the incidence of pathogens and pests that can negatively impact plant health and growth. Maintaining plant vigour through disease and pest management measures contributes to sustained photosynthetic activity, resulting in higher NAR and CGR.

5.3.2 Yield parameters

Number of tubers per plant were higher with treatment f_3h_2 (urea 2 per cent at 20 DAP + multi micronutrient mixture 0.5 per cent at 35 DAP *fb* vine top harvesting at 45 DAP) it was on par with f_3h_1 (urea 2 per cent at 20 DAP + multi micronutrient mixture 0.5 per cent at 35 DAP *fb* harvesting time of vine top at 30 DAP). Lowest number of tubers obtained in f_4h_1 (control- water spray *fb* harvesting time of vine top at 30 DAP). The increase in number of tubers is due to urea, being a rich source of nitrogen, promotes vegetative growth, including the development of vines and foliage. By providing adequate nutrients directly to the leaves, foliar application can stimulate overall plant growth, leading to more robust vines and potentially more tubers. Micronutrients such as boron, zinc, and manganese play essential roles in various metabolic processes, including carbohydrate metabolism and tuber formation. Pruning the vines can redirect the energy towards tuber development rather than excessive vine growth. By removing excess vegetative growth, the plant allocates more resources towards tuber formation and enlargement, potentially increasing the number of tubers per plant.

Tuber length and girth were more with treatment f_3h_2 (urea 2 per cent at 20 DAP + multi micronutrient mixture 0.5 per cent at 35 DAP *fb* vine top harvesting at 45 DAP) it was on par with f_3h_1 (urea 2 per cent at 20 DAP + multi micronutrient mixture 0.5 per cent at 35 DAP *fb* harvesting time of vine top at 30 DAP). The increase in length and girth of tuber is due to foliar application allows the plants to directly absorb nutrients through their leaves, bypassing potential soil nutrient limitations or uptake issues. Urea provides a readily available nitrogen source, which is essential for plant growth. Micronutrients are essential for enzyme activation and electron transport in photosynthesis. By ensuring an adequate supply of micronutrients and urea leading to increased carbohydrate production and subsequent tuber growth. Pruning vines redirects the plant's resources towards tuber development rather than maintaining excessive vegetative growth. By reducing the number of vines, the plant can allocate more nutrients and energy towards tuber bulking, resulting in larger and longer tubers.

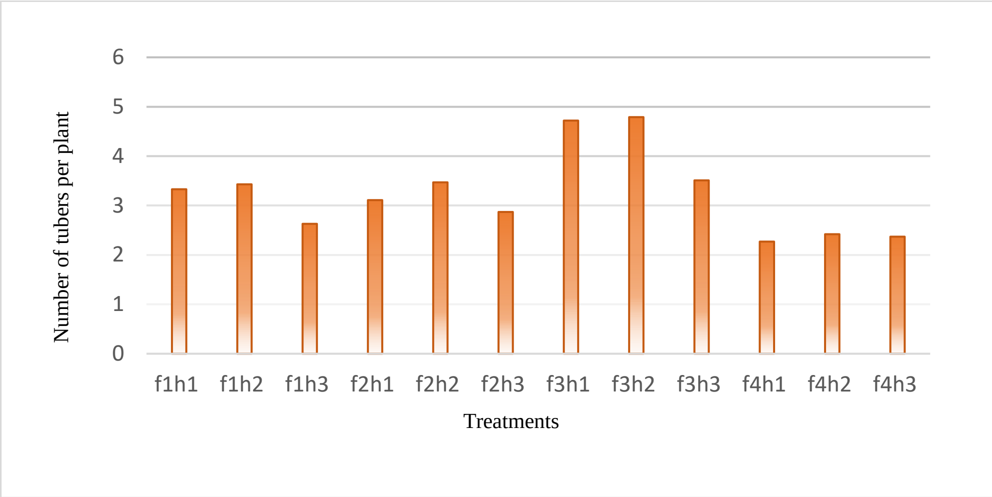

Fig 9. Interaction effects of foliar nutrition and harvesting time of vine top on number of tubers per plant

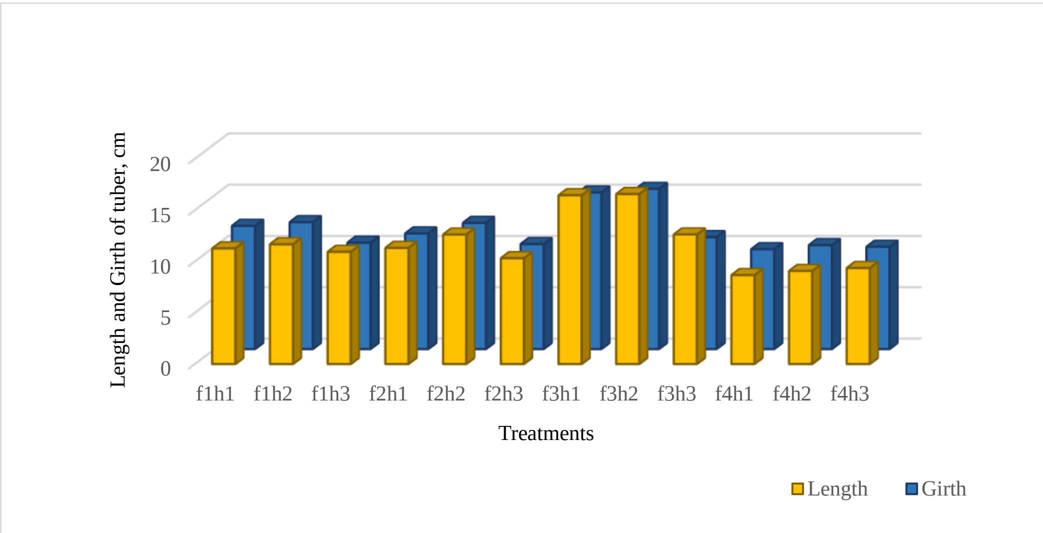

Fig 10. Interaction effects of foliar nutrition and harvesting time of vine top on length and girth of tuber, cm

Tuber bulking rate was higher with treatment f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine harvesting at 45 DAP) it was comparable with f_3h_3 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* no vine harvesting). This might be due to urea application can stimulate vegetative growth, including vine development. Pruning the vines redirects the plant's resources toward tuber formation rather than excessive vegetative growth. This shift in resource allocation may promote the production of hormones involved in tuberization, such as auxins and cytokinins, thereby enhancing tuber bulking. Micronutrients play vital roles as cofactors for enzymes involved in photosynthesis. By ensuring an adequate supply of micronutrients, foliar nutrition can optimize the efficiency of photosynthesis, leading to increased carbohydrate production leading to tuber enlargement.

