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Comparative Evaluation of Potassium Sources under Integrated Nutrient Management for Growth and Biomass Production in Mango Ginger (*Curcuma amada* Roxb.)

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Authors' contributions

This work was carried out in collaboration among all authors. Authors GV and SS contributed to the investigation, data collection, data curation, formal analysis, data interpretation and original draft preparation. Author CTS was responsible for conceptualization, methodology development, supervision, and validation, as well as the critical review and editing of the manuscript. Authors SR and SA contributed to resources, investigation, validation, data curation and the review and editing of the manuscript. All authors read and approved the final manuscript.

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Abstract

Mango ginger (*Curcuma amada* Roxb.) is an important rhizomatous spice crop with considerable culinary and medicinal value; however, crop-specific information on integrated nutrient management is limited. The present investigation was conducted to evaluate the influence of different integrated nutrient management practices on the growth and physiological attributes of mango ginger and to identify an efficient nutrient management strategy. A field experiment was conducted under open-field conditions at Pandrimalai, Dindigul district, Tamil Nadu, during 2023–2024 using mango ginger cv. Hosur local. The experiment was laid out in a randomised block design with eight treatments and three replications. The treatments comprised the 100% recommended dose of fertiliser (RDF) and combinations of 75 or 50% of the recommended doses of nitrogen and phosphorus with 100% of the recommended potassium dose supplied through polyhalite, potassium humate or potassium schoenite. Growth and physiological parameters were recorded at 30-day intervals until harvest. The results revealed that integrated nutrient management significantly influenced plant height, number of leaves, leaf area, leaf area index, leaf area duration, number of tillers, chlorophyll content, fresh and dry weights, whereas days to sprouting and sprouting percentage were not significantly affected. Among the treatments, T_2 [75% RDF (N and P only) + 100% K_2O through polyhalite] consistently recorded superior growth performance. At harvest, T_2 recorded the highest plant height (70.58 cm), number of leaves (7.64), leaf area (110.21 dm²), leaf area index (3.56), number of tillers (4.62), chlorophyll content (59.26 SPAD units at 150 DAP), fresh weight (524.56 g plant^{-1}) and dry weight (164.48 g plant^{-1}). T_6 [75% RDF (N and P only) + 100% potassium schoenite] was the next best treatment, while the control generally recorded the lowest values. The superior performance of T_2 may be attributed to the balanced and sustained supply of potassium, calcium, magnesium and sulphur through polyhalite, which supported canopy development, chlorophyll status, assimilate production and biomass accumulation. The study concludes that the application of 75% of the recommended N and P dose along with 100% K_2O through polyhalite was the most promising nutrient management practice under the conditions studied for improving growth and physiological performance of mango ginger.

Keywords: Curcuma amada Roxb.; polyhalite; potassium sources; plant growth; biomass production.

1. Introduction

Mango ginger (*Curcuma amada* Roxb.) is an important rhizomatous spice crop belonging to the family Zingiberaceae. It is characterised by rhizomes resembling ginger (*Zingiber officinale* Rosc.) in appearance, but possess the characteristic aroma and flavour of raw mango. The plant habit and foliage closely resemble turmeric (*Curcuma longa* L.) (Sasikumar, 2005). Owing to its distinctive flavour, culinary value and medicinal properties, mango ginger has considerable potential as a high-value spice and medicinal crop. Its rhizomes are used in salads, pickles, chutneys and other processed products and have also been reported to exhibit antioxidant, antimicrobial and anti-inflammatory properties (Chandarana *et al.*, 2005; Policegoudra *et al.*, 2011; Al-Qudah *et al.*, 2017).

