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Deepali V Kadam
Ph.D., Scholar, Department of Soil Science and Agricultural Chemistry, College of Agriculture, Dr. B S K K V, Dapoli, Ratnagiri, Maharashtra, India

Dr. Rajesh V Dhopavkar
Deputy Director of Research (Agri.), Dr. B. S. K. K. V., Dapoli, Ratnagiri, Maharashtra, India

Dr. MC Kasture
Head, Department of Soil Science and Agricultural Chemistry, College of Agriculture, Dr. B. S. K. K. V., Dapoli, Ratnagiri, Maharashtra, India

Dr. NH Khobragade
Assistant Professor, Department of Soil Science and Agril. Chemistry, College of Agriculture, Dapoli Ratnagiri, Maharashtra, India

Dr. Tushar J Bedse
Associate Professor, Department of Soil Science and Agril. Chemistry, College of Agriculture, Dapoli, Dr. BSKKV, Dapoli

Dr. Pradnya Gudadhe
In-charge AICRP on Tuber Crops, Central Experiment station, Wakawali. Dapoli, Ratnagiri, Maharashtra, India

Anjali Dinkar Kuwar
M.Sc. Agri, Department of Soil Science and Agriculture Chemistry, College of Agriculture, Dapoli, DBSKKV, Dapoli, Ratnagiri, Maharashtra, India

Subham R Kamble
M.Sc. Agri, Department of Soil Science and Agriculture Chemistry, College of Agriculture, Dapoli, Dr. BSKKV, Dapoli, Ratnagiri, Maharashtra, India

Corresponding Author:
Deepali V Kadam
Ph.D., Scholar, Department of Soil Science and Agricultural Chemistry, College of Agriculture, Dr. B S K K V, Dapoli, Ratnagiri, Maharashtra, India

Influence of different levels of fertilizer with biofertilizers on nutrient content and quality parameters of elephant foot yam corms [*Amorphophallus paeoniifolius* (Dennst.)] in lateritic soils of Konkan

Deepali V Kadam, Rajesh V Dhopavkar, MC Kasture, NH Khobragade, Tushar J Bedse, Pradnya Gudadhe, Anjali Dinkar Kuwar and Subham R Kamble

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Abstract

A field experiment was conducted during the *Kharif-Rabi* seasons of 2023-24 and 2024-25 at the All India Coordinated Research Project on Tuber Crops, Central Experiment Station, Wakawali, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Ratnagiri, to evaluate the effect of integrated nutrient management on elephant foot yam. The experiment was laid out in a factorial randomized block design with three replications, comprising three fertilizer levels (0%, 75%, and 100% of the recommended dose of fertilizers, RDF) and five biofertilizer treatments (no biofertilizer, *Azotobacter* + PSB, *Azotobacter*, *Azospirillum* + PSB, and *Azospirillum* + VAM). Growth observations were recorded periodically at 45, 80, 120 days after emergence (DAP) and at harvest

The study revealed that the integrated application of 100% recommended dose of fertilizers (RDF) with *Azotobacter* + PSB @ 10 kg ha⁻¹ each (F₂B₁) significantly improved soil fertility by increasing the availability of N, P, K, Fe, and Mn. The F₂B₁ treatment also recorded the maximum single corm weight, corm ring diameter, and corm volume. Application of 100% RDF alone produced the highest average corm yield (22.58 and 21.46 t ha⁻¹ during 2023-24 and 2024-25, respectively), whereas the control recorded the lowest yield (8.72 and 8.51 t ha⁻¹). Among the biofertilizer treatments, *Azotobacter* + PSB achieved the highest yields (20.89 and 20.20 t ha⁻¹), and the RDF × biofertilizer interaction significantly enhanced productivity, with yields ranging from 7.11-28.67 t ha⁻¹ in 2023-24 and 6.84-27.84 t ha⁻¹ in 2024-25.

The integrated application of 100% RDF + *Azotobacter* + PSB (F₂B₁) significantly enhanced the growth of elephant foot yam by recording the highest plant height, basal stem girth, canopy spread, total dry matter production recorded with 100% RDF (F₂) during both years. Among the biofertilizer treatments *Azotobacter* + PSB @ 10 kg ha⁻¹ each (B₁). The combine application RDF along with biofertilizers found highest with 100% RDF and *Azotobacter* + PSB (B₁), whereas lower values were observed under *Azotobacter* + VAM, *Azospirillum* + VAM, and control treatments. Therefore, integrating the recommended dose of fertilizers with *Azotobacter* + PSB is an effective, economically viable, and sustainable nutrient management strategy for elephant foot yam cultivation under Konkan lateritic soils.

Keywords: Elephant foot yam, lateritic soil, *Azotobacter*, PSB, *Azospirillum*, VAM

Introduction

Elephant foot yam (*Amorphophallus paeoniifolius* (Dennst.), syn. *A. campanulatus* (Roxb.)) is an important tropical tuber crop native to Southeast Asia and widely cultivated in India for its high yield potential, adaptability, and nutritional value. It is a popular vegetable used in several Indian cuisines and is also valued for its medicinal properties. Major producing states include West Bengal, Andhra Pradesh, Gujarat, Kerala, and Tamil Nadu, with cultivation also expanding to Maharashtra, Uttar Pradesh, and Jharkhand. The crop is often grown as an intercrop in coconut and banana plantations due to its efficient land use. In India, elephant foot yam is cultivated on about 40,000-42,100 ha, producing nearly 1.0 million tonnes annually, with an average productivity of 24.74 t ha⁻¹ (GOI, 2023; Byju & Jaganathan).

Research in the Konkan region has highlighted the importance of improved production technologies, with the variety Gajendra recording a superior yield of 26 t ha⁻¹, demonstrating its potential for enhancing productivity under diverse agro-climatic conditions (Mhaskar).

Tuber crops are the third most important food group after cereals and grain legumes, serving as a major source of energy for nearly one-fifth of the world's population. They are valuable as secondary staple foods, vegetables, and raw materials for feed and agro-based industries. Rich in carbohydrates, dietary fibre, beta-carotene, antioxidants, and essential minerals, these crops contribute significantly to nutritional security and rural livelihoods. Their ability to thrive under marginal conditions, low-input farming, and mixed cropping systems makes them particularly important for smallholder farmers. Tuber crops exhibit considerable resilience to climatic stresses, including drought, excessive rainfall, waterlogging, and temperature extremes, making them well suited to coastal agro-climatic conditions (Mhaskar). In Maharashtra, crops such as cassava, sweet potato, elephant foot yam, colocasia, xanthosoma, aerial yam, and yam bean have good cultivation potential as sole crops or as components of diversified cropping systems.

Balanced nutrient management through the combined application of recommended dose of fertilizers (RDF) and biofertilizers is an effective approach for improving crop productivity while maintaining soil health. Continuous and indiscriminate use of chemical fertilizers alone degrades soil physical properties, reduces nutrient-use efficiency, and leads to micronutrient deficiencies. In the lateritic soils of the Konkan region, which are acidic, low in organic matter, and prone to nutrient losses due to heavy rainfall, integrated nutrient management is particularly important. The combined use of RDF with biofertilizers such as *Azotobacter*, *Azospirillum*, and phosphate-solubilizing microorganisms enhances nutrient availability through biological nitrogen fixation, phosphorus solubilization, and the production of plant growth-promoting substances. This integrated approach improves soil fertility, nutrient uptake, crop productivity, and fertilizer-use efficiency while reducing dependence on chemical fertilizers, making it a sustainable nutrient management strategy for elephant foot yam cultivation in the Konkan region.

Importance of study

Nutritional composition

Elephant foot yam is a nutritious tuber crop rich in minerals and moderate in protein content. The protein content (1.126%) observed in the tubers was within the range reported for Indian cultivars (0.84-2.6%) by Chattopadhyay *et al.* (2009). Studies by Paul *et al.* (2013) [18] also reported that elephant foot yam is rich in minerals such as calcium, phosphorus, and iron, though comparatively low in protein. The crop is considered a valuable source of essential minerals that support enzymatic regulation, bone development, acid-base balance, and muscle function.

Anti-nutrient content

Anti-nutrient factors can influence animals in several manners, including directly intoxicating the animals, causing mortality or decreased production Cheeke and decreasing feed intake. The oxalate concentration was 31.851 mg/100 g, which is higher than that reported for cultivars in India (2.91-18.50 mg/100 g) Chattopadhyay.

The oxalate content in plants is affected by many factors, including the season, soil, water, climatic conditions and where the plant is grown. Oxalates can bind with calcium to form insoluble calcium oxalate, reducing calcium availability and potentially causing hypocalcemia and kidney stone formation in humans (Paul *et al.*, 2013) [18]. However, ruminants such as cattle and sheep are less affected due to oxalate degradation in the rumen (Allison).

Climate and soil

Elephant foot yam (*Amorphophallus paeoniifolius* Dennst.) is an important tropical tuber crop that performs well in warm, humid climates and well-drained, organic matter-rich soils. However, the lateritic soils of the Konkan region are acidic, low in fertility, and deficient in essential nutrients, which limit crop productivity and quality. Integrated nutrient management through the combined application of recommended fertilizer doses (RDF) and biofertilizers such as *Azotobacter*, *Azospirillum*, phosphate-solubilizing bacteria (PSB), and vesicular arbuscular mycorrhiza (VAM) can improve nutrient availability, nutrient uptake, soil microbial activity, and corm quality while reducing dependence on chemical fertilizers. Therefore, evaluating different fertilizer levels in combination with biofertilizers is essential to identify an efficient and sustainable nutrient management strategy for enhancing nutrient content and quality parameters of elephant foot yam corms under the lateritic soils of the Konkan region.