Vine top yield was highest with treatment f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine harvesting at 45 DAP). Lowest vine top yield observed in f_4h_2 (water spray *fb* vine harvesting at 45 DAP). The increase in vine top yield might be due to urea provides a quick nitrogen boost, promoting vegetative growth, including vine development. The micronutrients in the mixture support overall plant health and development, further stimulating vine growth. This increased growth leads to more extensive foliage, resulting in higher vine top yield. Pruning redirects nutrients from pruned vines to the remaining parts of the plant, including the remaining vines. This redistribution of nutrients supports continued vine growth and enhances vine top yield.

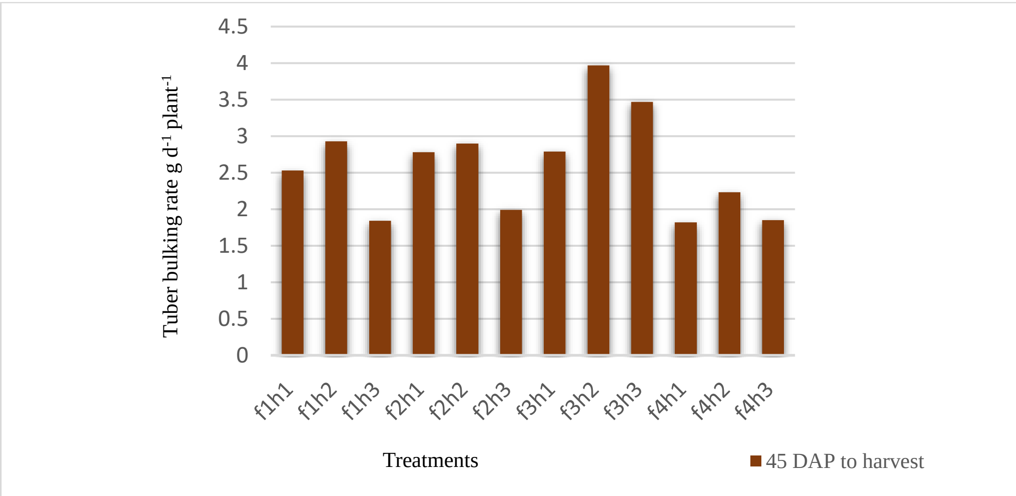

Fig 11. Interaction effects of foliar nutrition and harvesting time of vine top on tuber bulking rate g d^{-1} $plant^{-1}$

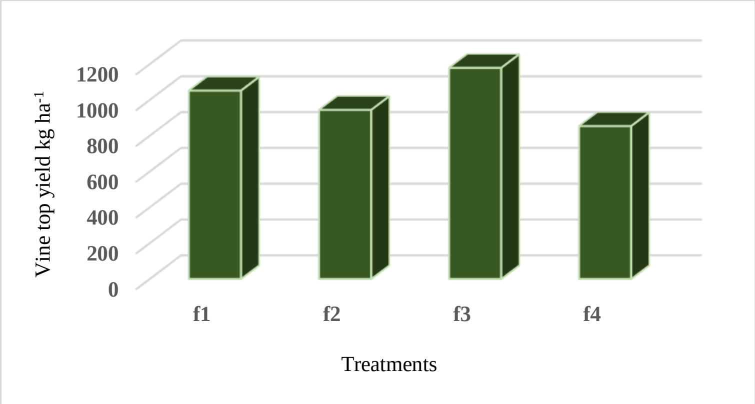

Fig 12. Effect of foliar nutrition management on vine top yield

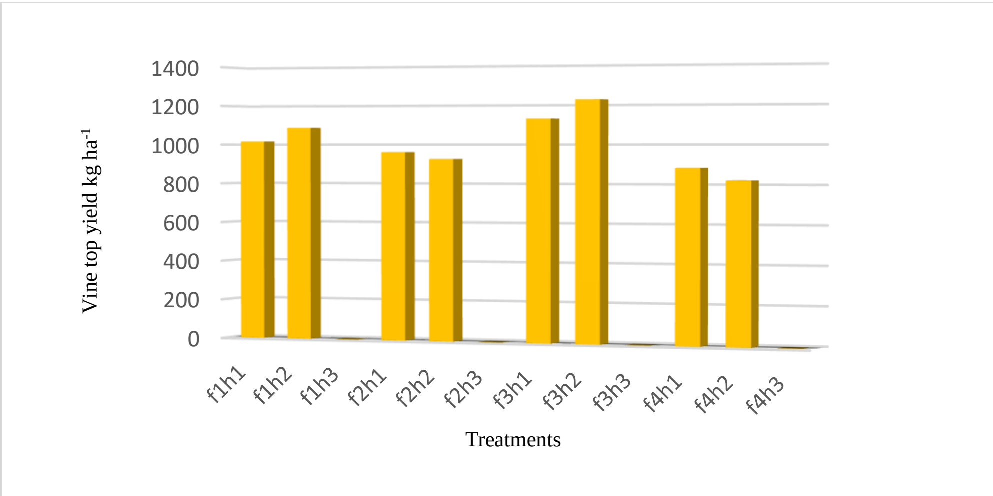

Fig 13. Interaction effects of foliar nutrition and harvesting time of vine top on vine top yield

Tuber yield and marketable tuber yield were higher with treatment f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine harvesting at 45 DAP) it was comparable with f_3h_1 (urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP *fb* vine top harvesting time at 30 DAP). The increase in tuber yield and marketable tuber could be because of nitrogen is provided via urea, which is crucial for plant growth and the main building block of chlorophyll. It encourages more vegetative growth by foliar applying nitrogen. In order to produce more energy for tuber growth and yield, higher vine growth increases the amount of photosynthetic surface area. The activation of enzymes and the transfer of electrons during photosynthesis depend on micronutrients like iron, zinc, manganese, and boron. Foliar feeding can maximize photosynthetic efficiency and raise the amount of carbohydrates produced by supplying a sufficient amount of micronutrients. The plant shifts its focus from vegetative growth to tuber development by pruning the vines. Auxins and cytokinins, two hormones involved in tuberization, may be produced more frequently as a result of this change in resource allocation, increasing tuber yield.

