



RESEARCH ARTICLE

Growth and nutrient uptake of rice (*Oryza sativa* L.) as influenced by varied rate of potassium humate foliar application

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Abstract

A field experiment was conducted during the *Kharif* season of 2021-22 at the Agronomy Main Research Farm, Odisha University of Agriculture and Technology, Bhubaneswar, to evaluate the effect of different rates of potassium humate foliar application on rice growth and nutrient uptake. The experiment followed a randomized complete block design (RCBD) with nine treatment combinations and three replications. The findings demonstrated that foliar application of potassium humate @ 3 g L⁻¹ at tillering and panicle initiation (PI) stages (T₇) significantly enhanced plant height (121.8 cm), tiller density (437.8 tillers m⁻²), dry matter accumulation (1079.11 g m⁻²), LAI (4.41), crop growth rate (18.18 g m⁻² day⁻¹), relative growth rate (40.82 mg g⁻¹ day⁻¹), grain yield (5234 kg ha⁻¹) and nutrient uptake compared to other treatments. However, it was statistically at par with T₉ (potassium humate @ 4 g L⁻¹ at tillering and PI stage) and T₅ (potassium humate @ 2 g L⁻¹ at tillering and PI stage), indicating a saturation effect beyond a certain dosage. This suggests that an optimal dose of potassium humate can enhance crop performance, supporting its potential use as a biostimulant for improving rice productivity under field conditions.

Keywords: growth parameters; LAI; nutrient uptake; potassium humate

Introduction

Rice (*Oryza sativa*) is the cornerstone of global nutrition, feeding more than half of the world's population and accounting for approximately 20 % of the global caloric intake. Alongside *Oryza sativa*, African rice (*Oryza glaberrima*) is another independently domesticated species, though *O. sativa* accounts for almost all global production. From 1961 to 2019, global rice production increased approximately three times from 215 million tonnes to 755 million tonnes, mostly contributed by Asia (China, India, Bangladesh) (1). India, being the world's second-largest producer and consumer, accounting for 136.7 million tonnes production (2), is driven by improved agronomic practices, favourable climatic conditions and government support. This crop serves not only as a vital food source providing carbohydrates, vitamins, but also underpins the economic livelihood of millions. The United Nations declared 2004 as the international year of rice, considering its importance. In Odisha, rice contributes a major role in sustaining the livelihood, economy and food security of the state. It is grown round the year, i.e., in *Kharif*, *Rabi*, *Zaid* and autumn, because of the ecological condition of the state, being a major food crop (3).

Integrated nutrient management plays a pivotal role in enhanced and sustained production, which could be achieved if organic and inorganic fertilizers are used in combination. Soil organic matter is a storehouse of nutrients, consisting of humus, obtained through microbial decomposition of plant and animal derivatives. Humus consists of humic substances, viz. humic acid, fulvic acid and humin. Humic acid and fulvic acid are alkali-soluble and acid-soluble, respectively. Whereas humin is the insoluble fraction (4). Humic acid is composed of functional groups like phenolics, carboxyls, alcohol and hydroxyls (5) and can be used as a soil amendment, fertilizer enhancer, seed treatment, hydroponics and as a biostimulant. These substances have been known to increase hormonal activity, enzyme activity, membrane permeability, cation exchange capacity and water-holding capacity (WHC) in soil. Specifically, WHC is enhanced by the increase in soil organic matter, which in turn improves porosity, aggregate formation and the presence of hydrophilic functional groups (-COOH, -OH) form hydrogen bonds with water molecules. All these positive benefits ultimately lead to increased yield as well as nutrient uptake (6, 7).

Potassium humate is a salt of humic acid and is a highly concentrated form of humus. It is derived from lignite, i.e., brown coal, a peat material that has not been fully converted into coal (8), which acts as a biostimulant. It is easily dissolved in water and absorbed by the plants, overcoming the limitation of humic acid, which only dissolves at higher pH. It is reported to have significant positive stimulating effects on the growth and yield of crops (9) by increasing chlorophyll content, thus photosynthesis (10), root proliferation (11), seed germination (12), nutrient availability in soil (13), stimulating microbial and enzymatic activity (14). Research on the foliar application of potassium humate on rice has been limited. Hence, a field experiment was designed to elucidate the response of rice to the bio-stimulating effects of potassium humate at varying levels of foliar applications.