Nutrient management plays a vital role in determining the growth and biomass production of mango ginger. Adequate and balanced nutrient availability is essential for vigorous vegetative growth, efficient photosynthesis and translocation of assimilates to developing plant parts. Nitrogen promotes vegetative growth and chlorophyll synthesis; phosphorus supports root development and energy transfer, while potassium plays an important role in carbohydrate synthesis and translocation (Sasikumar, 2005). Integrated nutrient management (INM), involving the complementary use of inorganic fertilisers and organic nutrient sources, offers a sustainable approach to meeting crop nutrient requirements while maintaining soil productivity (Mohanty *et al.*, 2014). Organic sources improve soil organic matter and support sustained nutrient availability, whereas inorganic fertilisers provide readily available nutrients during critical stages of crop growth. Studies in related rhizomatous crops, such as ginger and turmeric, have demonstrated the importance of balanced nutrient management in improving growth (Shadap & Pariari, 2016; Srinivasan *et al.*, 2016).

In soilless ginger production, NPK combinations influenced photosynthesis and seed-rhizome development (Wang *et al.*, 2025), whereas potassium humate, used with compost and inorganic fertilisers, affected maize growth attributes (Akhtar *et al.*, 2022). Polyhalite application has been associated with improved growth in groundnut (Sunitha *et al.*, 2023) and has been evaluated for growth, yield and nutrient uptake in onion and garlic (Arunachalam *et al.*, 2025). In sweetpotato, polyhalite gave yields comparable to muriate of potash but showed different potassium-release characteristics (Kile *et al.*, 2025).

However, crop-specific information on integrated nutrient management in mango ginger remains limited, and nutrient schedules developed for related crops are often adopted without adequate validation. Therefore, the present investigation was conducted to evaluate different integrated nutrient management practices and their influence on growth and dry matter production of mango ginger, with the aim of identifying a suitable and sustainable nutrient management strategy.

2. Materials and Methods

2.1 Experimental Site and Plant Material

The field experiment was conducted under open-field conditions at Pandrimalai, Dindigul district, Tamil Nadu, India, during the 2023–2024 cropping season. The experimental site is located at an elevation of approximately 1251 m above mean sea level and lies within the Western Agro-Climatic Zone of Tamil Nadu. The experiment used mango ginger (*Curcuma amada* Roxb.) cv. Hosur local.

The experimental field was prepared to a fine tilth and raised beds measuring 3.0 × 1.2 × 0.15 m were formed with a 45-cm space between adjacent plots. Healthy, mature and disease-free seed rhizomes weighing 15–20 g and containing 3–4 well-developed buds

were selected for planting. The seed rhizomes were treated with cow dung slurry and planted at a spacing of 30 × 30 cm and a depth of approximately 3.5–4.0 cm.

2.2 Experimental Design and Treatments

The field experiment was conducted in a randomised block design comprising eight treatments and three replications, with 30 plants maintained in each experimental plot. The recommended dose of fertilizer (RDF) for mango ginger was 30:30:60 kg $N:P_2O_5:K_2O$ ha^{-1}. Farmyard manure (FYM) at 25 t ha^{-1} was uniformly incorporated into the soil during the final land preparation.

Urea, single superphosphate (SSP) and muriate of potash (MOP) were used as conventional sources of nitrogen (N), phosphorus (P) and potassium (K), respectively. The treatments comprised 100% RDF and combinations of 75 or 50% of the recommended N and P doses with 100% of the recommended K dose supplied through polyhalite, potassium humate or potassium schoenite. To supply 60 kg K_2O ha^{-1}, 428.6 kg ha^{-1} of polyhalite, 500 kg ha^{-1} of potassium humate or 300 kg ha^{-1} of potassium schoenite was applied according to the respective treatment. All nutrient sources were applied to the soil, and fertilisers were applied in two equal splits at planting and 45 days after planting (DAP).

All plots were maintained under uniform cultural practices. Hand weeding was carried out at 40–50-day intervals and earthing up was performed during the crop growth period. Irrigation was provided during the initial establishment stage and thereafter according to crop requirements and rainfall. Shoot borer incidence was managed using 3% neem oil sprays. The crop was harvested at maturity, as indicated by drying and lodging of the plants.