Vine yield was highest with f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine harvesting at 45 DAP). The increase in vine yield might be due to the urea and micronutrient mixture can optimize the efficiency of photosynthesis by providing essential components for chlorophyll synthesis and enzyme activation. Improved photosynthesis leads to increased production of carbohydrates, which are essential for energy and biomass accumulation in the vines. Pruning the vines to a length of 15 cm reduces the competition for resources among the vines. This allows the remaining vines to receive a higher proportion of available resources, including sunlight, water, and nutrients. With reduced competition, the individual vines can grow more vigorously and produce more foliage, contributing to higher vine yield.

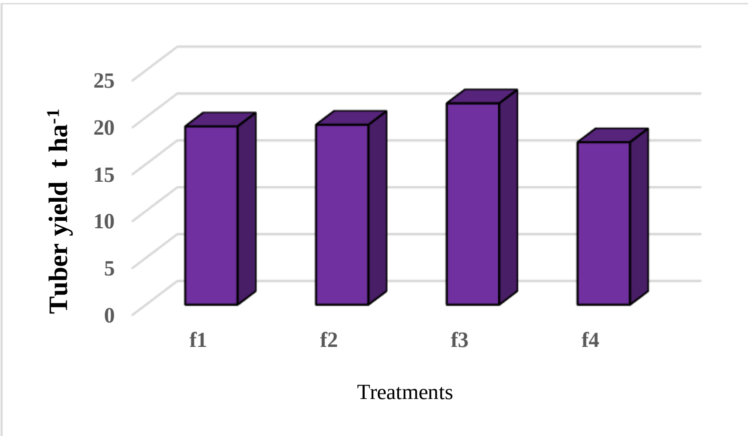

Fig 14. Effect of foliar nutrition management on tuber yield, t ha^{-1}

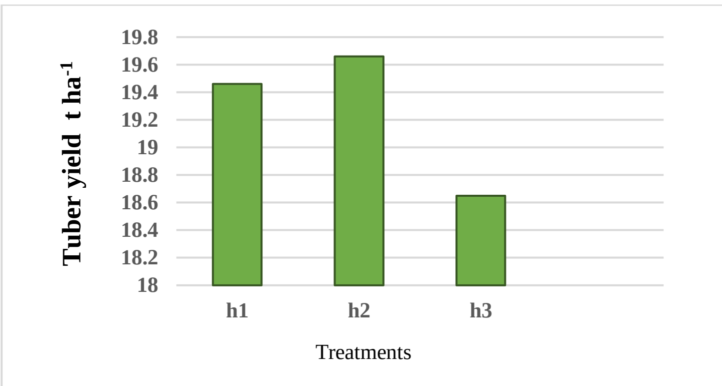

Fig15. Effect of harvesting time of vine top on tuber yield, t ha^{-1}

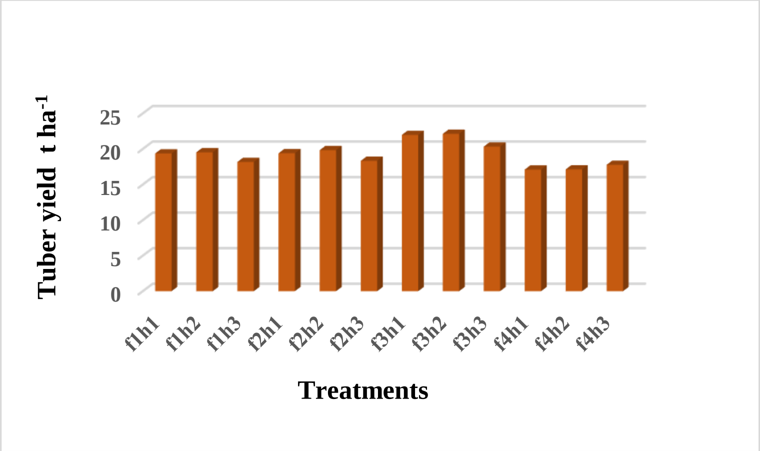

Fig 16. Interaction effects of foliar nutrition and harvesting time of vine top on tuber yield

5.3.3. Quality parameters

Starch and crude protein content in tuber were highest with treatment f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine harvesting at 45 DAP). This could be because one of the main ingredients of chlorophyll, the pigment that is involved in photosynthesis, is nitrogen. The use of urea topically improves the plant's capacity for photosynthetic energy production, which in turn causes a rise in the accumulation of carbohydrates, particularly starch, in the tubers. Micronutrients are essential cofactors in a variety of metabolic enzymatic pathways. The optimization of the plant's metabolic activities, such as protein creation and starch synthesis, is achieved by the provision of a sufficient amount of micronutrients. The energy from plants and resources can be redirected toward the formation of tubers by pruning the vines. The plant directs more nutrients and energy toward the expansion and storage of tubers when superfluous foliage is removed, which may cause the tubers to accumulate more starch and protein.

Total sugar content in tuber was highest with treatment f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine harvesting at 45 DAP). The high total sugar content in tuber might be due to micronutrients act as cofactors for the enzymes that are part of the metabolic pathways for sugar. The efficacy of enzymatic reactions linked to sugar synthesis and accumulation in the tubers is maximized by guaranteeing a sufficient supply of micronutrients. Vegetative growth, such as the growth of vines and tubers, is encouraged by urea. Through foliar application of nitrogen, it promotes rapid growth and increases the accumulation of carbohydrates in the tubers as sugars. Pruning by removing excess foliage, the plant allocates more energy and nutrients towards tuber enlargement and sugar accumulation.

Nitrate and crude protein content were highest with treatment f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine harvesting at 45 DAP). This might be due to urea is a rich source of nitrogen, which is a fundamental component of nitrate (NO_3^-) and proteins. Foliar application of urea provides readily available nitrogen to the plants, stimulating the synthesis of both nitrate and crude proteins in the vines. The micronutrient mixture complements the urea by providing essential elements required for enzymatic reactions involved in nitrogen metabolism and protein synthesis. Redirecting the plant's resources to the remaining vines through pruning encourages their growth and development. The pruned vines may have more crude protein and nitrate as a result of this targeted distribution of nutrients and energy.

Fibre content in vine top was the lowest in f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP *fb* vine top harvesting at 45 DAP). The highest fibre content of vine top recorded by the treatment f_4h_3 (control water spray *fb* no leaf harvesting. The lowest content of fibre in f_3h_2 might be due to supplying nitrogen through foliar application, it encourages lush vine growth with less emphasis on fibrous tissue development. By ensuring an adequate supply of micronutrients through foliar application, the efficiency of metabolic processes related to fibre formation and deposition may be reduced. Older, mature tissues which frequently contain more fibre than younger tissues are removed from the vines via pruning. By doing this, the resources from plants are redirected to the remaining, actively growing vines, which may lead to a decrease in the amount of fibre overall.