Content

Materials Methods

The field experiment entitled "Influence of different levels of fertilizer with biofertilizers on soil properties, yield, quality, and nutrient content of elephant foot yam (*Amorphophallus paeoniifolius* (dennst.) in lateritic soils of konkan" was conducted during the *kharif-rabi* seasons of 2023-24 and 2024-25 at the All India Coordinated Research Project on Tuber Crops, Central Experimental Station, Wakawali, Maharashtra, India. The materials used and experimental procedures adopted for the study are described in this section. The treatment-wise harvested tubers which were dried at 60°C and used for analytical purpose. After recording the dry weight, the samples were grinded in Willey type grinding mill and stored in plastic bags for digestion for determination of N sample were digested with conc. H₂SO₄ using H₂O₂ and was determined by Kjeldahl apparatus (Tandon). P, K and micronutrients (Fe, Mn, Zn, and Cu) content from corms of both the year sample was digested with di-acid mixture (HNO₃ + HClO₄) with the ratio 9:4 and acid extract was used for digestion of sample for P, K and micronutrients (Fe, Mn, Cu and Zn) (Singh *et al.*, 2024) [21]. For p content determination extract as mentioned above and Phosphorus was determined colorimetrically by using spectrophotometer at 420 nm wave length (Jakson, 1973) by using di-acid mixture extractant the yellow colour was developed with combined HNO₃ vanadomolybdate reagent while, K was estimated by flame photometrically by using diluted diacid digested solution duly diluted 10 times (Pipe). The concentration of the micronutrients (Fe, Mn, Cu, and Zn) the clear filtrate and measured using an Atomic Absorption Spectrophotometer (AAS).

The presence of calcium oxalate has been attributed to be one of the major causes of acidity which was determined by

method prescribed (AOAC official Methods of analysis, 1984) ^[6]. Determination of Starch and total sugar was determined by rapid titrimetric (Moorthy *et al.* 2002) ^[13] and crude fiber (AOAC official Method of analysis, 1975) ^[5] and crude protein is obtained by multiplying the total nitrogen content with a factor of 6.25.

Results and Discussion

The nutrient content of elephant foot yam, including nitrogen (%), phosphorus (%), and potassium (%) while total micronutrient content (Fe, Mn, Cu, and Zn) was assessed of corm. The study evaluated the influence of different fertilizer levels (0, 75, and 100% recommended dose of fertilizers, RDF) in combination with biofertilizers—*Azotobacter* + PSB, *Azospirillum* + PSB, *Azotobacter* + VAM, and *Azospirillum* + PSB.

Nitrogen content (%)

The data illustrating the effect of varying fertilizer levels in combination with biofertilizers on nitrogen content in at harvest from corm)—are presented in Table 1.

Effect of Fertilizer levels

Different levels of recommended dose of fertilizers (RDF) (0%, 75%, and 100%) significantly influenced the nitrogen content in elephant foot yam. During the *kharif-rabi* season of 2023-2024, nitrogen content ranged 0.49 to 0.60% in the corm at harvest. Similarly, during the 2024-2025 season, nitrogen content varied from 0.39 to 0.57% in the corm at harvest. The data further indicated that there was graded increase in nitrogen content in leaves with the graded application of RDF (i.e., 0%, 75%, and 100%) during both the years of experimentation, where the lowest of available nitrogen was reported with no fertilizers (F₀) at during both years.

The highest nitrogen content was significantly recorded with the application of 100% RDF (F₂) at all growth stages during both years. Higher fertilizer levels (75% and 100% RDF) supplied adequate nitrogen to the soil, which enhanced its absorption by plants, resulting in increased nitrogen content in corms. Similar trend was observed by sharmila (2001) nitrogen content in corms increased steadily with increasing the levels of nitrogen and potassium at harvest.

Effect of Biofertilizers

The nitrogen content in leaves and corm was significantly affected by the combined application of biofertilizers, including *Azotobacter*, *Azospirillum*, VAM, and PSB, in elephant foot yam. During the *kharif-rabi* season of 2023-2024, nitrogen content ranged from 0.40 and 0.64% in the corm at harvest. Similarly, in the 2024-2025 season, nitrogen content ranged from 2.21 to 0.40 and 0.58% recorded in the corm at harvest. Application of biofertilizers such as *Azotobacter*, *Azospirillum*, VAM, and PSB, in combination, increased the nitrogen content of leaves as well as corm over no application (B₀). *Azotobacter* and *Azospirillum* are known for their ability to fix atmospheric nitrogen, thereby directly enriching the soil nitrogen pool. The data revealed that the highest nitrogen content was recorded with the application of *Azotobacter* + PSB @ 10 kg ha⁻¹ each (B₁) in corm during 2023-24. This might be due to PSB (phosphate-solubilizing bacteria) not only makes phosphorus more available but also stimulates overall microbial activity in the rhizosphere. This creates a more favorable environment for nitrogen-fixing bacteria like *Azotobacter* and *Azospirillum* to function effectively. As a result, the combinations involving PSB (B₁ and B₃) lead to enhanced nitrogen fixation and better nitrogen uptake by the plant.

Table 1: Nitrogen, Phosphorus and potassium content (%) in corm of elephant foot yam as influenced by different fertilizer levels with biofertilizers during *kharif-rabi*, 2023-24 and 2024-25.

NPK content (%) in corm during <i>kharif-rabi</i> , 2023-24												
Treat	N content (%) in corm				P content (%) in corm				K content (%) in corm			
	F ₀	F ₁	F ₂	Mean	F ₀	F ₁	F ₂	Mean	F ₀	F ₁	F ₂	Mean
B ₀	0.38	0.39	0.42	0.40	0.13	0.14	0.16	0.14	0.78	0.85	0.93	0.85
B ₁	0.59	0.65	0.68	0.64	0.17	0.24	0.27	0.23	0.84	1.17	1.18	1.06
B ₂	0.50	0.63	0.66	0.60	0.15	0.17	0.21	0.18	0.82	1.00	1.03	0.95
B ₃	0.59	0.61	0.62	0.61	0.16	0.20	0.25	0.20	0.83	1.15	1.15	1.04
B ₄	0.37	0.49	0.64	0.50	0.14	0.15	0.17	0.15	0.79	0.92	1.03	0.92
Mean	0.49	0.56	0.60		0.15	0.18	0.21		0.81	1.02	1.06	
	F	B	F×B		F	B	F×B		F	B	F×B	
S.Em±	0.02	0.02	0.03		0.01	0.01	0.01			0.03	0.04	0.07
C.D. @5%	0.04	0.06	0.10		0.02	0.02	0.04			0.09	0.11	NS
NPK content (%) in corm during <i>kharif-rabi</i> , 2023-24												
Treat	N content (%) in corm				P content (%) in corm				K content (%) in corm			
	F ₀	F ₁	F ₂	Mean	F ₀	F ₁	F ₂	Mean	F ₀	F ₁	F ₂	Mean
B ₀	0.34	0.38	0.47	0.40	0.11	0.12	0.17	0.13	0.59	0.88	0.94	0.80
B ₁	0.45	0.59	0.72	0.58	0.15	0.22	0.25	0.21	0.89	1.15	1.18	1.07
B ₂	0.35	0.48	0.50	0.45	0.13	0.15	0.18	0.15	0.76	0.78	0.87	0.81
B ₃	0.41	0.55	0.71	0.56	0.14	0.20	0.23	0.19	0.86	1.14	1.16	1.06
B ₄	0.39	0.49	0.44	0.44	0.12	0.13	0.15	0.13	0.73	0.77	1.05	0.85
Mean	0.39	0.50	0.57		0.13	0.16	0.20		0.77	0.95	1.04	
	F	B	F×B		F	B	F×B		F	B	F×B	
S.Em±	0.01	0.02	0.03		0.01	0.01	0.01			0.06	0.08	0.14
C.D. @5%	0.04	0.05	0.09		0.02	0.02	0.03			0.18	0.23	NS

Combined effect of fertilizer levels and biofertilizers

The combined application of 0%, 75%, and 100% of the recommended dose of fertilizers (RDF) along with biofertilizers *Azotobacter*, *Azospirillum*, VAM, and PSB in

elephant foot yam showed significant influence on nitrogen content in the corm at harvest. During the 2023-2024 season, nitrogen content ranged from 0.38 to 0.68% in the corm at harvest. Similarly, during the 2024-2025 season, nitrogen content ranged from 0.34 and 0.72% recorded in the corm at harvest.

Among the treatment combination of 100% RDF with *Azotobacter* + PSB (F₂B₁) was highest value compare to other treatment might be due to combined effect of sufficient chemical nutrients (RDF), enhanced biological nitrogen fixation (*Azotobacter*), and improved nutrient solubilization and uptake (PSB) results in higher nitrogen accumulation in leaves during active growth stages and its subsequent translocation to the corm at harvest.