2.3 Observations and Measurements

Five representative plants from each replication were selected for recording growth parameters at 30-day intervals until harvest. The observations included days to sprouting, sprouting percentage, plant height, number of leaves per clump, number of tillers per clump, leaf length, leaf breadth, leaf area, leaf area index (LAI), leaf area duration (LAD) and chlorophyll content (SPAD value). Plant fresh and dry weights were also recorded at different growth stages.

Plant height was measured from ground level to the tip of the fully expanded leaf. Fully opened leaves and tillers were counted for each selected plant. Leaf length and breadth were measured on the third fully expanded leaf from the top of the tallest tiller. Leaf area was determined using a LI-3000C portable leaf area meter (LI-COR Biosciences, Lincoln, Nebraska, USA) and LAI and LAD were calculated using standard procedures. Chlorophyll content was measured using a SPAD-502 chlorophyll meter. For dry weight estimation, plant samples were oven-dried at 60 °C until constant weight was attained.

2.4 Statistical Analysis

The data were subjected to analysis of variance (ANOVA) appropriate for a randomised block design. The significance of treatment effects was assessed using the F-test and treatment means were compared at the 5% probability level (Gomez & Gomez, 1984). Statistical analyses were performed using R software.

3. Results and Discussion

The present investigation demonstrated that integrated nutrient management practices significantly influenced the growth and physiological attributes of mango ginger. The treatments did not significantly influence days to sprouting and sprouting percentage. Days to sprouting ranged from 8.61 to 9.02 days, while sprouting percentage varied from 70.99 to 71.63 per cent. The highest sprouting percentage was recorded in T_2 [75% of the recommended N and P dose + 100% K_2O through polyhalite] (71.63%), followed by T_6 (71.59%), whereas the control recorded 70.99 per cent. As the differences were not significant, the nutrient management treatments did not have a marked influence on sprouting behaviour (Table 1).

In contrast, plant height was significantly influenced by the nutrient management treatments at all stages of crop growth. Plant height increased progressively from 30 DAP to harvest in all treatments. The 75% RDF (N & P only) + 100% Polyhalite treatment recorded the highest plant height of 27.63, 35.96, 46.46, 55.52, 67.80 and 70.58 cm at 30, 60, 90, 120, 150 DAP and harvest, respectively. T_6 [75% RDF (N & P only) + 100% potassium schoenite] ranked next, with corresponding values of 26.55, 35.72, 46.15, 55.29, 67.40 and 70.34 cm. The lowest values were generally recorded in T_8 (Control), which registered 22.25, 31.86, 41.28, 51.59, 61.03 and 66.47 cm, respectively. Thus, T_2 consistently promoted greater plant height throughout the crop growth period. The significantly greater plant height observed under T_2 could be attributed to improved nutrient availability and metabolic activity, resulting in enhanced cell division and elongation. Potassium-mediated osmotic regulation and maintenance of cellular turgor favour cell expansion and vegetative growth (Zhu *et al.*, 2025). In addition, improved root development and nutrient absorption under balanced calcium nutrition may have supported vigorous shoot growth. Similar positive plant growth responses to balanced nutrient supply have been reported by Das *et al.* (2026).

The number of leaves was also significantly influenced by the nutrient management practices and increased progressively with crop growth. The 75% RDF (N & P only) + 100% Polyhalite treatment recorded the maximum number of leaves at all stages, with 2.50, 3.75, 4.55, 5.65, 6.32 and 7.64 leaves at 30, 60, 90, 120, 150 DAP and harvest, respectively. T_6 followed closely with 2.45, 3.72, 4.51, 5.63, 6.29 and 7.57 leaves, whereas T_8 recorded the lowest values of 1.62, 3.19, 3.90, 5.23, 5.73 and 6.43 leaves at the respective stages.

