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Seasonal Changes in Photosynthate Partitioning in High Yielding Sweet Potato Varieties under Varied K Nutrition Levels

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Abstract

Background: Potassium is a major nutrient needed by the crops including tuber crops. It is essential for tuber initiation and bulking process. Varietal differences in potassium uptake and utilization in many crops were reported. As many varieties of sweet potato are released so far, studies on understanding the variations in potassium accumulation and its influence on tuber yield are essential.

Methods: Field experiments were conducted during *kharif* and *rabi* seasons, 2021with an objective to assess the seasonal influence and potassium nutrition [0 kg K_2O/ha (K_1), 50 kg K_2O/ha (K_2), 75 kg K_2O/ha (K_3) and 100 kg K_2O/ha (K_4)] on growth and tuber yield of five sweet potato varieties - four high yielding varieties (HYV) and one local variety [Bhu Krishna (V_1), Sree Arun (V_2), Sree Bhadra (V_3), Bhu Sona (V_4) and Kanjanghad Local (V_5)]. There were 20 treatment combinations replicated thrice in a randomized block design.

Result: Significantly higher tuber yield (17.01 t/ha) during *kharif* season was recorded by variety Bhu Sona. But during *rabi* season, Sree Arun was superior with a tuber yield of 23.92 t/ha. The potassium nutrition up to 75 kg K_2O/ha increased the yield of sweet potato in *rabi* season. Interaction effect of two factors was also significant with respect to tuber yield, total chlorophyll content and tuber K content. Potassium Harvest Index (%) and Potassium Accumulation Value (g/plant) also significantly varied between varieties and K levels.

Key words: Dry matter, Potassium, Sweet potato, Tuber, Varieties, Yield.

Introduction

Tuber crops have important role in food security as these crops meet local food preferences and also provide more edible energy per hectare per day compared to any other crops. Among tuber crops, sweet potato (*Ipomoea batatas* L.) is important due to short growth period together with high tuber yield and is considered as an excellent source of natural health promoting compounds, such as β carotene and anthocyanins, for the functional food market (Mohanraj and Sivasankar 2014). It also has alternative uses as a forage crop and raw material in starch industry. It is regarded as the 7th most important food crop in the world (FAO, 2009) and considered to be a 'famine relief crop' (Mukhopadhyay *et al*., 2011).

Potassium has a major role in carbohydrate metabolism and source to sink photosynthate partitioning and thus is crucial in deciding yield and quality. It influences plant growth in terms of canopy development, photosynthetic assimilation, loading and unloading activities and thereby overall efficiency of plants (Sardans and Peñuelas, 2021). Potassium uptake can vary with crop, soil and plant nutrient content, soil factors, interaction with other nutrients as well as environmental factors. Potassium absorption capacity of crops varies with species and also intraspecific variation can also be noticed among different varieties of a same crop (Dong Wang *et al*., 2015). Not only uptake of a particular nutrient, its assimilation and utilization by the plant for its growth, development and differentiation is also significant. Several K^+ channels/transporters are present that controls the signalling, interactions and transportation of ions within plant (Sardans and Peñuelas, 2021). The quantity of potassium present in soil as well its form is important in determining uptake by the plants. Therefore, care should be taken to look at the potassium status of soil (deficient/ sufficient) while recommending K level.

Yield and quality of tubers are influenced by many factors like varietal characteristics, soil fertility, management practices and weather parameters. Among this, ample supply of nutrients especially potassium has prime importance.

Genotypic differences in K uptake and utilization is reported in many crops. Genotypes which can grow and yield well in soils low in available K are potassium efficient. Tuber crops have a high requirement for potassium compared with cereals, as the content of potassium in the harvested roots is high (Singh *et al*. 2020). There is still

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finite data on growth and potassium assimilation in sweet potato in response to varying potassium supply levels over time and the computation of such characteristics is necessary to screen for K efficient varieties (Rengel and Damon, 2008). Hence a study on response of different varieties of sweet potato to varied doses of potassium was planned to generate information on varietal variation in requirement of added K fertilizer.