Materials and Methods

Experimental site

The present study was carried out in the *Kharif* 2021 in the Agronomy Main Research (AMR) farm of Odisha University of Agriculture and Technology, Bhubaneswar. It is located at 20°15'N latitude and 85°52'E longitude, 64 km away from the Bay of Bengal in the east, at an altitude of 25.9 m above the mean sea level. The range of meteorological parameters like average maximum temperatures during the experimental period (July-December 2021) varied from 26.2 to 35 °C and the monthly average minimum temperatures varied from 18.3 to 27 °C, measured via maximum and minimum thermometer. December was the driest month with 72.6 mm of rainfall and September, with 579.4 mm of recorded rainfall, was the wettest month with 16 rainy days during the cropping period as recorded by the rain gauge. Mean monthly average relative humidity (RH) at 7 AM varied from 81.7% to 96.9% and at 1 PM from 60.1% to 84.4% as recorded by the hygrometer. Campbell-Stokes sunshine recorder reported 0.9 to 8.3 hr of monthly average bright sunshine hours (BSSH) during the experimental period and anemometer recorded 0.2 to 4.9 km hr⁻¹ monthly average wind velocity. USWB Class-A open pan evaporimeter values ranged from 2.0 to 4.2 mm day⁻¹ (Fig. 1). The

soil of the experimental plot was sandy loam in texture with acidic in reaction (5.8) (15), medium in organic carbon (0.63 %) (16) and non-saline (0.22 dS m⁻¹) (17). In case of nutrient content, it was low in available nitrogen (250.1 kg ha⁻¹) (18), medium in available phosphorus (22.2 kg ha⁻¹) (19) and medium in available potassium (199.2 kg ha⁻¹) (20).

Treatments

The experiment was conducted in a randomized complete block design (RCBD), replicated thrice, consisting of nine treatment combinations as shown in Table 1. The potassium humate used in the experiment had 85 % potassium humate and 8 % potassium procured from the market. Foliar spray was done in the early morning or late afternoon when temperatures are cooler and sunlight intensity is low with the help of knapsack sprayer with flat-fan nozzle.

Crop management

'Hasanta' (IET-21477) is a semi-dwarf, long duration (145 days) variety of rice suitable for irrigated shallow lowland and rainfed ecologies, moderately resistant to blast, bacterial leaf blight, sheath blight, leaf folder, tolerant to brown plant hopper, bearing short bold grain with yield potential of 5.5 t ha⁻¹ was chosen as the test crop variety. The Main field was prepared using mould board plough and power tiller. 25 days old seedlings were transplanted @ 2-3 seedlings hill⁻¹ at spacing of 20 × 10 cm. A uniform fertilizer dose of 80:40:40 kg ha⁻¹ N, P₂O₅, K₂O was applied to all the

Table 1. Treatment details

Codes	Treatment description
T ₁	Control
T ₂	Potassium humate @ 1 g L ⁻¹ at panicle initiation (PI) stage
T ₃	Potassium humate @ 1 g L ⁻¹ at tillering and PI stage
T ₄	Potassium humate @ 2 g L ⁻¹ at PI stage
T ₅	Potassium humate @ 2 g L ⁻¹ at tillering and PI stage
T ₆	Potassium humate @ 3 g L ⁻¹ at PI stage
T ₇	Potassium humate @ 3 g L ⁻¹ at tillering and PI stage
T ₈	Potassium humate @ 4 g L ⁻¹ at PI stage
T ₉	Potassium humate @ 4 g L ⁻¹ at tillering and PI stage