Table 1. Effect of integrated nutrient management on sprouting and plant height of mango ginger

Treatments		Days taken for sprouting	Sprouting percentage %	Plant height (cm)					
				30 DAP	60 DAP	90 DAP	120 DAP	150 DAP	AH
T_1	100% RDF (30:30:60 Kg/ha)	8.80	71.21	24.29	33.30	43.10	52.97	63.41	67.91
T_2	75% RDF (N & P only) + 100% Polyhalite	9.02	71.63	27.63	35.96	46.46	55.52	67.80	70.58
T_3	50% RDF (N & P only) + 100% Polyhalite	8.88	71.42	25.54	34.65	44.80	54.26	65.63	69.26
T_4	75% RDF (N & P only) + 100% Potassium humate	8.73	71.20	23.21	33.20	42.97	52.87	63.23	67.81
T_5	50% RDF (N & P only) + 100% Potassium humate	8.72	71.02	23.00	32.08	41.55	51.80	61.38	66.68
T_6	75% RDF (N & P only) + 100% Potassium schoenite	8.95	71.59	26.55	35.72	46.15	55.29	67.40	70.34
T_7	50% RDF (N & P only) + 100% Potassium schoenite	8.87	71.39	25.33	34.42	44.52	54.05	65.26	69.04
T_8	Control	8.61	70.99	22.25	31.86	41.28	51.59	61.03	66.47
S.Ed.		NS	NS	0.42	0.45	0.57	0.44	0.75	0.46
CD 5%		NS	NS	0.88	0.95	1.21	0.91	1.58	0.96

(**AH – At Harvest*)

Table 2. Effect of integrated nutrient management on leaf production and leaf area of mango ginger

Treatments		Number of leaves						Leaf area (dm^2)					
		30 DAP	60 DAP	90 DAP	120 DAP	150 DAP	AH	30 DAP	60 DAP	90 DAP	120 DAP	150 DAP	AH
T_1	100% RDF (30:30:60 Kg/ha)	1.93	3.39	4.13	5.38	5.94	6.86	45.09	58.98	71.10	96.07	109.07	103.85
T_2	75% RDF (N & P only) + 100% Polyhalite	2.50	3.75	4.55	5.65	6.32	7.64	48.95	65.13	78.34	102.25	120.81	110.21
T_3	50% RDF (N & P only) + 100% Polyhalite	2.22	3.57	4.34	5.52	6.13	7.25	46.53	62.09	74.76	99.19	113.45	107.06
T_4	75% RDF (N & P only) + 100% Potassium humate	1.91	3.37	4.11	5.37	5.92	6.83	43.84	58.74	70.80	95.82	105.25	103.59
T_5	50% RDF (N & P only) + 100% Potassium humate	1.67	3.22	3.93	5.25	5.76	6.50	43.60	56.15	67.75	93.22	104.52	100.91
T_6	75% RDF (N & P only) + 100% Potassium schoenite	2.45	3.72	4.51	5.63	6.29	7.57	47.70	64.57	77.68	101.68	116.99	109.63
T_7	50% RDF (N & P only) + 100% Potassium schoenite	2.17	3.54	4.31	5.49	6.10	7.19	46.29	61.57	74.15	98.67	112.70	106.53
T_8	Control	1.62	3.19	3.90	5.23	5.73	6.43	42.73	55.65	67.17	92.72	101.87	100.40
S.Ed.		0.10	0.06	0.07	0.05	0.07	0.13	0.48	1.05	1.24	1.06	1.47	1.09
CD 5%		0.20	0.13	0.15	0.10	0.14	0.28	1.02	2.21	2.60	2.22	3.09	2.28

(**AH – At Harvest*)