Vitamin A content was highest with treatment f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP *fb* vine top harvesting at 45 DAP). This could be because of foliar application of micronutrients optimizes the conversion of carotenoids into vitamin A. Urea application stimulates chlorophyll synthesis, improving photosynthetic efficiency. Increased photosynthesis may cause the leaves to produce and accumulate more carotenoids, such as beta-carotene, which is a precursor to vitamin A. Pruning vines redirects resources towards remaining vines, potentially enhancing vitamin A content by allocating more nutrients and energy.

Manganese content was highest with treatment f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP *fb* vine top harvesting at 45 DAP). This might be due to urea boosts vegetative growth by providing nitrogen through foliar application, leading to increased vine growth and manganese uptake. Pruning redirects resources toward remaining vines, allowing for more nutrient absorption. By applying a micronutrient mixture containing manganese directly to the foliage, the vines can readily absorb this essential nutrient.

Phosphorus uptake was highest with treatment f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP *fb* vine top harvesting at 45 DAP). This might be due to nitrogen facilitates phosphorus movement in plant tissues, enhancing growth and metabolism. Micronutrients, supplied through foliar application, optimize enzymatic reactions, enhancing phosphorus uptake and efficiency. Pruning vines allows the plant to allocate more energy and nutrients, including phosphorus, to the remaining ones, potentially increasing their uptake.

Tuber yield and yield parameters (number of tubers per plant, tuber length, tuber girth and vine yield) were correlated in studies. All the results for the above factors exhibited a positive correlation with yield (Fig 17).

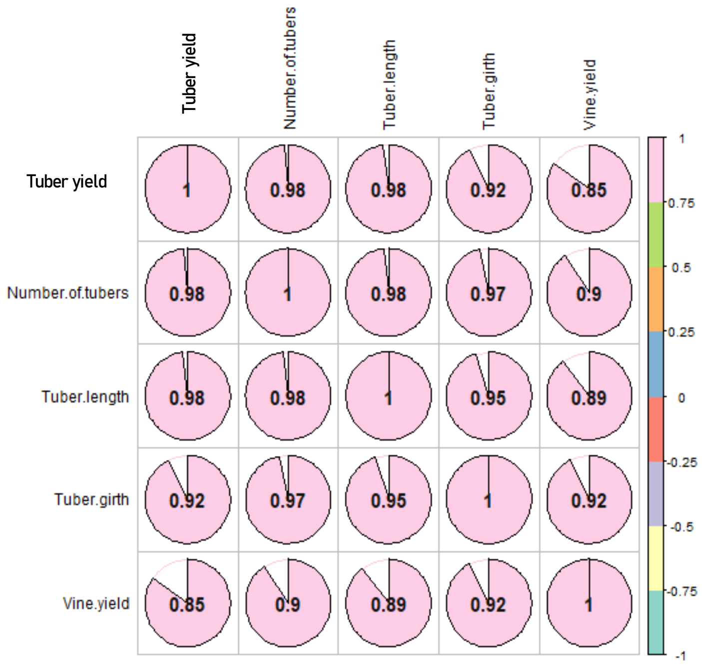

Fig 17. Correlation between yield and yield parameters

Through Economic analysis it was revealed that f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP *fb* vine top harvesting at 45 DAP) was the most profitable treatment combination for sweet potato dual-purpose cultivation. The net income and BCR computed were ₹ 581440 ha^{-1} and 2.44 respectively. The lowest net income and BCR was with f_4h_3 (control - water spray *fb* no vine top harvesting).

Summary

6. SUMMARY

The study entitled "Foliar nutrition in sweet potato (*Ipomoea batatas* (L) Lam.) for vine top and tuber yield" was conducted at College of Agriculture, Vellayani during 2021 - 2023. The objective of the study was to evaluate the impact of foliar nutrition on sweet potato (*Ipomoea batatas* (L) Lam) growth, vine top, and tuber yield.

The field experiment was conducted during November 2022 to March 2023 at the Farming Systems Research Station (FSRS), Sadanandapuram. The experiment was laid out in randomized block design with 4 x 3 treatments replicated thrice. Treatments were (Factor A: foliar nutrition management (F) and Factor B: Harvesting time of vine top (H) and treatment combination comprised f_1h_1: urea 2 per cent spray at 20 and 35 days after planting (DAP) *fb* vine top harvesting at 30 DAP, f_1h_2: urea 2 per cent spray at 20 and 35 DAP *fb* vine top harvesting at 45 DAP, f_1h_3: urea 2 per cent spray at 20 and 35 DAP *fb* no vine top harvesting, f_2h_1: multi micronutrient 0.5 per cent spray at 20 and 35 DAP *fb* vine top harvesting at 30 DAP, f_2h_2: multi micronutrient 0.5 per cent spray at 20 and 35 DAP *fb* vine top harvesting at 45 DAP, f_2h_3: multi micronutrient 0.5 per cent spray at 20 and 35 DAP *fb* no vine top harvesting, f_3h_1: urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP *fb* vine top harvesting at 30 DAP, f_3h_2: urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP *fb* vine top harvesting at 45 DAP, f_3h_3: urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP *fb* no vine top harvesting, f_4h_1: control (water spray) *fb* vine top harvesting at 30 DAP, f_4h_2: control (water spray) *fb* vine top harvesting at 45 DAP, f_4h_3: control (water spray) *fb* no vine top harvesting. Vine cuttings of Sree Arun variety of sweet potato was raised as per KAU POP recommendations.

Foliar application of urea 2 percent spray at 20 and 35 DAP (f_1) had the longer vine length at 30 DAP (69.66 cm), which was comparable to f_3 and f_2. When compared to the control (92.50 cm), significantly longest vine lengths at 45 DAP were found to be in treatment f_2 (multi micronutrient 0.5 per cent spray at 20 and 35 DAP), (103.43 cm). Nonetheless, it was comparable to f_1 and f_3. At the time of crop harvest, plants in treatment f_1 (urea 2 per cent spray at 20 and 35 DAP) showed significantly more vine length (128.69 cm) and it was on par with f_2 and f_3.

At 30 DAP, f_3 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP) recorded significantly higher number of branches (1.95) which was on par with f_1 and f_2. During 45 DAP and at harvesting significantly higher number of branches were observed in f_3

(3.42 and 4.17 respectively). Significant higher number of branches were observed in h_1 (vine top harvesting on 30 DAP) (3.18) was comparable to h_2 on 45 DAP. The observation during harvest indicated h_2 (vine top harvesting on 45 DAP) (3.78) registered significantly higher number of branches which was on par with h_1. Observations at 45 DAT and at harvest showed higher number of branches (3.90 and 4.80 respectively) for f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine top harvest at 45 DAP) Comparable with f_3h_1 and f_1h_1.