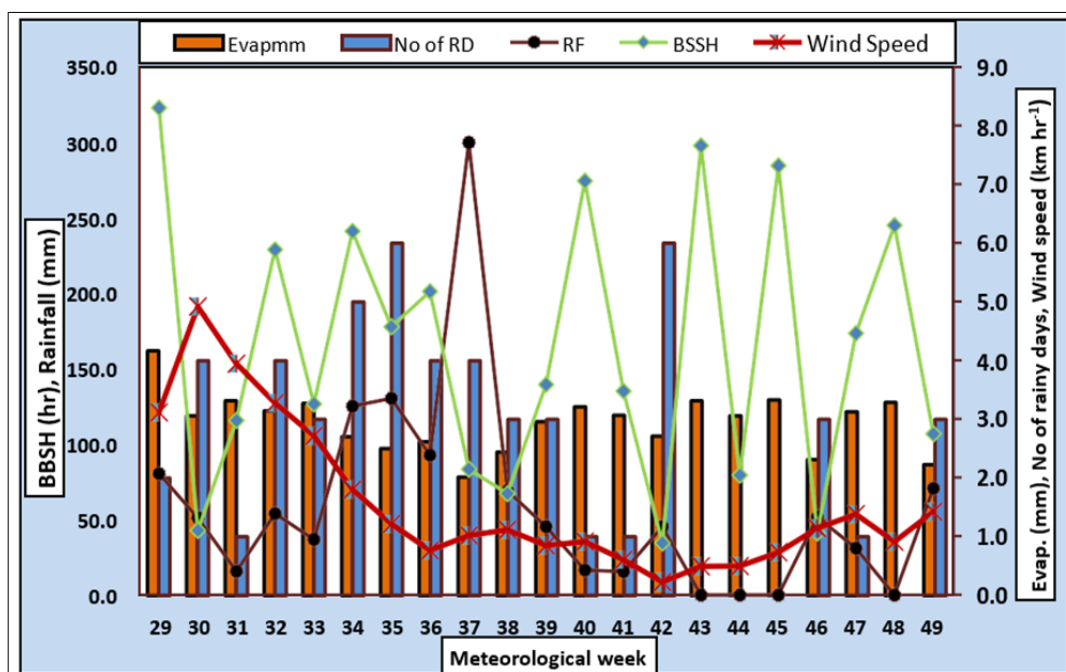


Fig. 1. Meteorological parameters during the cropping season.

treatments through urea, Di-Ammonium Phosphate (DAP) and Muriate of Potash (MOP). After final puddling, N half dose (40 kg ha⁻¹), P and K full dose (40 kg ha⁻¹) were applied. At the active tillering and booting stage, remaining N dosage was top-dressed @ 20 kg ha⁻¹. 4-5 cm of water was maintained in the field during the initial period and thereafter drained when the crop reached physiological maturity. Pretilachlor 50 % EC was applied as pre-emergence herbicide and Almix (metsulfuron methyl 10 % + chlorimuron ethyl 10 % WP) as post-emergence. All other agronomic practices were done according to the needs of the crop.

Observation

Periodically, growth parameters viz. plant height, tillers and dry matter accumulation were measured at 30-day intervals. Leaf area index (LAI), crop growth rate (CGR) and relative growth rate (RGR) were computed following the standard equations (21). At the time of harvest, plant samples were collected randomly from each treatment, oven-dried at 70 °C, then finely grounded, passed through a 2 mm sieve and analysed for N, P and K by the standard methods. Nutrient uptake (N, P and K) was analysed using the standard equations.

$$LAI = \frac{\text{Total leaf area}}{\text{Ground area}}$$

$$CGR \text{ (g/m}^2\text{/day)} = \frac{W_2 - W_1}{A(T_2 - T_1)}$$

$$RGR \text{ (mg/m}^2\text{/day)} = \frac{\text{Ln } W_2 - \text{Ln } W_1}{T_2 - T_1}$$

W₁ = Dry weight of plant at time T₁

W₂ = Dry weight of plant at time T₂

A = Ground area

Nutrient uptake (kg/ha) =

$$\frac{\text{Nutrient content (\%)} \times \text{dry matter yield (kg/ha)}}{100}$$

Statistical analysis

Data were analysed statistically by analysis of variance (ANOVA) (22). Critical difference (CD) and standard error of mean SE (m) were calculated at 5 % level of significance. The F-test was used to determine the significance of the treatment variation.