Phosphorous content (%)

The data demonstrating the impact of different fertilizer levels, in combination with biofertilizers, on the phosphorus content in the leaves of elephant foot yam at in the corm at harvest, are presented in Table 1.

Effect of fertilizer levels

Different levels of the recommended dose of fertilizers (RDF) (0%, 75%, and 100%) significantly influenced the phosphorus content in elephant foot yam. During the *kharif-rabi* season of 2023-2024, the phosphorus content ranged from 0.15 to 0.21% in the corm at harvest. Similarly, in the 2024-2025 season, phosphorus content varied 0.13 to 0.20% in the corm at harvest. The highest phosphorus content was significantly recorded with the application of 100% RDF (F₂) and lowest phosphorus content was consistently observed in the treatment without fertilizer application (F₀) during both years. This may be attributed to the absence of an external phosphorus supply, which limited phosphorus availability in the soil, resulting in reduced uptake and translocation within the plant. Lateritic soils are typically acidic and rich in iron and aluminum oxides. These compounds tend to fix phosphorus, making it less available to plants even if it is present in the soil. As a result, phosphorus becomes poorly soluble and less accessible for plant uptake. Therefore, in treatments without fertilizer application (F₀), the already limited available phosphorus in lateritic soil further reduces its uptake by elephant foot yam, leading to lower phosphorus content in leaves and corm. Thus, highest phosphorus content was significantly recorded with the application of 100% RDF (F₂) during both years.

Effect of biofertilizers

The phosphorus content in leaves and corm was significantly affected by the combined application of biofertilizers, including *Azotobacter*, *Azospirillum*, VAM, and PSB, in elephant foot yam. During the *Kharif-Rabi* season of 2023-2024, phosphorus content ranged 0.41 to 0.23 in the corm at harvest. Similarly, in the 2024-2025 it varies from 0.13 to 0.21 % in the corm at harvest. Application of biofertilizers such as *Azotobacter*, *Azospirillum*, VAM, and PSB, in combination, increased the phosphorus content of corm over no application (B₀). This improvement can be attributed to the synergistic action of these beneficial microorganisms. Phosphate-solubilizing bacteria (PSB) convert insoluble forms of phosphorus into forms readily available to plants enhances phosphorus uptake by expanding the root surface area through its hyphal network. Additionally, *Azotobacter* improve overall root

growth and nutrient absorption by producing growth-promoting substances. Together, these biofertilizers increase phosphorus availability and uptake, resulting in higher phosphorus content in plant tissues. The data revealed that the highest phosphorus content was recorded with the application of *Azotobacter* + PSB @ 10 kg ha⁻¹ each (B₁). Among the different biofertilizer combinations, treatments involving *Azotobacter* + VAM (B₂) and *Azospirillum* + VAM (B₄) recorded lower phosphorus content in both leaves and corms at harvest. In contrast, higher phosphorus content was observed with *Azotobacter* + PSB (B₁) and *Azospirillum* + PSB (B₃) treatments. This variation may be attributed to the role of phosphate-solubilizing bacteria (PSB) in converting insoluble forms of phosphorus into available forms, thereby enhancing phosphorus uptake by the crop. On the other hand, vesicular-arbuscular mycorrhiza (VAM), although beneficial for nutrient absorption, may have been less effective than PSB under the lateritic soil conditions of the Konkan region. Suja *et al.*, (2017) [9] demonstrated that organic nutrient management practices significantly enhanced mineral content in taro (*Colocasia esculenta*), with higher levels of phosphorus (P) by 3.22%, in cormels compared to conventional and traditional systems. This improvement was attributed to the combined application of organic inputs and biofertilizers such as *Azospirillum*, mycorrhiza, and phosphobacteria biofertilizer combinations, particularly those involving PSB, play a crucial role in improving nutrient uptake under such soil condition.

Combined effect of fertilizer levels and biofertilizers

The combined application of 0%, 75%, and 100% of the recommended dose of fertilizers (RDF) along with biofertilizers- *Azotobacter*, *Azospirillum*, VAM, and PSB- in elephant foot yam showed significant effect on phosphorus content at in the corm at harvest. This might be attributed to the initial slow establishment of biofertilizers and limited root development during early crop growth. Biofertilizers such as *Azotobacter*, *Azospirillum*, vesicular-arbuscular mycorrhiza (VAM), and phosphate-solubilizing bacteria (PSB) require time to colonize the rhizosphere and become functionally active. During the 2023-2024 seasons phosphorus content ranged from 0.13 to 0.27 % in the corm at harvest. Similarly, during the 2024-2025 season, phosphorus content ranged from 0.11 to 0.25 % recorded in the corm at harvest. Among the treatment combination of 100% RDF with *Azotobacter* + PSB (F₂B₁) was highest value compare to other treatment combination might be due to sufficient chemical nutrients (RDF), enhanced biological phosphorus fixation (*Azotobacter*), and improved nutrient solubilization and uptake (PSB) results in higher phosphorus accumulation in leaves during active growth stages and its subsequent translocation to the corm at harvest.

Potassium content (%)

Effect of fertilizer levels

The effect of different fertilizer levels, in combination with biofertilizers, on potassium content in elephant foot yam in the corm at harvest is presented in Table 1. Various levels of the recommended dose of fertilizers (RDF) (0%, 75%, and 100%) significantly influenced potassium content. During the *Kharif-Rabi* season of 2023-2024, potassium levels were 0.81-1.06% in the In the 2024-2025 season, the values ranged from 0.77-1.04% in the corm at harvest. The highest

potassium content was consistently observed with the application of 100% RDF (F_2) in both years. A field experiment was conducted Jata *et al.*, (2020) ^[19] during 2013 and 2014 at the Regional Centre of ICAR-Central Tuber Crops Research Institute, Dumuduma, Bhubaneswar, Odisha, to evaluate the effects of drip fertigation on the quality characteristics of elephant foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson] and the water use efficiency of an elephant foot yam + green gram (*Vigna radiata* L.) intercropping system in soil with a pH of 6.8. The levels of fertigation significantly influenced the phosphorus content of the corm in both years, although the mean values were similar across the two seasons. The highest phosphorus and potassium content was recorded under T_6 ($N-K_2O$ @ 140-140 kg ha⁻¹), which was significantly higher than all other fertigation levels in both years. The data further indicated a graded increase in potassium content in leaves and corm at harvest with increasing RDF levels (0%, 75%, and 100%) in both years. The lowest potassium content was consistently recorded in plants receiving no fertilizer (F_0). This pattern is attributed to the essential role of potassium in enzymatic activities, osmoregulation, and nutrient translocation. In the absence of supplemental fertilizer, plants depended solely on the native soil potassium, which was insufficient to meet the crop's demands, resulting in reduced accumulation in leaves and corm. Similar result was observed by sharmila (2001) potassium content in corms increased steadily with increasing the levels of potassium. Patel and Mehta (1987) ^[17] reported an application of N increased the P and K contents of the corms. Mukhopadhyay and Sen (1986) ^[14] reported that quality of corms improved with increasing levels of both N and K.

Effect of biofertilizers

The combined application of biofertilizers, including *Azotobacter*, *Azospirillum*, VAM, and PSB, significantly influenced potassium content in the leaves and corm of elephant foot yam. During the *Kharif-Rabi* season of 2023-2024, potassium content ranged from 1.39-1.54% at 40 DAP, 1.52-1.72% at 80 DAP, and 1.48-1.62% at 120 DAP, while corm potassium content at harvest varied from 0.85-1.06%. In the 2024-2025 season, potassium content ranged from 1.29-1.44% at 40 DAP, 1.46-1.66% at 80 DAP, and 1.42-1.65% at 120 DAP, with corm values ranging from 0.80-1.07% at harvest.

Application of biofertilizers such as *Azotobacter*, *Azospirillum*, VAM, and PSB, in combination, increased the potassium content of leaves as well as corm over no application (B_0). This improvement may be attributed to enhanced nutrient availability and uptake, as these biofertilizers promote root growth, increase microbial activity in the rhizosphere, and facilitate better solubilization and mobilization of nutrients. In particular, VAM improves potassium absorption through an extensive hyphal network, while PSB and associative nitrogen fixers indirectly enhance nutrient uptake by improving overall plant vigor and soil nutrient dynamics.

The data indicated that the highest potassium content was recorded with the application of *Azotobacter* + PSB @ 10 kg ha⁻¹ each (B_1) at all growth stages during both years. This treatment was significantly superior to all others at 40 and 80 DAP as well as at the corm harvest stage, while at 120 DAP it was statistically at par with B_2 , B_3 , and B_4 . During

2024-2025, treatment B_1 was found to be at par with B_2 and B_3 at 40 and 80 DAP. At 120 DAP, *Azospirillum* + PSB @ 10 kg ha⁻¹ each (B_3) was statistically comparable with the B_1 treatment. Similarly, at the corm harvest stage, potassium content under B_1 was at par with B_3 and B_4 .