Observation at 30 DAP and at 45 DAP expressed f_3 (urea 2 per cent spray at 20 DAP + multi-micronutrient spray at 35 DAP) for the largest leaf area per plant (360.91 cm^2, 969.46 cm^2 respectively) and was comparable to f_1 and f_2. Significant largest leaf area detected for f_3 at the harvest stage (907.05 cm^2). The larger leaf area per plant was found in treatment h_2 (vine top harvesting on 45 DAP) (963.67 cm^2, 867.03 cm^2 respectively for 45 DAT and at harvest) whereas at harvest the leaf area was comparable with h_1. In response to the interaction at 45 DAP, f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine top harvest at 45 DAT) (1030.33 cm^2) had the larger leaf area and were comparable to f_3h_1, f_1h_1 and f_1h_2. At the harvest stage, f_3h_2 (972.02 cm^2) had the higher leaf area per plant, on par with f_3h_1.

At 30 DAP significant higher production of dry matter was observed in f_2 (multi micronutrient 0.5 per cent spray at 20 and 35 DAP) (12.90 g $plant^{-1}$) which were on par with f_1 and f_3. At 45 DAP and harvest f_3 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP) registered the higher dry matter output per plant (21.26 g $plant^{-1}$, 34.79 g $plant^{-1}$ respectively) this was comparable to treatment f_2 and f_1. At harvesting stage significant higher dry matter production per plant was found in treatment h_1 (vine top harvesting on 30 DAP) (33.89 g $plant^{-1}$) which was on par with h_2. Treatment f_3h_1 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine top harvest at 30 DAT) (37.34 g $plant^{-1}$) had the higher dry matter production per plant, on par with f_3h_2, f_1h_3 and f_1h_1.

Urea 2 per cent spray at 20 DAP + multi micronutrient 0.5% spray at 35 DAP (f_3) recorded significantly the highest number of tubers per plant (4.34). In vine top harvesting higher number of tubers per plant (3.53) was obtained in vine top harvesting at 45 DAP (h_2) and it was on par with h_1. Treatment f_3h_2 (urea 2 percent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine top harvesting at 45 DAP) showed the higher number of tubers (4.79 $plant^{-1}$) and it was on par with f_3h_1.

Urea 2 per cent spray at 20 DAP + multi micronutrient 0.5% spray at 35 DAP (f_3) recorded significantly the longest of tubers (15.22 cm). vine top harvesting time at 45 DAP recorded longest tubers (12.48 cm) and it was on par with (h_2). Treatment f_3h_2 (urea 2 percent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine harvesting at 45 DAP) showed the higher length of tuber (16.57 cm) and it was on par with f_3h_3.

Urea 2 per cent spray at 20 DAP + multi micronutrient 0.5% spray at 35 DAP (f_3) recorded significantly the highest tuber girth (13.93 cm). Vine top harvesting at 45 DAP (h_2) observed significantly higher tuber girth (12.60 cm) and was on par with h_1. Treatment f_3h_2 (urea 2 percent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine harvesting at 45 DAP) showed the higher tuber girth (15.62 cm) and was comparable with f_3h_1.

At 30-45 DAP stage showed significant higher tuber bulking rate for f_3 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP) (1.89 kg^{-1} ha^{-1} d^{-1}) and was comparable with f_2. At 45 DAP- harvest stage foliar nutrition recorded significant highest tuber bulking rate for f_3 (3.40 kg^{-1} ha^{-1} d^{-1}). Treatment f_3h_2 (urea 2 percent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine harvesting at 45 DAP) showed the higher tuber bulking rate (3.67 kg^{-1} ha^{-1} d^{-1}) it was comparable with f_3h_1.

Significantly the highest vine top yield of sweet potato was observed with foliar application of urea 2 per cent spray at 20 DAP + multi micronutrient 0.5% spray at 35 DAP (f_3) (1178.8 kg ha^{-1}). Treatment f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine harvesting at 45 DAP) revealed significant highest vine top yield) (1226.7 kg ha^{-1}).

Foliar application of 2 per cent urea at 20 DAP + multi micronutrient 0.5% spray at 35 DAP (f_3) recorded significant highest tuber yield (21.48 t ha^{-1}). Significant higher tuber yield (19.66 t ha^{-1}) was obtained by vine top harvesting at 45 DAP (h_2) and it was on par with h_1. The treatment f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP *fb* vine top harvesting time at 45 DAP) recorded significantly higher tuber yield (22.13 t ha^{-1}) and it was comparable with f_3h_1.

Urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP (f_3) recorded significant highest vine yield (36.27 t ha^{-1}). Vine top harvesting at 45 DAP (h_2) registered significant higher vine yield (34.11 t ha^{-1}) and it was on par with (h_1). The treatment f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP *fb* leaf harvesting time 45 DAP) registered significant higher vine yield (38.57 t ha^{-1}) and it was comparable with vine yield of f_3h_1.

Foliar application of urea 2 per cent at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP (f_3) recorded significantly the higher chlorophyll content of leaf (3.40 mg g^{-1}) and it were on par with f_1. Significantly higher chlorophyll content of leaf (3.21 mg g^{-1}) was obtained by h_2 (vine top harvesting time at 45 DAP) and it was comparable with (h_1).

Quality parameters of tuber (starch, crude protein, total sugars and betacarotene content) were significantly highest with treatment f_3 (23.4 per cent, 5.17 per cent, 4.71 per cent, 0.53 mg 100 g^{-1} respectively). In case of vine top harvesting (h_2) yielded the maximum quality parameters in tuber. Among the interaction treatment f_3h_2 showed higher starch, crude protein and total sugars content of tuber and it was on par with f_3h_1.

Lowest nitrate content of vine top (666.89 mg 100g^{-1}) was obtained with (f_4). In interaction effects f_4h_1 (659.67 mg 100g^{-1}) were the lowest.

Foliar application of urea 2 per cent at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP (f_3) recorded significantly the highest crude protein content of vine top (23.60 per cent). The vine top harvesting at 30 DAP (h_1) yielded the maximum crude protein content (22.68 per cent), which was comparable to h_2. The treatment f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP *fb* vine top harvesting at 45 DAP) recorded significantly the higher crude protein content of vine top (25.16 per cent) and it was on par with f_3h_1.

