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Effect of Foliar Nutrition and Vine Top Harvesting in Sweet Potato (*Ipomoea batatas* (L.) Lam.) for Growth, Vine Top and Tuber Yield

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted at Farming Systems Research Station, Sadanandapuram, Kerala Agricultural University, Kerala, India during *rabi* 2022 with 12 treatments replicated thrice in randomised block design. Treatments included 2 factors, factor A having foliar nutrition (urea 2 %, multi-micronutrient mixture 0.5%, combination of urea 2% + micronutrient mixture 0.5%, and control). Factor B vine harvesting time (30, 45 DAP and control). The results showed that foliar application of 2% urea followed by 0.5 % multi micronutrient mixture registered significant highest growth attributes (vine length, number of branches, dry matter production), yield attributes, tuber

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and vine top yield. In case of time of vine top harvesting indicated that vine top harvest at 45 DAP gave the higher tuber and vine top yield and it was on par with vine harvesting time at 30 DAP. No leaf harvesting recorded the lowest tuber yield.

Keywords: Sweet potato; foliar nutrition; growth and yield attributes; vine top harvesting.

1. INTRODUCTION

Sweet potato (*Ipomoea batatas* L. (Lam) is a vital 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 ranked as the fifth most important food crop [1] It 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 [2]. Its high yield, affordability, and nutrition combat malnutrition and enhance food security, especially in resource-limited regions. These are one of the key staple food crops in India for the underprivileged population and 76 per cent of the country's total acreage and 79 per cent of its production from 4 states mainly from West Bengal, Uttar Pradesh, Kerala, and Odisha [3].

Sweet potatoes have a high edible biomass index because foliage and storage roots can be consumed. The tender portions of the foliage are an excellent source of vitamins A, B2 and C, Fe and protein. Sweet potato leaves are potent against various cancers due to anthocyanins and polyphenols [4,5] They offer antimicrobial properties, vitamins, dietary fibers, and immunity boost. Sweet potatoes are the most nutritious tropical tuber [6] with a low glycaemic index (54), making them appealing to health-conscious individuals.

Sweet potato production for food security lacks adequate information on optimizing tuber and shoot growth. In sweet potatoes, reducing vegetative growth can enhance root production and yield [7,8] Age at harvest is an important management factor that affects sweet potato fodder and tuberous root yield as well as quality [9].

Foliar sprays improve focused distribution, quick responsiveness, and the efficiency of nutrient uptake. It can alleviate nutritional deficiencies, increase plant vigour, and improve nutrient uptake efficiency results in plant vigour. Nitrogen augments sweet potato biomass and root yield [10,11] Micronutrients are essential for various plant functions. Application of micronutrients lead to superior plant performance and enhancing marketable tuber output [12]. Similarly [13] repported superior plant performance with micronutrient sprays and enhancing marketable output. Considering these facts, the present investigation was undertaken to find out the effect of foliar nutrition and time of vine top harvesting on growth, vine top and tuber yield in sweet potato.

2. MATERIALS AND METHODS

2.1 Study Area

The field experiment was conducted at Farming Systems Research Station, Sadanandapurram during *rabi* 2022 and field located in latitude 8.59'03" N and longitude 76.48'29" E. The soil in the experiment site was acidic (pH :4.37) in nature. Available nitrogen, phosphorus and potassium were 283 kg ha^{-1}, 13 kg ha^{-1} and 152 kg ha^{-1} respectively.

2.2 Plot Size

For this study, a total of 36 plots were used with each plot size 4.8X3 m.

2.3 Material

2.3.1 Variety selection

Sweet potato variety Sree Arun released from Central Tuber Crop Research Institute (CTCRI), Sreekariyam, Thiruvananthapuram, Kerala were used. Vines were planted on ridges with a spacing of 60 cm x 20 cm.

2.3.2 Multi micronutrient fertilizer

Micro nutrient developed by CTCRI was used for foliar spray. It contains of Zn 2%, Cu 0.6%, B 0.2%, Fe 0.5% and Mn 0.25%.