A similar trend was observed for leaf area (Table 2). T_2 [75% RDF (N & P only) + 100% Polyhalite] recorded the highest leaf area at all stages, with values of 48.95, 65.13, 78.34, 102.25, 120.81 and 110.21 dm² at 30, 60, 90, 120, 150 DAP and harvest, respectively. T_6 recorded the next highest values of 47.70, 64.57, 77.68, 101.68, 116.99 and 109.63 dm², while the control recorded the lowest values of 42.73, 55.65, 67.17, 92.72, 101.87 and 100.40 dm², respectively. Leaf area increased up to 150 DAP and declined slightly at harvest in all treatments. The higher number of leaves and greater leaf area under T_2 indicate the development of a more efficient photosynthetic canopy. Potassium improves nitrogen-use efficiency and promotes leaf expansion through the maintenance of cellular turgidity (Li *et al.*, 2022). Greater leaf area increases the interception of solar radiation and expands the photosynthetically active surface, thereby promoting dry matter accumulation. The greater leaf area observed under polyhalite nutrition may therefore have provided a larger photosynthetic surface for assimilate production and subsequent biomass accumulation (Sharvesh *et al.*, 2026; Madhavan *et al., 2025a*).

The leaf area index (LAI) followed a similar pattern and increased progressively with crop growth (Table 3). T_2 [75% RDF (N & P only) + 100% Polyhalite] recorded the highest LAI at all stages, recording values of 1.22, 1.84, 2.45, 2.92, 3.53 and 3.56 at 30, 60, 90, 120, 150 DAP and harvest, respectively. T_6 recorded 1.21, 1.83, 2.43, 2.90, 3.51 and 3.55, respectively, whereas the control recorded the lowest values of 1.12, 1.70, 2.16, 2.63, 3.27 and 3.31. The higher LAI under T_2 indicates greater canopy development and potentially greater interception of available radiation. The corresponding higher leaf area duration (LAD) further indicates prolonged maintenance of photosynthetically active leaf area. T_2 recorded the highest LAD values during the successive growth intervals and at harvest, whereas the control consistently recorded comparatively lower values.

The superior canopy development under 75% RDF (N & P only) + 100% Polyhalite may be attributed to the balanced and sustained supply of potassium, calcium, magnesium and sulphur through polyhalite. Potassium plays an important role in several physiological and biochemical processes, including enzyme activation, photosynthesis, protein synthesis, carbohydrate metabolism and assimilate translocation (Sardans & Peñuelas, 2021). Adequate potassium nutrition also regulates stomatal function and water relations, thereby supporting photosynthetic activity and biomass production. Calcium contributes to cell wall development, membrane stability and root growth, whereas magnesium, as the central constituent of the chlorophyll molecule, is directly involved in photosynthetic carbon assimilation (de Bang *et al.*, 2021). Sulphur is essential for the synthesis of sulphur-containing amino acids and proteins and supports several metabolic and enzymatic processes. The combined supply of these nutrients through polyhalite may therefore have created favourable conditions for enhanced growth and development (Sharvesh *et al., 2026*). The number of tillers was significantly influenced by the nutrient management treatments and increased with crop age.

T_2 recorded the highest number of tillers, with 2.45, 3.12, 3.90, 4.15, 4.62 and 4.62 tillers at 30, 60, 90, 120, 150 DAP and harvest, respectively. The 75% RDF (N & P only) + 100% Potassium schoenite treatment ranked next, recording 2.43, 3.10, 3.89, 4.14, 4.60 and 4.60 tillers, whereas T_8 recorded the lowest values of 2.19, 2.84, 3.67, 3.94, 4.33 and 4.33 tillers at the respective stages. The increased number of tillers under polyhalite application may be associated with improved nutrient availability and assimilate partitioning towards actively growing buds and shoots. Potassium plays a major role in source–sink relationships and facilitates the translocation of carbohydrates to developing plant parts (Sharvesh *et al.*, 2026; Hasanuzzaman *et al.*, 2018). Adequate calcium and sulphur nutrition may further support meristematic activity, tissue development and vegetative multiplication (Muruganandam *et al.,* 2025; Sharvesh *et al.*, 2026).