MATERIALS AND METHODS

Two field experiments were conducted during *kharif* and *rabi* seasons at the Agronomy Farm, Department of Agronomy, College of Agriculture, Vellanikkara, Thrissur, Kerala during 2021-22. The field is situated at 13° 32′N latitude and 76° 26′E longitude, at an altitude of 40 m above mean sea level. The soil of the experimental site was sandy clay loam, acidic in reaction with a pH of 4.82 and electrical conductivity of 0.083 dSm^{-1}. The available nitrogen, phosphorus and potassium content of soil were 163 kg ha^{-1}, 83 kg ha^{-1} and 100 kg ha^{-1} (low K), respectively. The crop received 2303 mm total rainfall during *kharif* season and 454 mm total rainfall during *rabi* season and the temperature varies from 22.5°C to 32.8°C and 21°C to 35°C during *kharif* and *rabi* seasons, respectively. Weather conditions during the growing period are depicted in Fig 1.

The first field experiment was conducted during July-November, 2021 (*kharif* season) and second, during October, 2021 to February, 2022 (*rabi* season). Treatment combinations included five varieties of sweet potato and four potassium levels in a factorial randomized block design with 20 treatment combinations and three replications. The plot size was 4.5 m × 4.5 m and three vine cuttings were planted on mounds at a spacing of 75 cm × 75 cm. Varieties used were Bhu Krishna (V_1), Sree Arun (V_2), Sree Bhadra (V_3), Bhu Sona (V_4) and Kanjanghad Local (V_5). Four potassium levels studied were 0 (K_1), 50 (K_2), 75 (K_3) and 100 kg K_2O/ha (K_4). Bhu Sona and Bhu Krishna are the varieties developed by the Regional centre, ICAR-Central Tuber Crops Research Institute (ICAR-CTCRI), Bhubaneswar, Odisha and are rich in β-carotene and anthocyanin, respectively. Sree Arun and Sree Bhadra are the varieties released from ICAR-CTCRI, Sreekaryam, Thiruvananthapuram, Kerala. Kanjanghad Local is a selection from local type grown in North Kerala released from Kerala Agricultural University which is comparatively having longer duration of days compared to other varieties.

N and P_2O_5 were applied @ 75 kg/ha and 50 kg/ha (as per Package of Practices recommendations by Kerala Agricultural University) uniformly for all treatments. Half of the nitrogen dose and full P and K were applied as basal and remaining half N was applied at four weeks after planting. Farmyard manure was applied @ 10 t/ha and lime @600 kg/ha, which were applied basally at the time of land preparation.

Chlorophyll content (mg/g) of leaves were analysed at 60 DAP by DMSO method (Dimethylsulfoxide method). Nutrient status of index leaf (lamina of the seventh to ninth youngest leaves from the tip of vine) was assessed at active growth phase. Tuber yield was recorded at harvest. Potassium Accumulation Value (KAV) and Potassium Harvest Index (KHI) were calculated using dry matter and K content (Dong Wang *et al*., 2015).

Potassium accumulation value (g/plant)

$$\text{KAV of tuber} = \text{Dry matter (g/plant)} \times \text{K content (\%)}$$

Potassium harvest index (%)

$$\text{KHI= KAV in tuber/plant KAV}$$

The data collected were subjected to analysis of variance and computed statistically by utilizing statistical package of KAU GRAPES (General R-shiny based Analysis Platform Empowered by Statistics) developed by Kerala Agricultural University (Gopinath *et al*., 2020).