2.4 Treatment Details

Experiment designed with two factors includes: Factor A: Foliar nutrition management (F) (f_1: urea 2% spray at 20 and 35 Days after planting (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) h_1: 30 DAP, h_2: 45 DAP, h_3: Control (No leaf harvest). The vines were harvested 15 cm at top portion. The factorial experiment was replicated thrice. The crop was raised as per POP recommendations of Kerala Agricultural University.

2.5 Foliar Application

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.

2.6 Details of Vine Harvest

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

2.7 Data Collection

Throughout the experimental period, data on growth parameters like vine length, number of branches and dry matter production. Yield parameters like number of tubers per plant, length of tuber, girth of tuber, vine top yield and tuber yield.

3. RESULTS AND DISCUSSION

3.1 Effect of Foliar Nutrition on Growth, Yield Attributes and Yield of Sweet Potato

3.1.1 Effect of foliar nutrition on vine length and dry matter production (Table 1a)

Among the foliar nutrition management treatments, f_1 produced the higher vine length (69.66 cm) and 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 crop harvest, f_1 showed significantly higher vine length (128.69 cm), number of branches (3.18) and was comparable to f_2 and f_3. At 30 DAP significant higher production of dry matter was observed in f_2 (12.90 g plant^{-1}) which were on par with f_1 (12.79 g plant^{-1}) and f_3 (12.65 g plant^{-1}).

Treatment f_3 and f_1 demonstrated enhanced vine length (Fig. 1), branch number, and dry matter production compared to other treatments. This improvement is attributed to their additional application of urea and a micronutrient mixture via foliar spray. The synergy between urea and micronutrients, such as iron and manganese, contributes to better nitrogen utilization, thus promoting growth and yield [14] emphasised the significance of nitrogen application in increasing vine length and branch number [12] and [15] also support the notion that higher nitrogen application levels significantly enhance fresh herbage, biomass, and dry matter yield.

3.1.2 Effect of foliar nutrition on leaf area, leaf area index (Table 1a)

At 45 DAP and at harvesting stage, 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).

At 30 and 45 DAP (f_3) resulted in larger leaf area per plant (360.91 cm^2, 969.46 cm^2 respectively) and was comparable to f_1 (353.57 cm^2, 931.24 cm^2 respectively) and f_2 (349.51 cm^2, 928.90 cm^2 respectively). During the harvest stage, f_3 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.

Leaf area and leaf area index were higher with f_3 and was on par with f_1. 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. [14] concluded that nitrogen application up to 62.5 kg ha^{-1} increased leaf area index.

3.1.3 Effect of foliar nutrition on tuber girth, length, tuber bulking rate (Table 2a)

Among the foliar nutrition, the yield attributes like the number of tubers per plant (4.34), tuber length (15.22 cm) and girth (13.93 cm) were significantly higher with f_3.

At 30-45 DAP stage showed higher tuber bulking rate for f_3 (1.89 kg^{-1} ha^{-1} d^{-1}) and was comparable with f_2 (1.53 kg^{-1} ha^{-1} d^{-1}). At 45 DAP- harvest stage the highest tuber bulking rate was with f_3 (3.40 kg^{-1} ha^{-1} d^{-1}).

Table 1a. Effect of foliar nutrition on growth attributes of sweet potato

Treatments	Vine length (cm)			Number of branches			Leaf area plant $^{-1}$ (cm^2)			Leaf area index			Dry matter production g plant^{-1}		
	30 DAP	45 DAP	At harvest	30 DAP	45 DAP	At harvest	30 DAP	45 DAP	At harvest	30 DAP	45 DAP	At harvest	30 DAP	45 DAP	At harvest
f_1	69.66	102.91	128.69	1.94	3.02	3.37	353.57	931.24	843.47	3.17	3.81	4.63	12.79	19.96	34.29
f_2	64.38	103.43	128.22	1.93	2.88	3.43	349.51	928.90	841.46	3.11	3.16	4.26	12.90	20.06	33.13
f_3	68.56	98.42	124.71	1.95	3.42	4.17	360.91	969.46	907.05	3.48	5.10	5.73	12.65	21.26	34.79
f_4	58.48	92.50	113.02	1.39	2.42	2.98	334.26	817.45	721.146	2.58	3.09	4.09	10.94	18.44	28.01
SE (m) ±	2.011	2.365	3.873	0.100	0.109	0.083	5.931	15.452	16.838	0.205	0.162	0.127	0.434	0.673	0.673
CD (0.05)	5.936	6.982	11.431	0.294	0.320	0.245	17.516	45.594	49.703	NS	0.479	0.374	1.281	1.987	1.985