Amongst application of biofertilizers combination, the lower values of potassium content in leaves and corm were reported by *Azotobacter* + VAM @ 10 kg ha⁻¹ each (B_2) and *Azospirillum* + VAM @ 10 kg ha⁻¹ each (B_4) treatments when compared with *Azotobacter* + PSB @ 10 kg ha⁻¹ each (B_1) and *Azospirillum* + PSB @ 10 kg ha⁻¹ each (B_3). The beneficial effects of *Azotobacter* and *Azospirillum* on nutrient content and crop performance can be attributed to their role as plant growth-promoting rhizobacteria (PGPR). *Azotobacter* is a free-living nitrogen-fixing bacterium that enhances soil fertility by fixing atmospheric nitrogen and releasing growth-promoting substances such as auxins, gibberellins, and vitamins. These compounds stimulate root proliferation and improve nutrient uptake efficiency, leading to increased accumulation of nutrients, including potassium, in plant tissues. Similarly, *Azospirillum* is an associative symbiotic bacterium known for its ability to fix atmospheric nitrogen in the rhizosphere and promote plant growth through the production of phytohormones, particularly indole-3-acetic acid (IAA). This enhances root architecture, increases root surface area, and facilitates better absorption of water and nutrients from the soil. Enhanced root growth and microbial interactions contribute to improved uptake and translocation of essential nutrients such as potassium, however, their effectiveness is often influenced by soil conditions and their interaction with other biofertilizers. When combined with phosphate-solubilizing bacteria (PSB), their synergistic effect further enhances nutrient availability and uptake. In contrast, when combined with VAM, the response may vary depending on soil characteristics, particularly in acidic lateritic soils where nutrient solubilization plays a critical role. Suja *et al.*, (2014) observed organic management resulted in slight improvements in potassium and magnesium contents compared to conventional practices. These variations were attributed to differences in nutrient sources (FYM, green manure, biofertilizers, (*Azospirillum*+ mycorrhiza + phospho-bacteria) ash and neem cake) and their availability under different production systems.

Combined effect of fertilizer levels and biofertilizers

The combined application of 0%, 75%, and 100% of the recommended dose of fertilizers (RDF) along with biofertilizers- *Azotobacter*, *Azospirillum*, VAM, and PSB in elephant foot yam showed a non-significant effect on nitrogen content at 40 DAP as well as in the corm at harvest during both years. However, it significantly influenced potassium content in leaves at 80 and 120 DAP. During the 2023-2024 season, potassium content ranged from 1.34 to 1.60% at 40 DAP, 1.46 to 1.81 % at 80 DAP, and 1.42 to 1.77 % at 120 DAP, while it varied from 0.78 to 1.18 % in the corm at harvest. Similarly, during the 2024-2025 season, potassium content ranged from 1.27 to 1.49 % at 40 DAP, 1.40 to 1.78 % at 80 DAP, and 1.38 to 1.79 % at 120 DAP, with values between 0.59 to 1.18 % recorded in the corm at harvest.

Among the treatment combination of 100% RDF with *Azotobacter* + PSB (F_2B_1) was highest value compare to other treatment might be due to combined application

improves soil nutrient dynamics by enhancing microbial activity, root development, and nutrient solubilization. Biofertilizers such as PSB and VAM facilitate better nutrient uptake, while *Azotobacter* and *Azospirillum* promote root growth through phytohormone production. Since potassium plays a key role in enzyme activation, osmoregulation, and translocation of assimilates, its uptake and accumulation are more pronounced during later growth stages and in the corm at harvest. The treatment combination of 100% RDF with *Azotobacter* + PSB (F₂B₁) was found to be statistically at par with F₂B₂, F₂B₃, F₂B₄, and F₁B₁ at 80 DAP during both seasons. At 120 DAP, during 2023-2024, F₂B₁ remained at par with F₂B₂, F₂B₃, and F₂B₄ in leaf potassium content. Similarly, in 2024-2025, F₂B₁ was statistically comparable with F₂B₂, F₂B₃, F₂B₄, and F₁B₁.

2. Micronutrient Fe, Mn, Zn and Cu (mg/100g) content of corm of elephant foot yam

Effect of fertilizer levels

The influence of varying fertilizer levels in combination with biofertilizers on the micronutrient content of elephant foot yam corms (on a dry weight basis) is summarized in Table 2. The application of different levels of the recommended dose of fertilizers (RDF) (0%, 75%, and 100%) had a significant effect on the concentrations of Fe, Mn, and Zn, while the effect on Cu was not significant. During the *Kharif-Rabi* season of 2023-2024, Fe content ranged from 4.34 to 5.42 mg/100 g, Mn from 2.91 to 3.74 mg/100 g, Zn from 8.98 to 11.11 mg/100 g, and Cu from 0.96 to 1.07 mg/100 g. In the 2024-2025 season, Fe values ranged from 3.0 to 4.85 mg/100 g, Mn from 2.84 to 3.62 mg/100 g, Zn from 7.95 to 9.28 mg/100 g, and Cu from 0.95

to 1.01 mg/100 g. The highest mineral content (Fe, Mn, Zn and Cu) in harvested corms was recorded with the application of 100% RDF (F₂) in both years. Adequate and balanced application of N, P, and K enhances root growth and increases root surface area, which improves the absorption of micronutrients from the soil. The application of 100% RDF compensates for nutrient losses, improves nutrient availability, and enhances root-induced solubilization of micronutrients. Thus, the combined effect of improved plant uptake efficiency and better nutrient availability in soil leads to higher accumulation of Fe, Mn, and Zn in harvested corms. However, the increase in Cu is usually less pronounced compared to Fe and Mn might be due to Copper tends to get tightly bound to organic matter and oxides of iron and aluminum, reducing its mobility and availability to plants. Additionally, higher levels of phosphorus (from RDF) can sometimes show antagonistic effects, slightly reducing Cu uptake. A similar result was reported by Biswanath *et al.* (2014) [7], who conducted a field experiment during 2011-12 and 2012-13 at CTCRI, Bhubaneswar, on sandy loam acidic soil (Alfisols) with a pH of 6.8. The results showed that increasing graded levels of N and K, particularly treatment T₄ (100:60:100 kg NPK ha⁻¹), recorded the highest Fe (2.773 ppm) and Mn (1.590 ppm) content in elephant foot yam corms. In contrast, lower Fe values were observed in the control (T₁). Zinc content ranged from 0.92 to 1.07 ppm, with the lowest value in the control, and the differences among treatments were statistically significant. For Mn, the lowest value was also recorded in the control (0.060 ppm), while higher values were observed in fertilized treatments. Overall, higher fertilizer doses improved micronutrient content compared to the control.

Table 2: Micronutrient content (mg/100g) in corm of elephant foot yam as influenced by different fertilizer levels with biofertilizers during *Kharif-Rabi*, 2023-24 and 2024-25

Micronutrient content (mg/100g) in corm on dry basis at harvest of elephant foot yam during <i>Kharif-Rabi</i> , 2023-24																
	Fe content				Mn content				Zn content				Cu content			
Treat	F ₀	F ₁	F ₂	Mean	F ₀	F ₁	F ₂	Mean	F ₀	F ₁	F ₂	Mean	F ₀	F ₁	F ₂	Mean
B ₀	3.84	4.26	4.97	4.36	2.65	2.68	3.06	2.80	8.50	8.65	10.86	9.34	0.81	1.03	1.07	0.97
B ₁	4.87	5.81	5.91	5.53	3.12	4.09	4.28	3.83	9.33	10.40	11.87	10.54	1.02	1.08	1.10	1.07
B ₂	4.39	4.32	5.12	4.61	3.01	3.75	3.77	3.51	9.04	9.21	10.80	9.68	0.98	1.04	1.06	1.03
B ₃	4.45	5.22	5.58	5.08	3.07	4.07	4.16	3.77	9.28	10.07	11.83	10.39	1.00	1.06	1.09	1.05
B ₄	4.14	4.31	5.51	4.66	2.73	3.38	3.42	3.18	8.74	9.74	10.17	9.55	0.96	0.98	1.01	0.98
Mean	4.34	4.78	5.42	4.85	2.91	3.60	3.74		8.98	9.62	11.11		0.96	1.04	1.07	
	F	B	F×B		F	B	F×B		F	B	F×B		F	B	F×B	
S.Em±	0.16	0.20	0.35		0.14	0.18	0.31		0.22	0.28	0.48		0.03	0.04	0.07	
C.D. @ 5%	0.46	0.59	NS		0.40	0.51	NS		0.63	0.81	NS		NS	NS	NS	
Micronutrient content (mg/100g) in corm of elephant foot yam during <i>Kharif-Rabi</i> , 2024-25																
	Fe content				Mn content				Zn content				Cu content			
Treat	F ₀	F ₁	F ₂	Mean	F ₀	F ₁	F ₂	Mean	F ₀	F ₁	F ₂	Mean	F ₀	F ₁	F ₂	Mean
B ₀	3.47	3.87	4.12	3.82	2.56	2.63	2.79	2.66	7.47	7.62	7.83	7.64	0.75	0.81	0.99	0.85
B ₁	4.30	5.42	5.66	5.13	3.17	3.71	4.19	3.69	8.30	9.37	9.84	9.17	1.07	1.10	1.12	1.10
B ₂	3.58	4.74	5.08	4.46	2.69	3.67	3.72	3.36	8.01	8.18	9.77	8.65	0.94	1.06	1.09	1.03
B ₃	3.64	4.97	5.52	4.71	3.12	3.69	4.04	3.62	8.25	9.04	9.80	9.03	1.04	1.08	1.10	1.08
B ₄	3.53	4.17	3.86	3.85	2.68	3.00	3.37	3.01	7.71	8.71	9.14	8.52	0.93	0.96	1.02	0.97
Mean	3.70	4.63	4.85	4.39	2.84	3.34	3.62		7.95	8.59	9.28		0.95	1.00	1.06	
	F	B	F×B		F	B	F×B		F	B	F×B		F	B	F×B	
S.Em±	0.14	0.17	0.30		0.15	0.19	0.34		0.20	0.26	0.45		0.05	0.07	0.11	
C.D. at 5%	0.39	0.51	NS		0.44	0.56	NS		0.58	0.75	NS		NS	NS	NS	

Effect of biofertilizers

The combined application of biofertilizers, including *Azotobacter*, *Azospirillum*, VAM, and PSB, significantly influenced mineral content viz., Fe, Mn and Zn in corm of

elephant foot yam While Cu influences non significantly during both season. Whereas Fe ranges from 4.36 to 5.53 mg/100g, Mn ranged from 2.80 to 3.83 mg/100g, Zn from 9.34 to 10.54 mg/100g, and Cu from 0.97 to 1.07 mg/100g.