Significant lower fibre vine top registered with (f_1) (4.74 per cent) and comparable with f_3. Significantly lowest fibre content of vine top (4.83 per cent) was obtained by vine top harvesting at 45 DAP (h_2). The highest fibre content of vine top (6.59 per cent) was obtained with no leaf harvest (h_3). Combination of f_3h_2 recorded lowest fibre content (4.09 per cent) which were comparable with f_3h_1, f_1h_1, f_1h_2 and f_3h_1.

Significantly the higher NPK uptake of sweet potato were observed with foliar application of urea 2 per cent spray at 20 DAP + multi micronutrient 0.5 per cent spray at 35 DAP (f_3) (53.36, 10.53, 55.04 kg ha^{-1} NPK respectively) and it was comparable with f_1 in case of nitrogen and potassium. Treatment (h_2) vine top harvesting at 45 DAP showed higher uptake of phosphorus and potassium (8.73, 49.85 kg ha^{-1} PK respectively), which is comparable to h_1. Treatment f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine harvesting at 45 DAP) revealed significant higher uptake on phosphorus (11.83 kg ha^{-1}) and it was on par with f_3h_1.

The f_3h_2 (foliar application of urea 2 per cent at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine harvesting at 45 DAP) registered highest overall tuber and vine top acceptability (score: 19.53 and 11.71 respectively).

The treatment f_3h_2 (urea 2 per cent spray at 20 DAP + multi micronutrient spray at 35 DAP *fb* vine harvesting at 45 DAP) resulted in highest net income (₹ 581440 ha^{-1}) and B:C ratio (2.44).

Therefore it can be concluded that foliar application of urea 2 per cent at 20 DAP + multi micronutrient mixture 0.5 per cent at 35 DAP followed by vine top harvesting at 45 DAP (f_3h_2) significantly enhanced growth attributes, yield attributes, quality parameters, vine top yield, tuber yield and net income.

FUTURE LINE OF WORK

1. Foliage yield can be tested with different water soluble major and micro nutrients which enhances the quantity and quality aspects
2. Different harvesting intensity can be tested for optimization
3. To assess the impact of multiple picking with varying time and intensity for vine top harvest without decline in tuber yield.

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Abstract

FOLIAR NUTRITION IN SWEET POTATO (*Ipomoea batatas* (L.) Lam.) FOR VINE TOP AND TUBER YIELD

by

BHUPASAMUDRAM NEERAJA

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ABSTRACT

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ABSTRACT

The study entitled "Foliar nutrition in sweet potato (*Ipomoea batatas* (L) Lam.) for vine top and tuber yield" was conducted at College of Agriculture, Vellayani during 2021 - 2023. The objective of the study was to evaluate the impact of foliar nutrition on sweet potato (*Ipomoea batatas* (L) Lam) growth, vine top, and tuber yield.

The field experiment was conducted during November 2022 to March 2023 at the Farming Systems Research Station (FSRS), Sadanandapuram. The experiment was laid out in randomized block design with 4 x 3 treatments replicated thrice. Factor A: Foliar nutrition management (F) includes (f_1: urea 2% spray at 20 and 35 DAP), (f_2: multi micronutrient 0.5 % spray at 20 and 35 DAP), (f_3: urea 2% spray at 20 DAP + multi micronutrient 0.5% spray at 35 DAP), (f_4: Control water spray). Factor B: Harvesting time of vine top (H) includes (h_1: at 30 DAP), (h_2: at 45 DAP), (h_3: Control (No leaf harvest)). The vine top was harvested 15 cm length. Multi micronutrient fertilizer developed by Central Tuber Crop Research Institute was used for foliar spray. It contains of Zn 2 %, Cu 0.6 %, B 0.2 %, Fe 0.5 % and Mn 0.25%. Vine cuttings of Sree Arun variety of sweet potato was raised as per POP recommendations of Kerala Agricultural University.

Among the foliar nutrition management treatments, f_1 produced longer vines (69.66 cm) and more number of branches (1.95) at 30 DAP and was comparable to f_3 (68.56 cm, 1.94) and f_2 (64.38 cm, 1.93) respectively. At the time of harvest, f_1 resulted in significantly longer vines (128.69 cm), and more number of branches (3.18), and was comparable to f_2 and f_3. Among treatment combinations, f_3h_1 produced higher dry matter production (37.34 g plant^{-1}) which were comparable with f_3h_2 (36.01 g plant^{-1}), f_1h_3 (35.34 g plant^{-1}) and f_1h_1 (34.51 g plant^{-1}).

The yield attributes like number of tubers per plant (4.34), tuber length (15.22 cm) and girth (13.93 cm) were significantly higher with f_3. Among time of vine top harvesting, h_2 resulted in significantly more number of tubers per plant (3.53), tuber length (12.48 cm) and girth (12.60 cm). Among the interactions, f_3h_2 showed higher number of tubers per plant (4.79), tuber length (16.57 cm) and tuber girth (15.62 cm) which were comparable with f_3h_1.

Among the foliar nutrition, significant higher vine top yield (1178.8 kg ha^{-1}) and tuber yield (21.48 t ha^{-1}) were observed with f_3 while f_4 registered the lowest. The interaction f_3h_2 recorded significantly higher vine top yield (1226.7 kg ha^{-1}) and the highest tuber yield (22.13 t ha^{-1}) and tuber yield was comparable with f_3h_1 (21.97 t ha^{-1}).

The chlorophyll content of the harvested leaf was higher with f_3 (3.71 mg g^{-1}) which were comparable to f_1 (3.34 mg g^{-1}) and f_2 (3.35 mg g^{-1}). Significant the lower fibre vine top was registered with (f_1) (4.74 per cent) and comparable with f_3 (4.82 per cent). Combination of f_3h_2 recorded lower fibre content (4.09 per cent) which were comparable with f_3h_1 (4.12 per cent), f_1h_1 (4.32 per cent), f_1h_2 (4.51 per cent) and f_3h_1 (4.55 per cent).

Quality parameters of tuber (starch, crude protein, total sugars and betacarotene content) were significantly the highest with treatment f_3 (23.4 per cent, 5.17 per cent, 4.71 per cent, 0.53 mg 100 g^{-1} respectively). In case of vine top harvesting (h_2) resulted in higher quality parameters of tuber. Among the interactions treatment f_3h_2 showed higher starch, crude protein and total sugars content of tuber and it was on par with f_3h_1. The vine top with the highest nitrate concentration (898.69 mg 100g 1) was found with (f1). In interaction effects f3h2 (964.28 mg 100g 1) were the highest.