(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)

Table 1b. Effect of vine top harvesting time on growth attributes of sweet potato

Treatments	Vine length (cm)			Number of branches			Leaf area plant $^{-1}$ (cm^2)			Leaf area index			Dry matter production g plant^{-1}		
	30 DAP	45 DAP	At harvest	30 DAP	45 DAP	At harvest	30 DAP	45 DAP	At harvest	30 DAP	45 DAP	At harvest	30 DAP	45 DAP	At harvest
h_1	65.77	100.13	123.98	1.83	3.18	3.68	350.94	912.94	839.97	3.10	3.97	4.80	11.82	19.28	33.89
h_2	66.34	101.08	125.57	1.89	3.05	3.78	352.27	963.67	867.03	3.22	3.99	4.82	13.09	20.25	33.11
h_3	63.69	96.73	121.43	1.69	2.58	2.99	345.47	866.18	777.84	2.94	3.40	4.41	12.05	19.52	30.67
SE (m) ±	1.742	2.049	3.354	0.086	0.094	0.072	5.139	13.38	14.582	0.178	0.141	0.110	0.376	0.583	0.582
CD (0.05)	NS	NS	NS	NS	0.277	0.212	NS	39.486	43.044	NS	0.415	0.324	NS	NS	1.719

(h_1: 30 DAP, h_2: 45 DAP, h_3: control - no leaf harvest)

Table 2a. Effect of foliar nutrition on yield attributes and yields of sweet potato

Treatments	No. of tubers plant^{-1}	Tuber length, (cm)	Tuber Girth, (cm)	Tuber bulking rate, kg ha^{-1} d^{-1}			Vine top yield (kg ha^{-1})	Tuber yield (t ha^{-1})	marketable tuber yield (t ha^{-1})	vine yield at harvest (t ha^{-1})
				15-30 DAP	30-45 DAP	45 DAP – harvest				
f_1	3.13	11.29	11.58	0.24	1.46	2.43	1051.7	19.02	13.38	32.21
f_2	3.14	11.42	11.27	0.25	1.53	2.56	944.0	19.19	13.80	32.51
f_3	4.34	15.22	13.93	0.26	1.89	3.41	1178.8	21.48	17.28	36.27
f_4	2.35	9.03	9.94	0.23	1.26	1.97	853.5	17.33	11.22	30.50
SE (m) ±	0.104	0.356	0.390	0.010	0.132	0.126	15.58	0.161	0.383	0.480
CD (0.05)	0.308	1.050	1.150	NS	0.391	0.371	47.728	0.474	1.131	1.416

(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)

Table 2b. Effect of vine top harvesting time on yield attributes and yields of sweet potato

Treatments	No. of tubers plant^{-1}	Tuber length, (cm)	Tuber Girth, (cm)	Tuber bulking rate, kg ha^{-1} d^{-1}			Vine top yield (kg ha^{-1})	Tuber yield (t ha^{-1})	marketable tuber yield (t ha^{-1})	vine yield at harvest (t ha^{-1})
				15-30 DAP	30-45 DAP	45 DAP – harvest				
h_1	3.36	11.93	12.07	0.23	1.56	2.48	998.3	19.46	13.92	33.86
h_2	3.53	12.48	12.60	0.25	1.71	3.01	1015.7	19.66	15.20	34.11
h_3	2.84	10.81	10.37	0.25	1.35	2.29	0	18.65	12.64	30.67
SE (m) ±	0.090	0.308	0.337	0.009	0.115	0.109	11.020	0.139	0.332	0.415
CD (0.05)	0.267	0.910	0.996	NS	NS	0.322	NS	0.411	0.979	1.226