In year 2024-2025, the values of Fe ranges from 3.82 to 5.13mg/100g, Mn ranged from 2.66 to 3.69 mg/100g, Zn from 7.64 to 9.17 mg/100g, and Cu from 0.85 to 1.10 mg/100g. Application of biofertilizers such as *Azotobacter*, *Azospirillum*, VAM, and PSB, in combination, increased the mineral content (Fe, Mn, Zn and Cu) of corm over no application (B₀). Biofertilizers such as *Azotobacter*, *Azospirillum*, PSB, and VAM increase the availability of Fe, Mn, Zn, and Cu in lateritic soils of the Konkan region through several rhizosphere mechanisms. These microorganisms produce organic acids that make favorable soil pH and solubilize micronutrients bound to iron and aluminum oxides. They also release siderophores and chelating compounds that convert micronutrients into soluble and plant-available forms. Biofertilizers also promote root growth and reduce nutrient fixation, thereby increasing the overall availability and uptake of micronutrients, resulting in higher accumulation in corms resulting in higher accumulation of Fe, Mn, Zn, and Cu in the corms compared to no biofertilizer application. Long-term field experiments conducted by Suja (2013) ^[24] at the Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, demonstrated the comparative agronomic and nutritional advantages of organic over conventional production systems in elephant foot yam and yams (*Dioscorea* spp.). The study, carried out over five years under both randomized block design (2004-2009) and split-plot design (2006-2011), revealed that organically managed (FYM, green manure, biofertilizers, ash and neem cake) elephant foot yam concentrations of micronutrients, ranges from Fe (7.90 mg/100 g), Zn (11.02 mg/100 g), and Cu (1.041 mg/100 g). These findings are consistent with the results of Suja *et al.*, (2017) ^[9], who reported that organic nutrient management significantly improved the mineral composition of taro (*Colocasia esculenta*). Their study indicated higher concentrations of Fe, Mn, Zn, and Cu in cormels under organic systems compared to conventional and traditional practices.

The data indicated that the highest mineral content (Fe, Mn, Zn and Cu) was recorded with the application of *Azotobacter* + PSB @ 10 kg ha⁻¹ each (B₁) of harvested Corm of elephant foot yam during both years. Among the biofertilizer combinations, lower Fe, Mn, Zn, and Cu content in corms under *Azotobacter* + VAM (B₂) and *Azospirillum* + VAM (B₄) compared to *Azotobacter* + PSB (B₁) and *Azospirillum* + PSB (B₃) is mainly due to differences in micronutrient solubilization ability in lateritic soils. Species like *Azotobacter chroococcum* and *Azotobacter vinelandii*, along with PSB such as *Bacillus megaterium* and *Pseudomonas striata*, enhance micronutrient availability by producing organic acids and siderophores that solubilize Fe, Mn, Zn, and Cu from Fe and

Al-bound forms. In contrast, *Azospirillum brasilense* and *Azospirillum lipoferum* mainly promote plant growth but have limited roles in micronutrient solubilization. Similarly, VAM fungi like *Glomus fasciculatum* and *Glomus mosseae* primarily improve uptake of already available nutrients but lack strong solubilization capacity. Therefore, in lateritic soils where nutrients are largely fixed, PSB-based combinations are more effective than VAM-based combinations in increasing micronutrient availability and uptake.

Combined effect of fertilizer levels and biofertilizers

The combined application of 0%, 75%, and 100% of the recommended dose of fertilizers (RDF) along with biofertilizers- *Azotobacter*, *Azospirillum*, VAM, and PSB in elephant foot yam showed a non-significant effect on Fe, Mn, Zn and Cu mg/100g content in the corm at harvest during both years. However, Fe ranges from 3.84 to 5.91 mg/100g, Mn ranged from 2.65 to 4.28 mg/100g, Zn from 8.50 to 11.87 mg/100g, and Cu from 0.81 to 1.10 mg/100g. In year 2024-2025, the values of Fe ranges from 3.47 to 5.66 mg/100g, Mn ranged from 2.56 to 4.19 mg/100g, Zn from 7.47 to 9.84 mg/100g, and Cu from 0.75 to 1.12 mg/100g.

Effect of different levels of fertilizer with biofertilizers on quality of elephant foot yam

Total sugar content (%)

The total sugar content of elephant foot yam as influenced by varying levels of fertilizers (0, 75 and 100% RDF) and biofertilizers (*Azotobacter* + PSB, *Azospirillum* + PSB, *Azotobacter* +VAM and *Azospirillum* +PSB) are presented in Table 3.

Effect of fertilizer levels

Varying levels of the recommended dose of fertilizers (RDF), namely 0%, 75%, and 100%, had a significant effect on the total sugar content (%) of elephant foot yam. During *Kharif-Rabi* season of 2023-2024, total sugar content ranged between 1.38 and 1.68%, whereas in 2024-2025 it ranged from 1.22 to 1.70%. The pooled mean analysis across both seasons indicated that total sugar content varied from 1.30 to 1.69%. Remya and Suja (2018) ^[10] reported the total sugar content of elephant foot yam of Gajendra variety in the range of 1.66 to 2.17%. Application of 100% RDF resulted in the maximum total sugar content in both seasons (1.68% during 2023-2024 and 1.70% during 2024-2025) as well as in the pooled data (1.69%), clearly outperforming the 75% RDF and unfertilized control treatments. These findings corroborate the results reported by Remya and Suja (2018) ^[10], in an acidic soils (pH 5.10) of Alathara, Kattela, Sreekariyam, Thiruvananthapuram district, Kerala.

Table 3: Total sugar content (%) in tuber of elephant foot yam as influenced by different fertilizer levels with biofertilizers during *Kharif-Rabi*, 2023-24 and 2024-25

Treat	Total sugar content (%) in tuber of elephant foot yam											
	<i>Kharif - Rabi</i> 2023-24				<i>Kharif - Rabi</i> 2024-25				Pooled data			
	F ₀	F ₁	F ₂	Mean	F ₀	F ₁	F ₂	Mean	F ₀	F ₁	F ₂	Mean
B ₀	1.15	1.17	1.23	1.19	0.60	1.26	1.31	1.06	0.88	1.21	1.27	1.12
B ₁	1.49	1.59	2.21	1.76	1.40	1.47	2.33	1.73	1.44	1.53	2.27	1.75
B ₂	1.38	1.60	1.66	1.55	1.34	1.48	1.58	1.47	1.36	1.62	1.68	1.55
B ₃	1.49	1.77	1.78	1.68	1.46	1.53	1.65	1.55	1.48	1.56	1.65	1.57
B ₄	1.40	1.18	1.51	1.36	1.32	1.54	1.63	1.50	1.36	1.39	1.57	1.44
Mean	1.38	1.46	1.68		1.22	1.46	1.70		1.30	1.46	1.69	
	F	B	F×B		F	B	F×B		F	B	F×B	
S.Em±	0.05	0.06	0.11		0.04	0.06	0.10		0.04	0.05	0.09	
C.D. at 5%	0.14	0.18	0.32		0.13	0.17	0.29		0.12	0.15	0.26	
F ₀ - No fertilizer	B ₀ - No biofertilizer											
F ₁ - 75% RDF	B ₁ - <i>Azotobacter</i> + PSB @ 10 kg/ha each											
F ₂ - 100 % RDF	B ₂ - <i>Azotobacter</i> + VAM@ 10 kg/ha each											
	B ₃ - <i>Azospirillum</i> + + PSB@ 10 kg/ha each											
	B ₄ - <i>Azospirillum</i> ++ VAM @ 10 kg/ha each											

Effect of biofertilizers

Application of biofertilizers in combinations such as *Azotobacter* + PSB (B₁), *Azospirillum* + PSB (B₂), *Azotobacter* +VAM (B₃), and *Azospirillum* +PSB (B₄) increased the total sugar content (%) of elephant foot yam over no application (B₀), which ranged from 1.19 to 1.76% during 2023-2024, 1.06 to 1.73% during 2024-2025 and 1.12 to 1.75% in pooled analysis. Application of biofertilizers in combinations such as *Azotobacter* + PSB (B₁), *Azospirillum* + PSB (B₂), *Azotobacter* +VAM (B₃) and *Azospirillum* +PSB (B₄) increased the total sugar content over no application (B₀). Better nutrient uptake and photosynthetic efficiency facilitate greater synthesis and translocation of carbohydrates to the storage corms, leading to higher sugar accumulation. The findings highlight the positive role of biofertilizer combinations in improving the quality attributes of elephant foot yam. Among the biofertilizer treatments, total sugar content was highest with *Azotobacter* + PSB @ 10 kg ha⁻¹ each (B₁).