Chlorophyll content also differed significantly among the treatments (Table 4). The SPAD values increased from 30 to 120 DAP and subsequently showed a slight decline at 150 DAP. T_2 recorded the highest chlorophyll content at all stages, with values of 47.35, 52.18, 57.32, 60.14 and 59.26 SPAD units at 30, 60, 90, 120 and 150 DAP, respectively. T_6 followed with 47.02, 51.84, 55.80, 59.85 and 58.93 SPAD units, while the control (T_8) recorded the lowest values of 41.80, 46.37, 48.52, 55.27 and 53.78 SPAD units, respectively. Magnesium is indispensable for chlorophyll biosynthesis and functions as an activator of several enzymes involved in photosynthesis. Adequate magnesium availability promotes chloroplast development and photosynthetic activity, whereas its deficiency can result in chlorosis and reduced biomass accumulation (Tränkner *et al.*, 2018; Madhavan *et al., 2025b*).

The improvement in vegetative growth under T_2 was further reflected in plant fresh and dry weights (Table 5). Fresh weight increased markedly with crop growth in all treatments. T_2 recorded the highest fresh weight at all stages, reaching 35.13, 127.73, 269.56, 345.54, 438.89 and 524.56 g plant^{-1} at 30, 60, 90, 120, 150 DAP and harvest, respectively. T_6 [75% RDF (N & P only) + 100% Potassium schoenite] followed with 35.01, 125.16, 268.41, 344.03, 437.44 and 511.21 g plant^{-1}, while the control (T_8) recorded 33.13, 112.87, 250.18, 320.16, 414.48 and 447.34 g plant^{-1}, respectively.

Dry weight showed a similar trend. T_2 recorded the highest dry weight at 30, 60, 90, 120, 150 DAP and harvest, with values of 5.27, 19.16, 46.20, 86.45, 132.78 and 164.48 g plant^{-1}, respectively. T_6 recorded the next highest values of 5.18, 19.08, 45.98, 85.99, 129.08 and 159.49 g plant^{-1}, whereas comparatively lower values were observed under the control (T_8). The greater fresh and dry matter accumulation under T_2 [75% RDF (N & P only) + 100% Polyhalite] may be the cumulative consequence of enhanced leaf production, larger leaf area, higher LAI, prolonged LAD, greater tillering and improved chlorophyll status, which together favoured photosynthate production and biomass accumulation. The present findings are broadly supported by previous studies reporting improved plant growth and biomass production following polyhalite application. Satisha and Ganeshamurthy (2016) reported improved vegetative growth and biomass accumulation in cabbage and cauliflower, while Sacks *et al.* (2017) and Da Costa Mello *et al.* (2018) observed enhanced vegetative vigour and plant growth in tomato. Similarly, Dal Molin *et al.* (2020) reported increased dry matter accumulation under polyhalite fertilisation, whereas Bhatt *et al.* (2021) and Karthikeyan *et al.* (2023) also observed improvements in growth-related parameters in sugarcane and blackgram, respectively. The beneficial response has generally been associated with the simultaneous supply of potassium, calcium, magnesium and sulphur.

Table 3. Effect of integrated nutrient management on leaf area index and leaf area duration of mango ginger