Economic analysis revealed f_3h_2 as the more profitable treatment combination for sweet potato dual purpose cultivation. The net income and BCR computed were ₹ 581440 ha^{-1} and 2.44 respectively. Compared to control 19.7%, tuber yield enhancement and 1226.7 kg ha^{-1} vine top yield was obtained.

Based on the results of the study foliar application of urea 2 per cent at 20 DAP + multi micronutrient mixture 0.5 per cent at 35 DAP followed by vine top harvesting at 45 DAP (f_3h_2) can be recommended as the most suitable option for dual purpose cultivation of sweet potato without affecting the tuber yield and enhancing the quality.

സംഗ്രഹം

2021-2023 കാലയളവിൽ വെള്ളായണി കാർഷിക കലാലയത്തിൽ വച്ച് "മധുരക്കിഴങ്ങിൽ (ഐപ്പോമിയ ബറ്റാറ്റസ്) പത്രപോഷണത്തിലൂടെ തലപ്പ് വള്ളിയുടെയും, കിഴങ്ങിന്റെയും ഉത്പാദന വർദ്ധനവ്" എന്ന വിഷയത്തിൽ പഠനം നടത്തുകയുണ്ടായി. മധുരക്കിഴങ്ങിൽ പത്രപോഷണം നടത്തുമ്പോൾ ഉള്ള വളർച്ചയിലും തലപ്പ് വള്ളിയുടെയും, കിഴങ്ങിന്റെയും ഉത്പാദന വ്യതിയാനങ്ങളെക്കുറിച്ചുള്ള പഠനമായിരുന്നു ഉദ്ദേശലക്ഷ്യം.

2022 നവംബർ മുതൽ 2023 വരെ സദാനന്ദപുരം കൃഷി സമ്പ്രദായ ഗവേഷണ കേന്ദ്രത്തിൽ വച്ച് ഫീൽഡ് തല പരീക്ഷണം നടത്തി. 4x3 ട്രീറ്റ്മെന്റുകൾ മൂന്ന്തവണ ആവർത്തിക്കുന്ന ക്രമരഹിത ബ്ലോക്ക് ഡിസൈനിലായിരുന്നു പരീക്ഷണം നടത്തിയത്.

പ്രധാന 2 ഘടകങ്ങളാണ് പഠനത്തിന് വിധേയമാക്കിയത്. ഒന്ന്: പത്രപോഷണം (എഫ്), രണ്ട്: തലപ്പ് വള്ളി വിളവെടുപ്പ് സമയം (എച്ച്). പത്രപോഷണത്തിൽ (എഫ് 1: യൂറിയ 2% വീര്യത്തിൽ മധുരക്കിഴങ്ങ് നട്ടതിന് ശേഷം 20, 35 ദിവസത്തിൽ ഇലകളിൽ തളിക്കുക, എഫ് 2: സൂക്ഷ്മ മൂലക മിശ്രിതം 0.5% വീര്യത്തിൽ മധുരക്കിഴങ്ങ് നട്ടതിന് ശേഷം 20, 35 ദിവസത്തിൽ ഇലകളിൽ തളിക്കുക, എഫ് 3: യൂറിയ 2% വീര്യത്തിൽ 20-ാം മത്തെ ദിവസത്തിലും, 0.5% വീര്യത്തിൽ സൂക്ഷ്മ മൂലക മിശ്രിതം 35-ാം മത്തെ ദിവസത്തിലും തളിക്കുക) ഉൾപ്പെട്ടിരുന്നു. തലപ്പ് വള്ളി വിളവെടുപ്പ് സമയത്തിൽ (എച്ച് 1: തലപ്പ് വള്ളി 30-ാം മത്തെ ദിവസത്തിൽ വിളവെടുക്കുക, എച്ച് 2: തലപ്പ് വള്ളി 45-ാം മത്തെ ദിവസത്തിൽ വിളവെടുക്കുക, എച്ച് 3: തലപ്പ് വള്ളി വിളവെടുക്കാതിരിക്കുക), എന്നിവയും ഉൾപ്പെട്ടിരിക്കുന്നു. 15 സെ: മീറ്റർ നീളത്തിൽ ഉള്ള തലപ്പ് വള്ളിയാണ് വിളവെടുത്തത്. കേരള കാർഷിക സർവകലാശാല ശുപാർഷ ചെയ്ത വിള പരിപാലനക്രമമാണ് ശ്രീഅരുൺ എന്ന മധുരക്കിഴങ്ങ് ഇനത്തിൽ പഠനം നടത്തിയത്.

പത്രപോഷണം വഴിയുള്ള പരീക്ഷണത്തിൽ എഫ്. ഒന്നിൽ (യൂറിയ 2% വീര്യത്തിൽ തളിക്കുന്നത് വഴി) 30-ാം ദിവസത്തിൽ 69.66 സെ: മീറ്റർ നീളത്തിലും, 1.95 ശിഖിരങ്ങളും മികവ് രേഖപ്പെടുത്തി. ഇത് എഫ്.3 (യൂറിയ 2% വീര്യത്തിലും, സൂക്ഷ്മ മൂലകങ്ങൾ 0.5% വീര്യത്തിലും തളിക്കുന്നതിന്) സമാനമായി പരിഗണിക്കാവുന്ന ചെടിയുടെ നീളവും (68.56 സെ: മീറ്റർ), ശാഖകൾ (1,94) എന്നിവ ആയിരുന്നു. ചെടികളുടെ വിളവെടുപ്പ് സമയത്ത് 2% വീര്യത്തിൽ യൂറിയ തളിക്കുന്ന ചെടികൾക്ക് ഉയർന്ന നീളവും (128.69 സെ: മീറ്റർ കൂടുതൽ ശാഖകൾ (3.18) എന്നിവ രേഖപ്പെടുത്തിയത് എഫ് 2, എഫ് 3 എന്നിവയുമായ് സമാന ഗണത്തിൽ വരുന്നു.

രണ്ട് ഘടകങ്ങളുടെയും സംയുക്ത ഫലമായി എഫ് 3, എച്ച് 1 ചെടികളിൽ മികച്ച ഉണക്ക് ഭാരം (37:34 ഗ്രാം) രേഖപ്പെടുത്തിയത് എഫ് 3, എച്ച് 2 (36.01 ഗ്രാം), എഫ് 1, എച്ച് 3 (35.34 ഗ്രാം) എന്നിവക്ക് സമാനമാണ്.