Combined effect of fertilizer levels and biofertilizers

The total sugar content of elephant foot yam was significantly influenced by the combined application of different levels of RDF (0%, 75%, and 100%) along with biofertilizer combinations such as *Azotobacter* + PSB, *Azospirillum* + PSB, *Azotobacter* +VAM, and *Azospirillum* +PSB, where total sugar content ranged from 1.15 to 2.21% and 0.60 to 2.33%, respectively during 2023-24 and 2024-25 *Kharif-Rabi* seasons, with pooled means varying from 0.88 to 2.27%. Among the treatments, 100% RDF combined with *Azotobacter* + PSB (F₂B₁) recorded the highest sugar content (2.21% and 2.33%, respectively during 2023-24 and 2024-25) and was significantly superior to all other treatment combinations.

3.2 Starch content (%)

Data pertaining to starch content (%) of elephant foot yam under different fertilizer levels combined with biofertilizer application are presented in Table 3.2. The results of statistical analysis showed that the combined effect of fertilizers and biofertilizers significantly affected tuber starch content during both seasons of the experiment.

Effect of Fertilizer levels

The starch content (%) of elephant foot yam was significantly influenced by varying levels of the recommended dose of fertilizers (RDF) showing range of

11.06 to 13.75% during 2023-2024, 10.73 to 13.24% during 2024-2025 with a mean range of 10.89 to 13.49%.

The significant increase in starch content of elephant foot yam with higher levels of the recommended dose of fertilizers (RDF) can be attributed to improved nutrient availability, particularly nitrogen, phosphorus, and potassium, which play a crucial role in photosynthesis and carbohydrate metabolism.

Effect of biofertilizers

Application of biofertilizers in combinations such as *Azotobacter* + PSB (B₁), *Azospirillum* + PSB (B₂), *Azotobacter* +VAM (B₃), and *Azospirillum* +PSB (B₄) increased the starch content (%) of elephant foot yam over no application (B₀), which ranged from 11.57 to 13.88% during 2023-2024, 11.07 to 14.49% during 2024-2025 and 11.32 to 14.18% in pooled analysis. The starch content in elephant foot yam was highest (13.88 % during 2023-2024, 14.49% during 2024-2025 with mean of 14.18%) with *Azotobacter* + PSB @ 10 kg ha⁻¹ each (B₁), might be due to physiologically nitrogen-fixing bacteria (*Azotobacter*) enhance nitrogen availability, promoting chlorophyll synthesis, leaf expansion, and photosynthetic efficiency, which increases the production of photoassimilates. PSB improve phosphorus uptake and root nutrient absorption, facilitating ATP-driven enzymatic processes involved in starch biosynthesis. The synergistic effect of these biofertilizers therefore optimizes carbohydrate synthesis and translocation from source leaves to corms, resulting in higher starch content. Navya *et al.* (2017) [15] also found increase in starch of elephant foot yam with application of biofertilizers i.e. combination of *Azospirillum*, Phosphate solubilizing bacteria (PSB) and Potash Mobilizing Bacteria (KMB) over no application.

Combined effect of fertilizer levels and biofertilizers

The starch content of elephant foot yam was significantly influenced by the combined application of different levels of RDF (0%, 75%, and 100%) along with biofertilizers in combinations such as *Azotobacter* + PSB, *Azospirillum* + PSB, *Azotobacter* +VAM, and *Azospirillum* +PSB, which varied 10.06 to 15.76% and 10.00 to 16.13%, respectively during 2023-24 and 2024-25 with a mean range of 10.03 to 15.94%. Among the treatment combinations, 100% RDF applied with *Azotobacter* + PSB (B₁) recorded the highest starch content during both the year.

Table 4: Starch content (%) in tuber of elephant foot yam as influenced by different fertilizer levels with biofertilizers during *Kharif-Rabi*, 2023-24 and 2024-25

Treat	Starch content (%) in tuber of elephant foot yam											
	<i>Kharif - Rabi</i> 2023-24				<i>Kharif - Rabi</i> 2024-25				Pooled data			
	F ₀	F ₁	F ₂	Mean	F ₀	F ₁	F ₂	Mean	F ₀	F ₁	F ₂	Mean
B ₀	10.06	11.47	13.17	11.57	10.00	11.58	11.63	11.07	10.03	11.53	12.40	11.32
B ₁	10.80	15.07	15.76	13.88	11.45	15.90	16.13	14.49	11.12	15.48	15.94	14.18
B ₂	11.60	11.87	13.97	12.48	10.07	11.48	12.85	11.47	10.83	11.68	13.41	11.97
B ₃	11.74	13.91	14.17	13.27	11.40	13.36	14.23	13.00	11.57	13.64	14.20	13.14
B ₄	11.08	11.57	11.71	11.45	10.71	10.94	11.34	11.00	10.90	11.25	11.52	11.22
Mean	11.06	12.78	13.75		10.73	12.65	13.24		10.89	12.72	13.49	
	F	B	F×B		F	B	F×B		F	B	F×B	
S.Em±	0.27	0.35	0.60		0.25	0.32	0.56		0.17	0.22	0.39	
C.D. at 5%	0.78	1.01	1.75		0.72	0.94	1.62		0.50	0.64	1.12	
F ₀ - No fertilizer	B ₀ - No biofertilizer											
F ₁ - 75% RDF	B ₁ - <i>Azotobacter</i> + PSB @ 10 kg/ha each											
F ₂ - 100 % RDF	B ₂ - <i>Azotobacter</i> + VAM@ 10 kg/ha each											
	B ₃ - <i>Azospirillum</i> + + PSB@ 10 kg/ha each											
	B ₄ - <i>Azospirillum</i> + + VAM @ 10 kg/ha each											

Saroj (2020) reported significant increase in starch content of elephant foot yam with the combined application of consortia mixture of PSB + *Azotobacter* + ZSB (*Zinc Solubilizing Bacteria*) with different doses of fertilizers over its sole dose of fertilizers.

Crude Fiber (%)

Data on crude fiber (%) of elephant foot yam under varying fertilizer levels in combination with biofertilizer application are presented in Table 4.24 and illustrating in fig.no.12.

Effect of Fertilizer levels

The crude fiber content (%) of elephant foot yam was significantly affected by different levels of the recommended dose of fertilizers (RDF), ranging from 1.19 to 1.53 % during 2023-2024 and from 1.22 to 1.46 % during 2024-2025, with a pooled mean ranging between 1.21 to 1.50 %. Application of 100% RDF resulted in higher crude fiber content compared to 75% RDF and the control (0% RDF); however, it remained statistically at par with 75% RDF (F₁) during 2023-24 and 2024-25, as well as in the pooled analysis. Adequate nutrient availability supports the formation of well-developed parenchymatous tissues and strengthens cell walls, resulting in relatively higher crude fiber content at optimum fertilizer levels. On the parallel line, Sharmila (2001) also observed graded increase in crude fibre content with graded level of fertilizer applied in splits to elephant foot yam. In a study on customized fertilizer (CF) formulations for elephant foot yam in laterite soils (pH 5.70) of Kerala, Anju *et al.* (2020) ^[1] noticed increase in crude fibre content with the application of higher customized fertilizer dose over lower once.

Effect of biofertilizers

Application of biofertilizers in various combinations,

namely *Azotobacter* + PSB (B₁), *Azospirillum* + PSB (B₂), *Azotobacter* + VAM (B₃), and *Azospirillum* + PSB (B₄), resulted in increased crude fiber content (%) of elephant foot yam compared to no biofertilizer application (B₀). The increase in crude fiber content due to biofertilizer application may be attributed to improved nutrient availability and enhanced root activity. The fiber content ranged from 1.19 to 1.55 % during 2023-2024, from 1.16 to 1.51 % during 2024-2025, and from 1.17 to 1.53 % in the pooled analysis.

The highest crude fiber content in elephant foot yam was recorded with the application of *Azotobacter* + PSB @ 10 kg ha⁻¹ each (B₁). This treatment was statistically at par with *Azotobacter* + VAM @ 10 kg ha⁻¹ each (B₂) and *Azospirillum* + PSB @ 10 kg ha⁻¹ each (B₃) during both the year with pooled analysis. The superiority of *Azotobacter* + PSB in enhancing crude fiber content can be attributed to improved nitrogen fixation and phosphorus solubilization in lateritic soils, which are characteristically acidic, low in available nitrogen, and rich in iron and aluminum oxides that fix phosphorus. PSB plays a crucial role in solubilizing native and applied phosphorus, thereby improving its availability to plants, while *Azotobacter* enhances nitrogen supply through biological fixation and growth-promoting substances. In an investigation on effect of integrated nutrient management (INM) practices on yield and quality attributes of elephant foot yam conducted at instructional farm of College of Agriculture, Vellayani, Thiruvananthapuram, Kerala, Dhanalakshmi and Rajasree (2023) ^[23] observed an increase in crude fiber content of elephant foot yam with application of RDF applied with consortium of *Azospirillum lipoferum*, *Azotobacter chroococcum*, *Bacillus megaterium* and *B sporothermodurans* over the lower dose of fertilizers in slightly acidic soils having pH 6.1.