Treatments		leaf area index (dm^2)						Leaf Area Duration					
		30 DAP	60 DAP	90 DAP	120 DAP	150 DAP	AH	30 DAP	60 DAP	90 DAP	120 DAP	150 DAP	AH
T_1	100% RDF (30:30:60 Kg/ha)	1.16	1.75	2.26	2.73	3.36	3.40	44.51	60.93	77.16	93.54	103.37	1.16
T_2	75% RDF (N & P only) + 100% Polyhalite	1.22	1.84	2.45	2.92	3.53	3.56	45.91	64.35	80.55	96.75	106.35	1.22
T_3	50% RDF (N & P only) + 100% Polyhalite	1.19	1.80	2.36	2.83	3.45	3.48	45.22	62.21	78.87	95.16	104.88	1.19
T_4	75% RDF (N & P only) + 100% Potassium humate	1.15	1.75	2.26	2.72	3.35	3.39	44.45	59.81	77.02	93.41	103.25	1.15
T_5	50% RDF (N & P only) + 100% Potassium humate	1.13	1.71	2.18	2.64	3.28	3.32	43.86	59.60	75.59	92.06	102.00	1.13
T_6	75% RDF (N & P only) + 100% Potassium schoenite	1.21	1.83	2.43	2.90	3.51	3.55	45.78	63.24	80.24	96.46	106.08	1.21
T_7	50% RDF (N & P only) + 100% Potassium schoenite	1.18	1.79	2.34	2.81	3.43	3.47	45.10	61.99	78.59	94.89	104.63	1.18
T_8	Control	1.12	1.70	2.16	2.63	3.27	3.31	43.75	57.91	75.32	91.80	101.76	1.12
S.Ed.		0.01	0.02	0.03	0.03	0.03	0.03	0.24	0.43	0.58	0.55	0.51	0.24
CD 5%		0.02	0.03	0.07	0.07	0.06	0.06	0.50	0.90	1.22	1.15	1.07	0.50

*(*AH – At Harvest)*

Table 4. Effect of integrated nutrient management on tillering and chlorophyll content of mango ginger

Treatments		Number of tillers						Chlorophyll content (SPAD)				
		30 DAP	60 DAP	90 DAP	120 DAP	150 DAP	AH	30 DAP	60 DAP	90 DAP	120 DAP	150 DAP
T_1	100% RDF (30:30:60 Kg/ha)	2.28	2.94	3.75	4.01	4.43	4.43	43.75	48.41	52.64	56.98	55.71
T_2	75% RDF (N & P only) + 100% Polyhalite	2.45	3.12	3.90	4.15	4.62	4.62	47.35	52.18	57.32	60.14	59.26
T_3	50% RDF (N & P only) + 100% Polyhalite	2.37	3.03	3.83	4.08	4.53	4.53	45.57	50.32	54.39	58.58	57.50
T_4	75% RDF (N & P only) + 100% Potassium humate	2.27	2.93	3.74	4.01	4.43	4.43	43.61	48.26	51.12	56.86	55.56
T_5	50% RDF (N & P only) + 100% Potassium humate	2.20	2.85	3.68	3.95	4.35	4.35	42.09	46.67	50.83	55.53	54.07
T_6	75% RDF (N & P only) + 100% Potassium schoenite	2.43	3.10	3.89	4.14	4.60	4.60	47.02	51.84	55.80	59.85	58.93
T_7	50% RDF (N & P only) + 100% Potassium schoenite	2.35	3.01	3.81	4.07	4.51	4.51	45.27	50.00	54.09	58.31	57.20
T_8	Control	2.19	2.84	3.67	3.94	4.33	4.33	41.80	46.37	48.52	55.27	53.78
S.Ed.		0.03	0.03	0.03	0.02	0.03	0.03	0.61	0.64	0.59	0.54	0.61
CD 5%		0.06	0.07	0.05	0.05	0.07	0.07	1.29	1.35	1.23	1.13	1.28

(**AH – At Harvest*)

Table 5. Effect of integrated nutrient management on fresh and dry biomass production of mango ginger