(h_1: 30 DAP, h_2: 45 DAP, h_3: control - no leaf harvest)

Picture 1. Foliar spraying of urea and micronutrients

Picture 2. Vine top harvesting at 30 DAP

Picture 3. Vine top harvesting at 45 DAP

The application of urea at 2% at 20 days after planting (DAP) followed by a multi-micronutrient mixture at 0.5% at 35 DAP resulted in the highest number of tubers per plant. This can be attributed to urea's role in boosting plant photosynthesis by providing nitrogen, which generates more carbohydrates for underground tuber growth. Additionally, micronutrients like zinc, iron, manganese, and boron are vital for plant physiological functions, and their foliar application ensures easy access, promoting healthy tuber formation [16] also found that micronutrient treatments increased the number of storage roots.

Tuber length and girth were highest in treatment f_3 (Fig. 2), likely due to urea's provision of readily available nitrogen, crucial for tuber development. Micronutrients like boron, zinc, and manganese play essential roles in various physiological processes necessary for tuber enlargement, aligning with the findings of Saif El-Deen et al. [12] and [17].

Tuber bulking rate was the highest with f_3. 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.

3.1.4 Effect of foliar nutrition on tuber yield, marketable tuber yield, vine top yield and vine yield (Table 2a)

Significantly higher vine top yield (1178.8 kg ha^{-1}), tuber yield (21.48 t ha^{-1}), marketable tuber yield (17.28 t ha^{-1}) and vine yield (36.27 t ha^{-1}) and were observed with f_3 while f_4 registered lowest.

Marketable tuber yield was the highest with (f_3). While foliar spraying primarily targets above-ground plant parts, some nutrients may also be translocate 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. The studies of Hartemink et al. [18] and [12] 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.

The highest vine top yield (Fig. 3), vine yield and tuber yield (Fig. 4) were observed in treatment f_3, which involved the application of urea at 2% concentration at 20 days after planting, followed by a multi-micronutrient mixture at 0.5% at 35 days after planting. This outcome may be attributed to urea's provision of readily available nitrogen, a crucial nutrient for plant growth. Nitrogen is essential for chlorophyll synthesis, facilitating photosynthesis and overall plant vigour, ultimately leading to increased biomass production. Foliar spraying of nitrogen can enhance vegetative growth, promoting greater vine development and ultimately higher vine yield. Micronutrients also play vital roles as enzyme cofactors in nutrient uptake and utilization. Consistent with our findings, [19] observed a significant increase in vine fresh weight with the foliar application of a microelement mixture. These results are supported by previous studies by Hassan et al. [13,20].

3.2 Effect of Time of Vine Top Harvesting on Growth, Yield Attributes and Yield of Sweet Potato

3.2.1 Effect of time of vine top harvesting on vine length and dry matter production (Table 1b)

It was observed that the time of vine top harvesting had no significant influence on plant height and dry matter production. Significantly more number of branches were observed in h_1 (3.18) and was comparable to h_2 (3.05) on 45 DAP. A substantially higher number of branches were seen during harvest by h_2 (3.78), which were comparable with h_1 (3.68).

During the vine top harvesting phase at 30 days after planting (DAP), there was a notable increase in the number of branches at 45 DAP compared to other harvest times. This rise in branch numbers is likely attributable to the removal of apical dominance, which stimulates the growth of dormant buds, resulting in the emergence of additional branches. Additionally, this method of harvesting promoted higher levels of dry matter production at the harvest stage. This increase in dry matter can be attributed to the plant reallocating its energy towards root development rather than vine growth, leading to the establishment of more extensive root systems capable of enhanced nutrient and water absorption, consequently supporting increased dry matter production. These findings are in line with previous research by Suminarti and Novriani

[21] on defoliation's effects, as well as Krishanveni et al. [22] observations on the positive impact of leaf pinching on dry matter production.