Table 5: Crude Fiber (g/ 100g) in tuber of elephant foot yam as influenced by different fertilizer levels with biofertilizers during *Kharif-Rabi*, 2023-24 and 2024-25

Treat	Crude Fiber (g/ 100g) in tuber											
	Kharif - Rabi2023-24				Kharif - Rabi2024-25				Pooled data			
	F ₀	F ₁	F ₂	Mean	F ₀	F ₁	F ₂	Mean	F ₀	F ₁	F ₂	Mean
B ₀	1.10	1.12	1.35	1.19	1.02	1.23	1.23	1.16	1.06	1.17	1.29	1.17
B ₁	1.31	1.66	1.67	1.55	1.35	1.55	1.64	1.51	1.33	1.60	1.66	1.53
B ₂	1.20	1.42	1.51	1.37	1.28	1.48	1.48	1.41	1.24	1.45	1.49	1.39
B ₃	1.23	1.58	1.65	1.49	1.30	1.52	1.58	1.47	1.27	1.55	1.62	1.48
B ₄	1.12	1.35	1.50	1.32	1.13	1.27	1.38	1.26	1.13	1.31	1.44	1.29
Mean	1.19	1.42	1.53		1.22	1.41	1.46		1.21	1.42	1.50	
	F	B	F×B		F	B	F×B		F	B	F×B	
S.Em±	0.05	0.07	0.12		0.06	0.07	0.13		0.04	0.05	0.10	
C.D. at 5%	0.15	0.19	NS		0.17	0.22	NS		0.12	0.16	NS	
F ₀ - No fertilizer	B ₀ - No biofertilizer											
F ₁ - 75% RDF	B ₁ - Azotobacter + PSB @ 10 kg/ha each											
F ₂ - 100 % RDF	B ₂ - Azotobacter + VAM@ 10 kg/ha each											
	B ₃ - Azospirillum+ + PSB@ 10 kg/ha each											
	B ₄ - Azospirillum + + VAM @ 10 kg/ha each											

Combined effect of Fertilizer levels and Biofertilizers

The interaction effect of RDF levels (0%, 75%, and 100%) and biofertilizer combinations (*Azotobacter* + PSB, *Azospirillum* + PSB, *Azotobacter* + VAM, and *Azospirillum* + PSB) did not significantly influence the crude fiber content of elephant foot yam. The crude fiber content varied from 1.10 to 1.67 % in 2023-24 and from 1.02 to 1.64 % in 2024-25, with a pooled mean ranging between 1.06 and 1.66%. Suja *et al.* (2020) also clarified that the quality of the produce is determined by various factors like variety, genetic makeup, location, fertilization and weather conditions during crop growth. Further, Chhonkar (2008) [8] also noted that regardless of the source, plants absorb nutrients as inorganic ions and after absorption, the nutrients are re-synthesized into compounds that determine the quality of the produce which is mainly governed by the genetic makeup of the plants.

Crude protein (%)

The crude protein content (%) of elephant foot yam on fresh weight basis as influenced by different fertilizer levels in combination with biofertilizer application is presented in Table 3.4.

Effect of Fertilizer levels: The crude protein content (%) of elephant foot yam was significantly influenced by different levels of the recommended dose of fertilizers (RDF), with values ranging from 2.94 to 3.46% during 2023-2024 and from 2.33 to 3.17% during 2024-2025, while the pooled mean varied between 2.64and 3.32%. Among fertilizer application of 100% RDF resulted in higher crude protein content compared to 75% RDF and the control (0% RDF) The increase in crude protein content with higher levels of RDF may be attributed to enhanced nitrogen availability, which plays a crucial role in amino acid synthesis and protein formation. Adequate nutrient supply improves nitrogen uptake and assimilation, leading to increased synthesis of structural and enzymatic proteins in the tubers.

These findings corroborate the results reported by Remya and Suja (2018) [10], in an acidic soils (pH 5.10) of Alathara, Kattela, Sreekariyam, Thiruvananthapuram district, Kerala. Sharmila (2001) also observed graded increase in crude protein content with graded level of fertilizer applied in splits to elephant foot yam.

Effect of Biofertilizers

The crude protein content of elephant foot yam ranged from 2.44 to 3.65% during 2023-2024, from 2.22 to 3.23 % during 2024-2025, and from 2.33 to 3.52% in the pooled analysis. Application of biofertilizers in various combinations, namely *Azotobacter* + PSB (B₁), *Azospirillum* + PSB (B₂), *Azotobacter* + VAM (B₃), and *Azospirillum* + PSB (B₄), resulted in increased crude protein content (%) of elephant foot yam compared to no biofertilizer application (B₀). The increase in crude protein content of elephant foot yam with the application of biofertilizers may be attributed to their role in enhancing nutrient availability and uptake. *Azotobacter* contribute to biological nitrogen fixation, thereby increasing the supply of available nitrogen, which is essential for amino acid and protein synthesis. Phosphate-solubilizing bacteria (PSB) improve phosphorus availability by converting insoluble soil phosphates into plant-available forms, facilitating energy transfer and metabolic processes involved in protein formation. Significantly higher crude protein content was consistently recorded with the application of *Azotobacter*+ PSB @ 10 kg ha⁻¹ each (B₁). In an investigation on effect of integrated nutrient management (INM) practices on yield and quality attributes of elephant foot yam conducted at instructional farm of College of Agriculture, Vellayani, Thiruvananthapuram, Kerala, Dhanalakshmi and Rajasree (2023) [23] observed an increase in crude protein content of elephant foot yam with application of RDF applied with consortium of *Azospirillum lipoferum*, *Azotobacter chroococcum*, *Bacillus megaterium* and *B sporothermodurans* over the lower dose of fertilizers in slightly acidic soils having pH 6.1.

Table 6: Crude protein (g/ 100 g) in tuber of elephant foot yam as influenced by different fertilizer levels with biofertilizers during *Kharif-Rabi*, 2023-24 and 2024-25

Treat	Crude protein (g/100g) in tuber of elephant foot yam (FW%)											
	Kharif - Rabi2023-24				Kharif - Rabi2024-25				Pooled data			
	F ₀	F ₁	F ₂	Mean	F ₀	F ₁	F ₂	Mean	F ₀	F ₁	F ₂	Mean
B ₀	2.23	2.45	2.63	2.44	2.13	2.20	2.33	2.22	2.18	2.33	2.48	2.33
B ₁	3.44	3.75	3.76	3.65	2.58	3.18	3.93	3.23	3.01	3.64	3.92	3.52
B ₂	3.33	3.35	3.58	3.42	2.22	2.96	3.12	2.76	2.77	3.44	3.35	3.19
B ₃	3.42	3.69	3.62	3.57	2.56	2.93	3.67	3.05	2.99	3.45	3.54	3.33
B ₄	2.30	3.20	3.74	3.08	2.18	2.43	2.83	2.48	2.24	2.81	3.29	2.78
Mean	2.94	3.29	3.46	3.23	2.33	2.74	3.17	2.75	2.64	3.13	3.31	3.03
	F	B	F×B		F	B	F×B		F	B	F×B	
S.Em±	0.08	0.10	0.17		0.07	0.09	0.16		0.05	0.07	0.11	
C.D. at 5%	0.22	0.28	0.49		0.21	0.27	0.47		0.15	0.19	0.33	
F ₀ - No fertilizer	B ₀ - No biofertilizer											
F ₁ - 75% RDF	B ₁ - <i>Azotobacter</i> + PSB @ 10 kg/ha each											
F ₂ - 100 % RDF	B ₂ - <i>Azotobacter</i> + VAM@ 10 kg/ha each											
	B ₃ - <i>Azospirillum</i> + PSB@ 10 kg/ha each											
	B ₄ - <i>Azospirillum</i> + + VAM @ 10 kg/ha each											

Combined effect of fertilizer levels and biofertilizers

The interaction effect of RDF levels (0%, 75%, and 100%) and biofertilizer combinations (*Azotobacter* + PSB, *Azospirillum* + PSB, *Azotobacter* + VAM, and *Azospirillum* + PSB) significantly influence the crude protein content of elephant foot yam. The crude protein content varied from 2.23 to 3.76 % in 2023-24 and from 2.13 to 3.93% in 2024-25, with a pooled mean ranging between 2.18 to 3.92 %. Among the treatment combinations, application of 100% RDF along with *Azotobacter* + PSB (B₁) recorded the highest crude protein content (3.76% and 3.93% during 2023-24 and 2024-25, respectively, with a pooled mean of 3.92%). The higher crude protein content under these treatment combinations may be attributed to adequate and balanced nitrogen supply through RDF and biological nitrogen fixation by biofertilizers. Improved nitrogen availability enhances amino acid synthesis, and once the crop's nitrogen requirement is fulfilled,

Calcium oxalate content (%)

Lower oxalate content in elephant foot yam is important from a human consumption perspective because oxalates can cause throat irritation and reduce mineral bioavailability, particularly calcium and iron. Reduced oxalate levels improve palatability, digestibility, and nutritional safety, making the tuber more acceptable for regular consumption. The calcium oxalate content (%) of elephant foot yam on a dry weight basis, as affected by varying fertilizer levels in combination with biofertilizer application, is presented in Table 3.5.