RESULTS AND DISCUSSION

Data showed genetic differences in nutrient uptake and K accumulation among sweet potato varieties. Generally, application of potassium fertilizer increased the yield of sweet potato. But, being a photosensitive crop, weather parameters have a significant role in tuberization of sweet potato. Sunny days and cool nights are favourable for better tuber development. Therefore, while comparing weather data (Fig 1) during these seasons, performance of sweet potato was very poor during *kharif* season due to excess rainfall. In *kharif* season, total sunshine hours obtained was 47 per cent less than sunshine hours in *rabi* season. Continuous rainfall had been there from planting to harvesting and this had a huge impact on the tuberization in these varieties. This incessant rainfall on *kharif* season led to vigorous vegetative growth at the expense of tuberization, photosynthates were more utilized for canopy development and very less share was allocated for tuber development (Fig 4). All varieties of sweet potato performed better during *rabi* due to favourable weather conditions. More sunshine hours were received during this season especially at tuber initiation and bulking stages which favoured yield of marketable tubers. Influence of different seasons on sweet potato tuberization and yield performance based on their varietal characteristics was reported by Nedunchezhiyan and Byju (2005). The differences in varietal performances under same soil and weather parameters indicate the differences in their edaphic requirements for growth and tuberization.

Total chlorophyll content in the sweet potato leaf also varied with varieties and potassium levels. There was visual difference in greenness among varieties included in the study and leaf colour varied from light green to dark green. Among the varieties, Sree Bhadra had recorded significantly higher total chlorophyll content in both seasons (1.50 mg/g and 1.14 mg/g fresh weight, respectively for *kharif* and *rabi* seasons). Total chlorophyll content varied with different potassium levels also and significantly higher chlorophyll content was recorded for 75 kg K_2O/ha (1.33 mg/g and 1.20 mg/g fresh weight, respectively for *kharif* and *rabi* seasons), which was on par with 50 kg K_2O in *kharif* season (1.35 mg/g fresh weight). Interaction between varieties and potassium levels was significant (*kharif* season) (Fig 2) and variety Sree Bhadra recorded significantly higher total chlorophyll for 50 kg (1.72 mg/g fresh weight) and 75 kg (1.71 mg/g fresh weight) potassium. Varieties used in study showed different shades of green because of different amounts of chlorophyll in their leaves as well as other pigments like anthocyanin. Sree Bhadra had more chlorophyll content irrespective of seasons and had comparatively darker leaves than other varieties. Chlorophyll content was more in rainy season than *rabi*. This was mainly due to lower sunshine hours and more moisture availability during the growing period (Li *et al*., 2018). This increase in chlorophyll content increases the amount of light absorbed by the leaves, which in turn increases the rate of photosynthesis. This resulted in more contribution of photosynthate to vegetative production and contribution of total dry matter to tuber bulking was less in *kharif* season (Fig 4). The chlorophyll content had also improved with addition of potassium fertilizer and it had a positive impact on photosynthate production especially in *rabi* season. Importance of potassium nutrition for more chlorophyll production and assimilates partitioning is documented by Liu *et al*. (2017).

Varieties varied significantly with respect to potassium content in the index leaf (Table 1 and Fig 3) indicating differential response to available K and its utilization for plant development. The highest potassium content of index leaf in variety Bhu Sona (5.71%) which was comparable with Bhu Krishna (5.29%) and Sree Arun (5.20%) during *kharif* season. While during *rabi* season, significantly higher potassium content was noticed for Sree Arun (5.16%) which was comparable with Bhu Sona (5.01%). In General, potassium content of the index leaf increased with increase in K level up to 75 kg per ha but decrease at 100 kg per ha. This was also depending on varietal characters as in some varieties K content in the index leaf was more at 100 kg/ha potassium level. K content was 5.65 per cent and 5.51 per cent, respectively for 50 kg and 75 kg K_2O per ha during *kharif* and for *rabi*, it was significantly higher for 75 kg K_2O per ha (5.42 %). The interaction between varieties and K levels was significant during *rabi* season (Fig 3). Significantly higher value was recorded for the variety Sree Arun with 75 kg K_2O (V_2K_3) (5.85 %) which was comparable with variety Bhu Sona having 75 kg K_2O (V_4K_3) (5.78 %) and variety Sree Arun having 100 kg K_2O (V_2K_4) (5.54 %).