Treatments		Fresh weight of plants (g plant^{-1})						Dry weight of plants (g plant^{-1})					
		30 DAP	60 DAP	90 DAP	120 DAP	150 DAP	AH	30 DAP	60 DAP	90 DAP	120 DAP	150 DAP	AH
T_1	100% RDF (30:30:60 Kg/ha)	33.83	119.83	256.99	329.08	423.06	483.52	5.01	18.29	43.75	81.46	121.41	149.13
T_2	75% RDF (N & P only) + 100% Polyhalite	35.13	127.73	269.56	345.54	438.89	524.56	5.27	19.16	46.20	86.45	132.78	164.48
T_3	50% RDF (N & P only) + 100% Polyhalite	34.49	122.78	263.35	337.40	431.06	498.86	5.10	18.73	44.99	83.98	125.65	154.87
T_4	75% RDF (N & P only) + 100% Potassium humate	33.78	117.26	256.49	328.42	422.43	470.18	4.92	18.26	43.66	81.26	117.69	144.14
T_5	50% RDF (N & P only) + 100% Potassium humate	33.23	116.78	251.19	321.49	415.76	467.64	4.90	17.89	42.63	79.15	116.99	143.19
T_6	75% RDF (N & P only) + 100% Potassium schoenite	35.01	125.16	268.41	344.03	437.44	511.21	5.18	19.08	45.98	85.99	129.08	159.49
T_7	50% RDF (N & P only) + 100% Potassium schoenite	34.38	122.27	262.29	336.01	429.73	496.21	5.09	18.66	44.78	83.56	124.92	153.88
T_8	Control	33.13	112.87	250.18	320.16	414.48	447.34	4.77	17.82	42.43	78.75	111.36	135.61
S.Ed.		0.22	0.99	2.15	2.81	2.71	5.15	0.03	0.15	0.42	0.85	1.43	1.93
CD 5%		0.47	2.08	4.51	5.91	5.68	10.81	0.07	0.31	0.88	1.79	3.00	4.14

(**AH – At Harvest*)

Overall, the findings indicate that the application of 75% of the recommended N and P dose in combination with 100% of the recommended K_2O through polyhalite provided favourable nutritional conditions for mango ginger. T_2 consistently recorded superior performance for plant height, number of leaves, leaf area, LAI, LAD, number of tillers, chlorophyll content, fresh weight and dry weight, while the control (T_8) generally recorded the lowest values. The superior growth performance under T_2 may be attributed to the balanced supply of potassium, calcium, magnesium and sulphur through polyhalite, which collectively improved nutrient availability, canopy development, chlorophyll status, assimilate production and biomass accumulation. Thus, T_2 emerged as the most promising integrated nutrient management treatment for enhancing vegetative growth and physiological performance of mango ginger.

4. Conclusion

The field experiment demonstrated differences in the growth and biomass responses of mango ginger to the tested nutrient management treatments. The combination of 75% of the recommended nitrogen and phosphorus doses (22.5 kg N and 22.5 kg P_2O_5 ha^{-1}) with 100% of the recommended potassium dose (60 kg K_2O ha^{-1}) supplied through polyhalite (T_2) produced the highest recorded values for several vegetative parameters. At harvest, T_2 attained a plant height of 70.58 cm, 7.64 leaves per clump, 4.62 tillers per clump, a leaf area index of 3.56, a fresh plant weight of 524.56 g and a dry plant weight of 164.48 g. The corresponding treatment using potassium schoenite (T_6) generally produced the next highest values, whereas the control showed comparatively lower growth and biomass. Days to sprouting and sprouting percentage were not significantly affected by the treatments. Taken together, the results suggest that polyhalite can be considered as a potassium source in the tested nutrient management programme for improving vegetative performance of mango ginger under the prevailing experimental conditions. Further investigation would be needed before extending this recommendation to other cultivation environments.

5. Limitations

The experiment was conducted at one location during the 2023–2024 cropping season with a single mango ginger cultivar. Accordingly, the results describe treatment responses under the specific field conditions studied and should not be generalised without further validation. The reported observations principally concern sprouting, vegetative growth, chlorophyll status and plant biomass. Rhizome yield, economic returns and post-harvest soil nutrient changes were not presented. Additional field trials across locations and seasons, including rhizome yield and economic assessments, would strengthen the evidence for wider nutrient management recommendations.

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Declaration of AI Use

This manuscript was prepared through the intellectual contributions of the author(s) to the study design, data analysis, interpretation of results, and scholarly content. ChatGPT, Claude and Perplexity were used solely to assist with grammatical refinement and reference formatting during manuscript revision. The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

Competing Interests

Authors have declared that no competing interests exist.

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