3.2.2 Effect of time of vine top harvesting on leaf area, leaf area index (Table 1b)

The largest leaf area per plant was found in treatment h_2 (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 (839.97 cm^2). Lowest leaf area was registered with control (h_3). The treatment h_2 showed higher leaf area index (3.99 and 4.82 respectively at 45 DAP and at harvest) which was comparable with h_1 (3.97 and 4.80 respectively) at 45 DAP and harvesting stages. At harvesting stage higher dry matter production per plant was found in treatment h_1 (33.89 g $plant^{-1}$) which was on par with h_2 (33.11 g $plant^{-1}$).

Significant higher number of branches were observed in h_1 (3.18) was comparable to h_2 on 45 DAP. The observation during harvest indicated h_2 (3.78) registered significantly higher number of branches which was on par with h_1 (3.68).

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). 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 more lateral branches, and number of leaves after the cutting of vines.

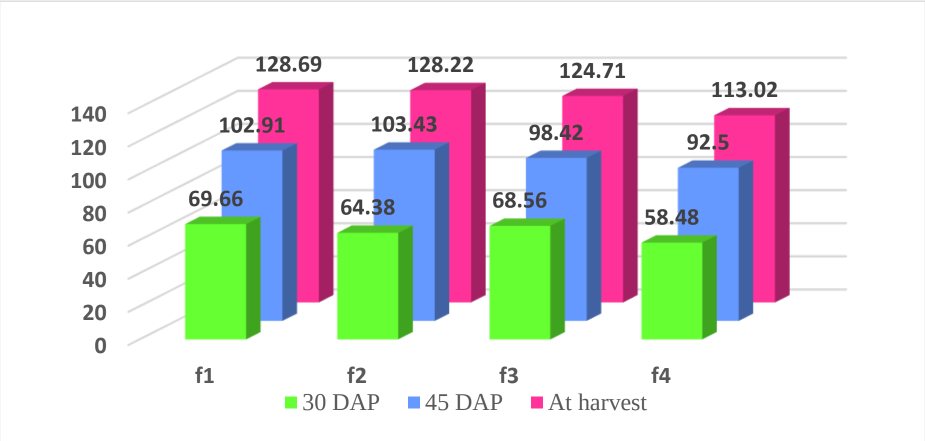

Fig. 1. Effect of foliar nutrition on vine length

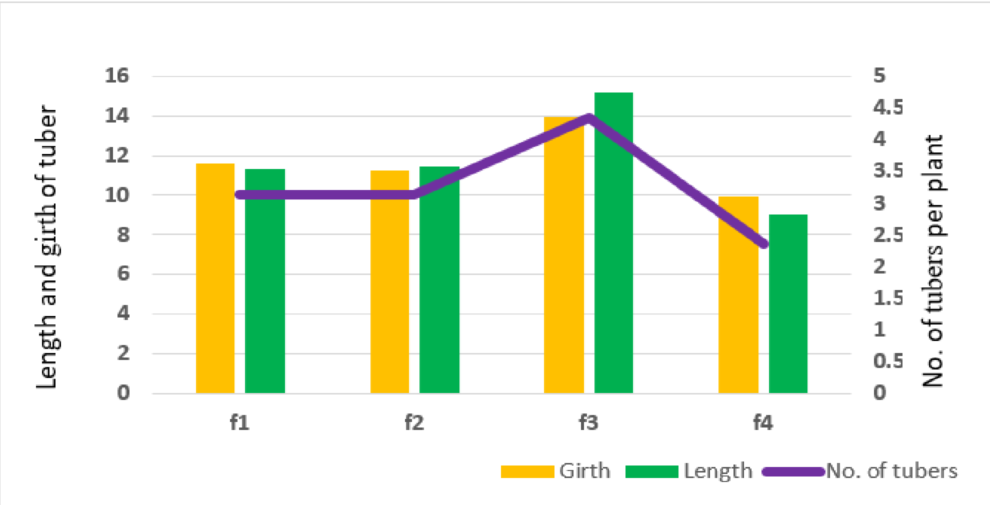

Fig. 2. Effect of foliar nutrition on number of tubers, length and girth of tuber