Significant variation in tuber yield could be observed among varieties with K levels (Table 2). The varietal performances were greatly influenced by seasons also. Bhu Sona was the superior variety and recorded significantly higher tuber yield per ha (17.01 t/ha) during *kharif* season. But during *rabi* season, significantly higher yield was for the

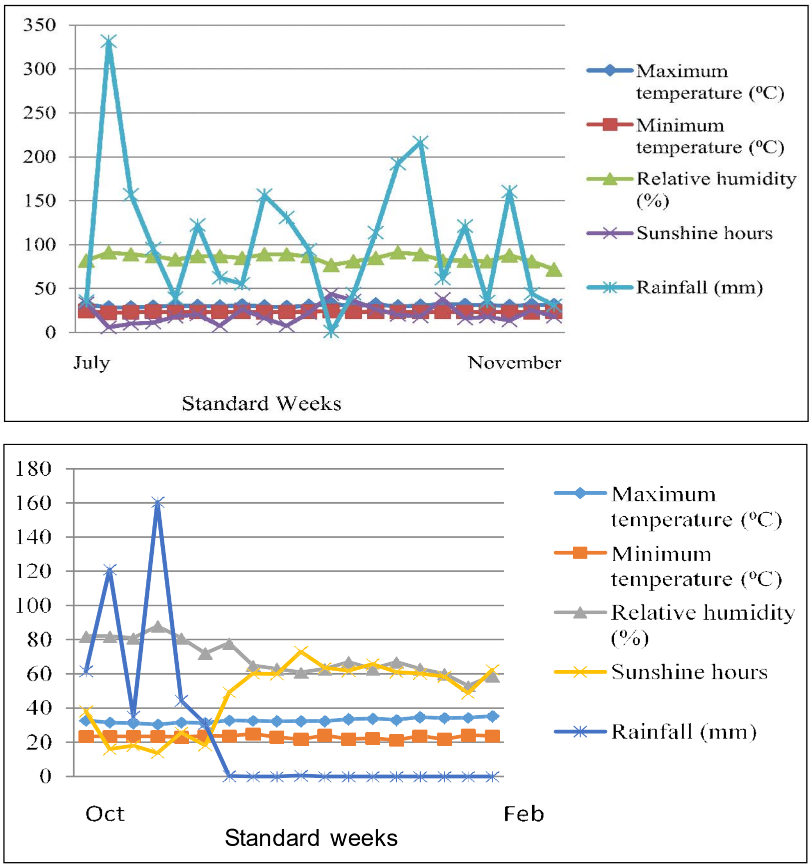

Fig 1: Weather data during *kharif* and *rabi* seasons (2021-2022).

variety Sree Arun with tuber yield of 23.92 t/ha. Performance of Kanjanghad Local was inferior in both seasons. Significantly higher yield was recorded for 50 kg and 75 kg K_2O/ha compared to higher dose (100 kg K_2O/ha). The potassium application increased the yield of sweet potato only up to 75 kg K_2O/ha. Similarly, influence of potassium on tuber yield and yield components of potato crop was reported by Turamyenyirijuru *et al.* (2019).

The percentage of dry matter contributed from total dry matter is important in determining tuber bulking (Fig 4). While considering the per cent value in both seasons, more dry matter partitioning to tuber was during *rabi* season and for the variety Sree Arun, variety Bhu Krishna and variety Sree Bhadra, about 63-65 per cent of total dry matter contributed for tuber bulking when potassium was applied at 50 kg and 75 kg per ha. While during *kharif* season, more partitioning