Effect of fertilizer levels

The oxalate content (%) of elephant foot yam was significantly affected by varying levels of the recommended dose of fertilizers (RDF). During 2023-2024, oxalate content ranged from 0.277 to 0.243%, while in 2024-2025 it varied from 0.271 to 0.230 %. The pooled mean values across both years showed a narrow range from 0.274 to 0.237%, indicating minimal variation among RDF treatments. Among the fertilizer treatments, application of 100% RDF recorded the significantly lowest oxalate content compared to 0% RDF and was found to be at par with 75% RDF (F₁) during both seasons as well as in the pooled analysis. Application of RDF ensures an adequate and balanced supply of nitrogen, phosphorus, and potassium,

which enhances overall plant growth and metabolic efficiency. In particular, SSP supplies calcium in addition to phosphorus, and increased calcium availability promotes the formation of insoluble calcium oxalate complexes, thereby reducing the accumulation of free oxalic acid in plant tissues. Balanced nitrogen nutrition also prevents excessive synthesis of organic acids, including oxalates, which often occurs under nutrient stress. Furthermore, improved nutrient status reduces physiological stress in plants grown on nutrient-poor lateritic soils, leading to better regulation of oxalate metabolism. As a result, fertilized plants exhibit lower oxalate content compared to unfertilized plants under such soil conditions. These results are in agreement with the findings of Remya and Suja (2018) ^[10], who reported the lowest oxalate content in elephant foot yam grown in acidic soils (pH 5.10) at Alathara, Kattela, and Sreekariyam of Thiruvananthapuram district, Kerala, under improved packages of practices such as conservation chemicals, compared to farmers' practices. Anju *et al.* (2020) ^[1] noticed decrease in oxalate content with the application of higher customized fertilizer dose over traditional farmers' practice and conventional PoP.

Effect of biofertilizers

The oxalate content of elephant foot yam ranged from 0.313 to 0.216 % during 2023-2024, from 0.281 to 0.214 % during 2024-2025, and from 0.297 to 0.215 % in the pooled analysis. Application of biofertilizers in various combinations, namely *Azotobacter* + PSB (B₁), *Azospirillum* + PSB (B₂), *Azotobacter* + VAM (B₃), and *Azospirillum* + PSB (B₄), resulted in decreased oxalate content (%) of elephant foot yam compared to no biofertilizer application (B₀). The decrease in oxalate content of elephant foot yam with the application of biofertilizers can be explained by their positive influence on nutrient availability, uptake, and plant metabolism. Biofertilizers such as *Azotobacter* and *Azospirillum* enhance biological nitrogen fixation and improve root growth, leading to balanced nitrogen nutrition and better metabolic regulation. Phosphate-solubilizing bacteria (PSB) and VAM (arbuscular mycorrhizal fungi) increase the availability and uptake of phosphorus and associated cations such as calcium and magnesium, which play a key role in oxalate metabolism. Adequate calcium availability promotes the formation of stable calcium oxalate complexes and regulates intracellular calcium levels,

thereby limiting excessive oxalic acid synthesis. Significantly lower oxalate content was consistently

recorded with the application of *Azotobacter* + PSB @ 10 kg ha⁻¹ each (B₁).

Table 3.5: Calcium oxalate (%) in tuber of elephant foot yam as influenced by different fertilizer levels with biofertilizers during *Kharif-Rabi*, 2023-24 and 2024-25

Treatment	Calcium oxalate content (%) in tuber											
	<i>Kharif - Rabi</i> 2023-24				<i>Kharif - Rabi</i> 2024-25				Pooled data			
	F ₀	F ₁	F ₂	Mean	F ₀	F ₁	F ₂	Mean	F ₀	F ₁	F ₂	Mean
B ₀	0.342	0.290	0.308	0.313	0.333	0.260	0.250	0.281	0.337	0.275	0.279	0.297
B ₁	0.218	0.220	0.210	0.216	0.217	0.215	0.209	0.214	0.217	0.218	0.210	0.215
B ₂	0.285	0.250	0.231	0.256	0.262	0.260	0.242	0.255	0.274	0.254	0.236	0.255
B ₃	0.236	0.224	0.214	0.225	0.220	0.230	0.219	0.223	0.228	0.227	0.216	0.224
B ₄	0.303	0.308	0.252	0.288	0.325	0.267	0.232	0.275	0.314	0.287	0.242	0.281
Mean	0.277	0.258	0.243		0.271	0.246	0.230		0.274	0.252	0.237	
	F	B	F×B		F	B	F×B		F	B	F×B	
S.Em±	0.01	0.01	0.02		0.01	0.01	0.02		0.01	0.01	0.02	
C.D. at 5%	0.02	0.03	NS		0.03	0.04	NS		0.02	0.03	NS	
F ₀ - No fertilizer	B ₀ - No biofertilizer											
F ₁ - 75% RDF	B ₁ - <i>Azotobacter</i> + PSB @ 10 kg/ha each											
F ₂ - 100 % RDF	B ₂ - <i>Azotobacter</i> + VAM@ 10 kg/ha each											
	B ₃ - <i>Azospirillum</i> + + PSB@ 10 kg/ha each											
	B ₄ - <i>Azospirillum</i> + + VAM @ 10 kg/ha each											

According to Dhanalakshmi and Rajasree (2023) [23], integrated nutrient management comprising the recommended dose of fertilizers along with a microbial consortium (*Azospirillum lipoferum*, *Azotobacter chroococcum*, *Bacillus megaterium* and *B. sporothermodurans*) resulted in the lowest oxalate content in elephant foot yam corms grown under slightly acidic soil conditions (pH 6.1), as compared with reduced fertilizer levels. Similar reductions in oxalate content due to organic and biological nutrient sources were earlier reported by Suja (2013) and Nedunchezhiyan *et al.* (2017) [12]. Navya *et al.* (2017) [15] also found decreases in calcium oxalate content of elephant foot yam with application of biofertilizers i.e. combination of *Azospirillum*, Phosphate solubilizing bacteria (PSB) and Potash Mobilizing Bacteria (KMB) over no application.

Combined effect of fertilizer levels and biofertilizers

The interaction effect of RDF levels (0%, 75%, and 100%) and biofertilizer combinations *Azotobacter* + PSB, *Azospirillum*+ PSB, *Azotobacter*+ VAM, and *Azospirillum* + PSB did not significantly influence the oxalate content of elephant foot yam, while the oxalate content varied from 0.342 to 0.210% in 2023-24 and from 0.333 to 0.209 % in 2024-25, with a pooled mean ranging between 0.337 to 0.210%. Among the treatment combinations, 100% RDF applied with *Azotobacter* + PSB (B₁) recorded the numerically lowest oxalate content (0.210 % and 0.209 %, respectively during 2023-24 and 2024-25 with a mean of 0.210 %). Similar findings were reported by Navya *et al.* (2017) [15] who observed that the calcium oxalate content of elephant foot yam corms was not significantly influenced by the application of different integrated nutrient management (INM) sources. Comparable results were also reported earlier by Annepu (2011) [2] and Kumar *et al.*, (2015) [11] who likewise found no significant effect of nutrient management practices on oxalate content. Similar decrease in oxalate content of elephant foot yam with the combined application of consortia mixture of PSB + *Azotobacter* + ZSB (Zinc Solubilizing Bacteria) with different doses of fertilizers over its sole dose and maximum calcium oxalate content (0.235 %) under control was also observed by Saroj (2020).

Conclusion

The nutrient content of elephant foot yam corms were significantly influenced by different levels of recommended fertilizer dose (RDF) and biofertilizer application. The application of 100% RDF (F₂) consistently recorded the highest nitrogen, phosphorus, potassium, and micronutrient (Fe, Mn, and Zn) contents in leaves and corms during both years of study. Among the biofertilizer treatments, *Azotobacter* + PSB @ 10 kg ha⁻¹ each (B₁) proved superior by significantly enhancing nutrient concentration over the other treatments. The combined application of 100% RDF + *Azotobacter* + PSB (F₂B₁) produced the highest N, P, and K contents in leaves and corms, indicating a positive synergistic effect of chemical fertilizers and biofertilizers on nutrient accumulation. Micronutrient contents (Fe, Mn, and Zn) also improved with 100% RDF and B₁ treatments, whereas copper (Cu) content remained statistically unaffected. Overall, integrated nutrient management involving 100% RDF supplemented with *Azotobacter* and PSB was found to be the most effective strategy for improving nutrient content

The application of 100% RDF (F₂) consistently improved total sugar, starch, crude fiber, and crude protein contents while significantly reducing oxalate content compared to lower fertilizer levels and the control. Among the biofertilizer treatments, *Azotobacter* + PSB @ 10 kg ha⁻¹ each (B₁) proved most effective in enhancing quality attributes and minimizing oxalate content. The combined application of 100% RDF + *Azotobacter* + PSB (F₂B₁) recorded the highest total sugar, starch, and crude protein contents, whereas the interaction effect on crude fiber and oxalate content was non-significant. Overall, integrated nutrient management through 100% RDF supplemented with *Azotobacter* and PSB was the most effective strategy for improving the nutritional quality and reducing anti nutritional oxalate content of elephant foot yam corms under the lateritic soils of the Konkan region.

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