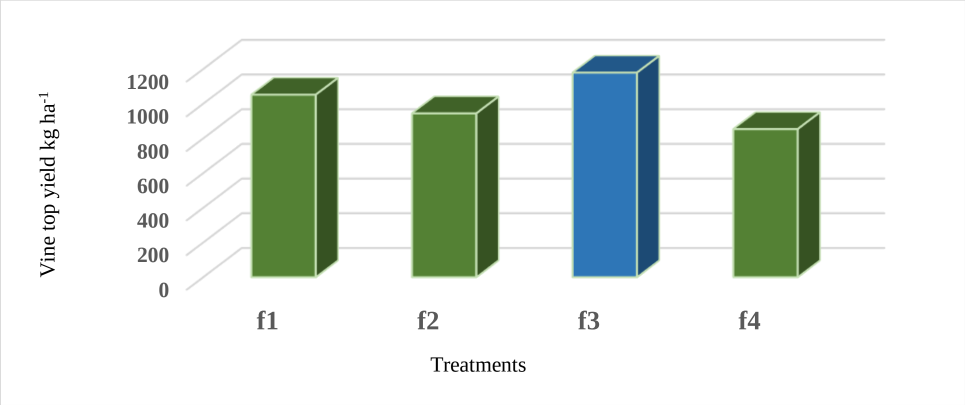

Fig. 3. Effect of Foliar nutrition management on vine top yield

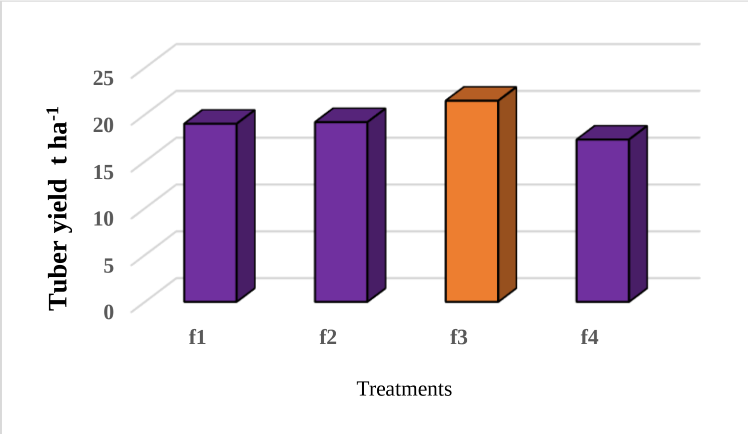

Fig. 4. Effect of Foliar nutrition management on tuber yield

3.2.3 Effect of time of vine top harvesting on tuber girth, length, tuber bulking rate (Table 2b)

Among time of vine top harvesting, h_2 observed significantly higher number of tubers per plant (3.53), tuber length (12.48 cm) and girth (12.60 cm). Significantly the highest vine top yield of sweet potato was observed with foliar application of (f_3) (1178.8 kg ha^{-1}). Significant higher tuber yield (19.66 t ha^{-1}) was obtained by (h_2) and it was on par with the yield of h_1 (19.46 t ha^{-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 kg^{-1} ha^{-1} d^{-1}) it was on par with the vine top harvesting at 30 DAP *i.e.*, h_1 (2.69 kg^{-1} ha^{-1} d^{-1}).

Treatment h_2, involving vine top harvesting at 45 days after planting (DAP), resulted in a higher tuber count compared to other treatments (Fig. 5) This increase in tuber numbers may be attributed to the timely vine top harvesting, which likely stimulated more nodes along the remaining vines, potentially enhancing tuber production per plant. Furthermore, treatment h_2 also yielded the longest and thickest tubers, on par with results observed with h1, where vine top harvesting occurred at 30 DAP. The augmentation in tuber size could be ascribed to the additional assimilates generated through improved photosynthesis. These extra resources likely bolstered tuber growth and enlargement, leading to increased length and girth. Similarly, [23] documented significant effects on storage root length, diameter, and vine weight based on cutting position and pruning levels, corroborating the notion that strategic vine top harvesting and pruning methods can influence tuber attributes and overall plant development.

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.