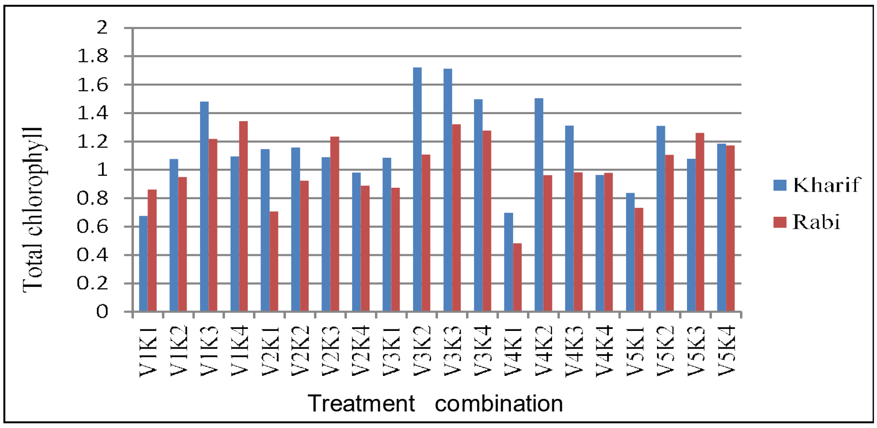

Fig 2: Influence of varied K levels on leaf chlorophyll content of sweet potato varieties.

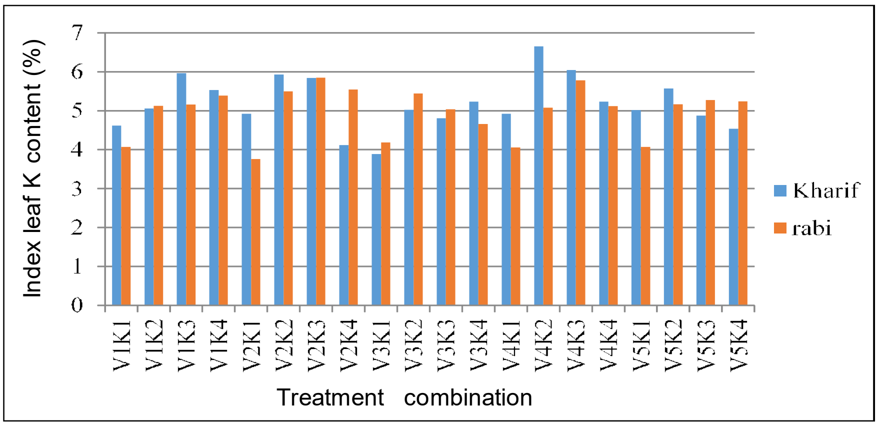

Fig 3: Influence of different levels of K on index leaf potassium content of sweet potato varieties.

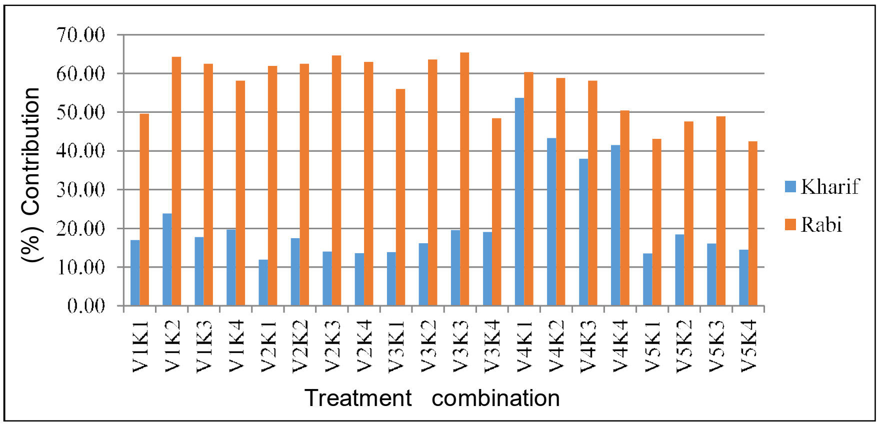

Fig 4: Percentage contribution of total dry matter to tuber dry matter production.

of dry matter from whole plant to tuber was recorded for Bhu Sona at lower potassium level (50-55 %) and contribution was very less for other varieties at different potassium levels.

KAV (Fig 5) was significantly higher for the variety, Bhu Sona during *kharif* and Sree Arun during *rabi* season. Similarly, KHI (Fig 6) was higher for Bhu Sona during *kharif* which was significantly higher than other varieties. During *rabi*, Sree Arun recorded significantly higher KHI compared to other varieties.