വിളവിനെ ബാധിക്കുന്ന ഘടകങ്ങൾ നിരീക്ഷിച്ചപ്പോൾ കിഴങ്ങിന്റെ എണ്ണം (4.34) നീളം (15.22 സെ: മീറ്റർ), വണ്ണം (13.93 സെ: മീറ്റർ) ഇവ എഫ് 3- യിൽ മികവ് രേഖപ്പെടുത്തി. തലപ്പ് വള്ളി വിളവെടുപ്പ് പഠനത്തിൽ എച്ച് 2 ഉയർന്ന കിഴങ്ങിന്റെ എണ്ണവും (3.53), നീളം (12.48 സെ: മീറ്റർ), വണ്ണം (12.60 സെ: മീറ്റർ) രേഖപ്പെടുത്തി. സംയുക്ത ഫലമായി എഫ് 3 എച്ച് 1 മികവുറ്റ കിഴങ്ങിന്റെ എണ്ണം (4.79), നീളം (16.57 സെ: മീറ്റർ), വണ്ണം (15.62 സെ: മീറ്റർ) കാണപ്പെട്ടു.

യൂറിയ 2% വീര്യത്തിലും, സൂക്ഷ്മ മൂലകങ്ങൾ 0.5% വീര്യത്തിലും ഇലകളിൽ തളിക്കുന്നത് മികച്ച തലപ്പ് വള്ളി ഉത്പാദനത്തിനും (ഹെക്ടറിന് 1178. 8 കിലോഗ്രാം), കിഴങ്ങ് വിളവ് (ഹെക്ടറിന് 21.48 ടൺ) നൽകുവാൻ കഴിയുമെന്ന് മനസ്സിലാക്കി. സംയുക്ത ഫലമായി എഫ് 3 എച് 2 മികച്ച തലപ്പ് വള്ളി ഉത്പാദനം (ഹെക്ടറിന് 1226.7 കിലോഗ്രാം), കിഴങ്ങ് വിളവ് (ഹെക്ടറിന് 22:13 ടൺ) രേഖപ്പെടുത്തിയത് എഫ് 3 എച്ച് 1 ന് സമാനമായി പരിഗണിക്കാവുന്നതാണ്.

എഫ് 3- യിൽ ഹരിതകത്തിന്റെ അളവ് (3.71 മില്ലിഗ്രാം/ഗ്രാം ഇലയിൽ) രേഖപ്പെടുത്തി. നാരുകൾ പരിശോധിച്ചപ്പോൾ താഴ്ന്ന അളവ് (4.74%) എഫ് 1 രേഖപ്പെടുത്തിയത് എഫ് 3 (4.82%) ന് സമാന നിലവാരമാണ്.

സംയുക്ത ഫലമായി എഫ് 3 എച് 2 കുറഞ്ഞ നാര് (4.09%), എഫ് 3 എച് 1 (4.55%) രേഖപ്പെടുത്തി. ഗുണനിലവാര പഠനത്തിൽ (അന്നജം, മാസ്യം, പഞ്ചസാര, ബീറ്റ കരോട്ടിൻ) എന്നിവ എഫ് 3- യിൽ മികച്ചതായ് കണ്ടെത്തി. സംയുക്ത ഫലമായി എഫ് 3 എച് 2 ഉയർന്ന അന്നജം, മാസ്യം, പഞ്ചസാര ഉള്ളതായി കണ്ടെത്തിയത് എഫ് 3 എച്1 ന് സമാനമാണ്. താഴ്ന്ന അളവിലുള്ള നൈട്രേറ്റ് (100 ഗ്രാമിൽ 666.89 മില്ലിഗ്രാം) അളവിലുള്ള നൈട്രേറ്റ് എഫ് 4-ൽ രേഖപ്പെടുത്തി.

സാമ്പത്തിക വിശകലനത്തിൽ ഉയർന്ന അറ്റാദായം (ഹെക്ടറിന് 581440 രൂപ), ബിസിആർ (2.44) എന്നിവ എഫ് 3 എച്ച് 2 ൽ രേഖപ്പെടുത്തി.

ഈ പഠനത്തിൽ നിന്നും മധുരക്കിഴങ്ങ് കൃഷിയിൽ 2% വീര്യത്തിൽ യൂറിയ 20-ാം മത്തെ ദിവസം തുടർന്ന് 35-ാം മത്തെ ദിവസം 0.5% വീര്യത്തിൽ സൂക്ഷ്മ മൂലക മിശ്രിതം പത്രപോഷണം വഴി നൽകുന്നതും, 45-ാം മത്തെ ദിവസം 15 സെ: മീറ്റർ നീളത്തിൽ തലപ്പ് വിളവെടുക്കുന്നത് ചെടികളുടെ വളർച്ച, വിളവിനെ ബാധിക്കുന്ന ഘടകങ്ങൾ, തലപ്പ് വള്ളി വിളവ്, കിഴങ്ങിന്റെ വിളവ് എന്നിവ ഉയർത്തുന്നതിനോടൊപ്പം മെച്ചപ്പെട്ട വരുമാനവും നൽകുമെന്ന് കണ്ടെത്തി.

Appendix

APPENDIX I

Weather data during crop season November 2022 to march 2023

Standard weeks	Temperature (^0C)		Relative humidity (%)		Rainfall (mm)
	Max	Min	RH I	RH II	
46	32.40	22.98	90.63	63.71	20.28
47	32.04	23.38	90.28	60.57	12.42
48	31.75	22.62	87.56	63.72	1.13
49	33.38	21.30	84.67	66.28	0.57
50	32.51	23.31	86.84	63.71	0.14
51	30.60	22.62	88.12	67.57	4.85
52	32.98	21.72	78.59	62.71	0.92
1	33.52	22.50	82.87	64.57	0.00
2	33.77	22.28	87.54	61.57	0.00
3	33.85	21.82	75.97	54.14	0.00
4	33.81	19.72	71.23	56.71	0.00
5	33.84	22.08	65.52	50.85	0.00
6	33.40	21.68	73.03	50.28	0.64
7	32.91	14.27	76.05	55.71	0.71
8	35.17	19.84	72.45	52.05	0.00
9	35.64	20.05	69.28	53.43	0.00
10	35.85	21.82	68.77	51.32	0.00

APPENDIX II

Sl.no	ITEMS	COST (₹)
A	**Labour**	
1	Man	1000 per day
2	Woman	850 per day
B	**Input**	
1	Vine cuttings	1 per vine
2	FYM	5 per kg
3	Lime	15 per kg
4	Urea	8 per kg
5	Mussooriphos	9 per kg
6	Muriate of potash	17 per kg
C	**Output**	
1	Vine top	10 per kg
2	Tuber yield	50 per kg

*Cost of cultivation: 397577 ₹ ha^{-1}