3.2.4 Effect of time of vine top harvesting on tuber yield, marketable tuber yield, vine top yield and vine yield (Table 2b)

Significantly higher marketable tuber yield (15.20 t ha^{-1}) was obtained by leaf harvesting time at 45 DAP (h_2). 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 highest vine yield observed in treatment h_1 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.

Marketable tuber yield was highest with h_2 (vine top harvesting at 45 DAP). 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.

The tuber yield was greater with h_2 (vine top harvesting at 45 DAP) (Fig. 6). This increase in tuber yield can be attributed to the redirection of the plant's energy towards root development, including the formation of tubers. A robust root system, fostered by vine top harvesting, can facilitate enhanced tuber growth and yield by improving nutrient and water absorption. The results of Abewoy et al. [24] also align with our findings, indicating that sweet potato plants subjected to 50 percent vine pruning exhibited the highest root yield. This further supports the notion that strategic vine management practices, such as vine top harvesting and pruning, can significantly influence tuber yield in sweet potato cultivation [25-27].

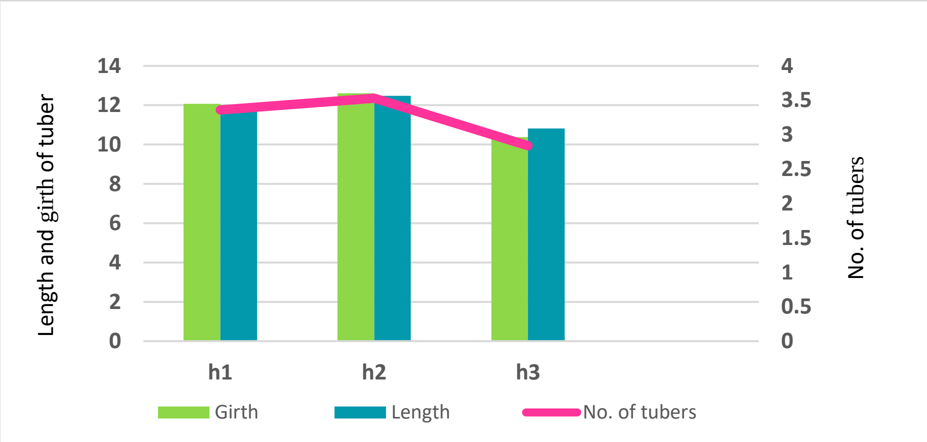

Fig. 5. Effect of vine top harvesting on number of tubers, length and girth of tuber

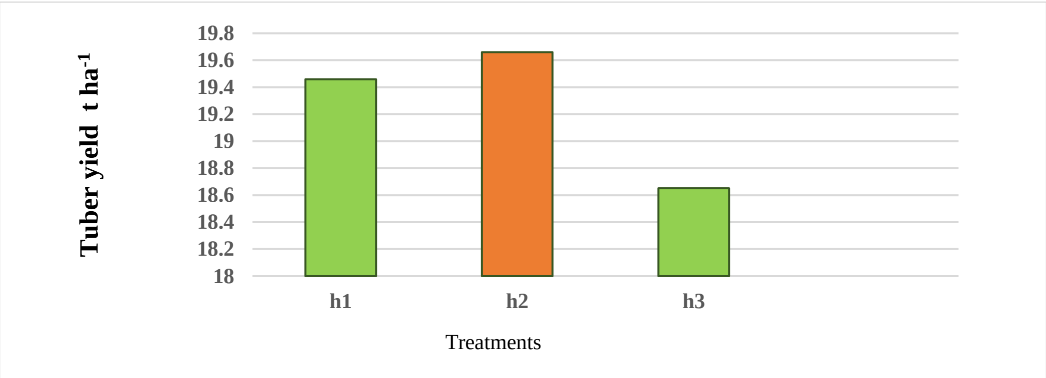

Fig. 6. Effect of vine top harvesting on tuber yield

4. CONCLUSION

Foliar application of urea 2% at 20 DAP followed by multi micronutrient 0.5% spray at 35 DAP recorded highest growth, yield attributes, vine top and tuber yield. The study established that vine top harvesting at 30 DAP or at 45 DAP enhanced growth, yield attributes and yield in sweet potato.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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