The K absorption is more during active growth phase and the rate of absorption during this stage influences how assimilate can be effectively translocated from source to sink and tuber bulking (Dong Wang *et al*., 2015). But varietal influence was more pronounced in sweet potato and there were differences in the potassium content at active growth phase as well at harvest stage. It can be inferred that there were differences in effective translocation from source to sink for tuber initiation and bulking as some varieties like Bhu Sona performed well under low potassium levels. This might be due to effectively utilizing available potassium content in the soil as well as effective loading and unloading the assimilates from vegetative to economic parts. Eventhough the leaves of this variety were lighter in colour than other varieties, this had relatively more chlorophyll pigment during rainy season which might have improved photosynthesis and thus improved KAV and KHI values in comparison with other varieties. Varieties which require low concentration of certain nutrients and a higher photosynthetic rate are the most economical since they require quantity of less mineral fertilizer for higher yields (Xia *et al*., 2011). It can be inferred that, while in *rabi* season, Sree Arun had significantly higher tuber K content and KAV and KHI were also significantly higher for this variety under different potassium levels. This shows that variety Sree Arun was effective in translocating nutrients from shoot to root for tuber initiation and bulking. Potassium nutrition is also very important in all crops especially tuber crops for the uptake and utilization of other nutrients for the accomplishment of metabolic activities in these plants and

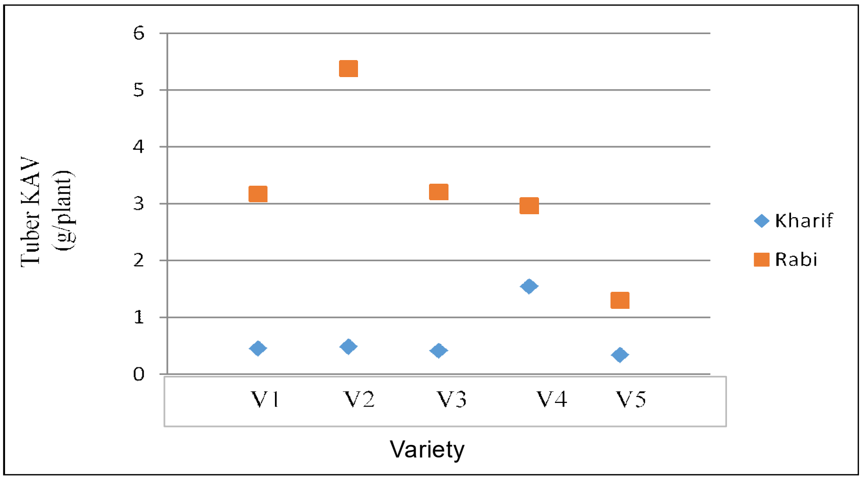

Fig 5: Tuber K accumulation value of sweet potato varieties during *kharif* and *rabi*.

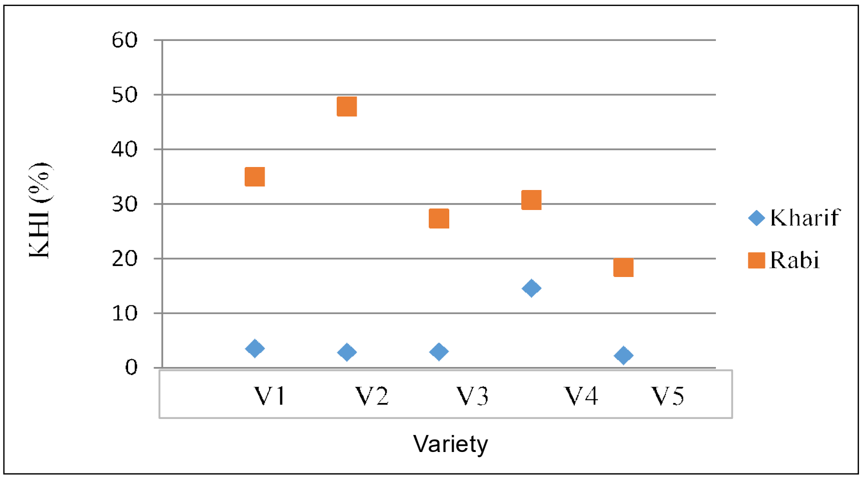

Fig 6: K harvest index of sweet potato varieties during *kharif* and *rabi* .

Table 1: Potassium content of the index leaf and leaf chlorophyll content of sweet potato varieties.

Treatments	K content (%) on index leaf		Total chlorophyll content (mg/g fresh weight)	
	kharif	*rabi*	*kharif*	*rabi*
Variety (V)				
V_1-Bhu Krishna	5.29^{ab}	4.93^{bc}	1.08^{b}	1.09^{ab}
V_2-Sree Arun	5.20^{abc}	5.16^{a}	1.09^{b}	0.94^{bc}
V_3-Sree Bhadra	4.74^{c}	4.83^{c}	1.50^{a}	1.14^{a}
V_4-Bhu Sona	5.71^{a}	5.01^{ab}	1.12^{b}	0.85^{c}
V_5-Kanjanghad local	5.00^{bc}	4.93^{bc}	1.11^{b}	1.07^{ab}
SEm	0.19	0.06	0.06	0.07
CD (0.05)	0.55	0.17	0.17	0.19
K levels (K)				
K_1- 0 kg/ha	4.67^{b}	4.02^{c}	0.88^{c}	0.73^{c}
K_2-50 kg/ha	5.65^{a}	5.26^{b}	1.35^{a}	1.01^{b}
K_3-75 kg/ha	5.51^{a}	5.42^{a}	1.33^{a}	1.20^{a}
K_4-100 kg/ha	4.93^{b}	5.18^{b}	1.14^{b}	1.13^{ab}
SEm	0.17	0.05	0.05	0.06
CD (0.05)	0.49	0.16	0.15	0.17

Table 2: Tuber yield/ha of different sweet potato varieties (V_1 to V_5) at varied K levels (K_1 to K_4).

Treatments	Tuber yield per ha (t/ha)	
	kharif	*rabi*
Variety (V)		
V_1-Bhu Krishna	6.32^{b}	16.71^{bc}
V_2-Sree Arun	5.77^{b}	23.92^{a}
V_3-Sree Bhadra	6.74^{b}	17.95^{b}
V_4-Bhu Sona	17.01^{a}	16.08^{c}
V_5-Kanjanghad local	6.04^{b}	10.40^{d}
SEm	0.40	0.61
CD (0.05)	1.15	1.75
K levels (K)		
K_1-0 kg/ha	8.19^{bc}	13.48^{c}
K_2-50 kg/ha	9.53^{a}	19.11^{a}
K_3-75 kg/ha	8.55^{ab}	20.17^{a}
K_4-100 kg/ha	7.23^{c}	15.28^{b}
SEm	0.36	0.54
CD (0.05)	1.03	1.56

Treatments with same letters are not significantly different.

hence influences dry matter and tuber yield. This response can vary with varieties (Ali *et al*., 2021; Senanayake *et al*., 2022). Tuber yield was more for Bhu Sona during *kharif* probably because of its efficiency in utilizing all available soil K. The performance of other varieties was poor during this season and did not achieve potential yield at any potassium levels. But, the yield of all varieties was higher during *rabi* season except Kanjanghad Local. The tuber yield increased with increase in potassium dose up to 75 kg, however it was comparable to 50 kg potassium. Xia *et al*. (2011) also proposed that varietal differences could influence the capacity to produce high economic yield per unit potassium.

CONCLUSION

The performance of sweet potato varieties is highly influenced by the weather parameters as well as by the nutrient status in the soil. The tuber yield is highly related with genetic makeup of the varieties which influence the efficiency of utilization of available nutrients even in soils of low fertility.

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Conflict of interest: None.

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