Results and Discussion

Foliar application of potassium humate at different dosages and stages had a lucid effect on the growth characteristics of rice cv. Hasanta. Plant height increased with the advancement of the growth stages and it reached its maximum at harvest. However, the rate of increase declined after 90 DAT (days after transplanting). Maximum plant height (121.8 cm) was recorded at harvest with the application of potassium humate @ 3 g L⁻¹ at tillering and PI stage (T₇), recording 9.7 % taller plants than the control. It remained at par with T₉ (potassium humate @ 4 g L⁻¹ at tillering and PI stage) and T₅ (potassium humate @ 2 g L⁻¹ at tillering and PI stage). T₇ recorded the highest number of tiller m⁻² (437.8) at 60 DAT, which declined at harvest (358.6). However, at harvest, T₇ was at par only with T₉ (354.3) and T₅ (346.6) (Table 2). Leaf area index (LAI) attained its peak at 60 DAT and thereafter it declined irrespective of the treatment applied. The differences in LAI among the treatments were significant at different stages of crop growth. The maximum LAI was observed in T₇ (4.41) at 60 DAT, being par with T₉ (4.34) and T₅ (4.30), whereas the control recorded the lowest LAI (3.87).

There was a successive increase in dry matter accumulation throughout the growth stages of the crop. However, the maximum rate of increase was noticed at 30-60 DAT and thereafter the rate of increase was slow (Table 3). The maximum dry matter accumulation was noticed at harvest for all the treatments, irrespective of the potassium humate dosage and time of application. T₇, T₉ and T₅ recorded 17.4 %, 14.2 % and 13.1 % increase in dry matter over control, respectively. The increased growth attributes and dry matter of rice due to foliar application of potassium humate might be due to higher root and shoot proliferation with increased cell division. It acted as a growth stimulant by enhancing Indole acetic acid synthesis and activity, thereby enhancing the growth attributes (23). Increased biochemical processes in plants, such as photosynthetic rate, total chlorophyll content, transpiration rate, respiration, as well as increased stomatal conductance through foliar application of potassium humate have also been reported in previous study (24).

The maximum value of crop growth rate (CGR) for all the treatments was obtained at 30-60 DAT, after which it declined. Furthermore, the decline continued up to harvest for all the treatments and no significant differences were observed. T₇ recorded the highest value, whereas control (T₁) recorded the lowest CGR during 30-60 DAT. Also, the relative growth rate (RGR) of the crop was not significantly influenced by different treatments, irrespective of the dosage and time of application for all the intervals (Table 4).

Table 2. Effect of varied rate of potassium humate application on plant height and tiller no. m⁻² of rice

Treatments	Plant height (cm)				Tiller no. m ⁻²			
	30 DAT	60 DAT	90 DAT	Harvest	30 DAT	60 DAT	90 DAT	Harvest
T ₁ : Control	36.3	72.1	108.2	111.0	226.8	355.0	327.1	291.1
T ₂ : PH @ 1 g L ⁻¹ at PI	36.6	72.7	108.3	111.2	229.4	365.6	344.2	309.8
T ₃ : PH @ 1 g L ⁻¹ at T and PI	37.1	73.4	110.1	112.7	241.2	374.8	354.0	318.6
T ₄ : PH @ 2 g L ⁻¹ at PI	37.3	72.9	109.3	111.5	234.5	370.3	349.3	314.4
T ₅ : PH @ 2 g L ⁻¹ at T and PI	38.7	77.9	115.0	118.9	267.6	413.0	385.1	346.6
T ₆ : PH @ 3 g L ⁻¹ at PI	37.4	74.0	110.5	112.9	250.0	380.7	355.8	320.2
T ₇ : PH @ 3 g L ⁻¹ at T and PI	38.6	80.1	118.8	121.8	268.8	437.8	398.5	358.6
T ₈ : PH @ 4 g L ⁻¹ at PI	38.0	74.6	110.9	113.1	256.9	383.6	357.8	321.9
T ₉ : PH @ 4 g L ⁻¹ at T and PI	38.9	78.3	117.1	120.9	264.8	429.8	393.7	354.3
SE (m) ±	1.24	1.74	2.44	2.70	9.63	15.56	13.18	12.20
CD (P=0.5)	NS	5.2	7.3	8.1	28.8	46.6	39.5	36.5

PH: potassium humate; T: tillering; PI: panicle initiation.

Table 3. Effect of varied rate of potassium humate application on LAI and dry matter accumulation of rice

Treatments	LAI			Dry matter accumulation (g m ⁻²)			
	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT	Harvest
T ₁ : Control	1.76	3.87	2.75	197.81	671.40	871.85	918.98
T ₂ : PH @ 1 g L ⁻¹ at PI	1.78	3.90	2.79	198.33	677.94	890.67	941.47
T ₃ : PH @ 1 g L ⁻¹ at T and PI	1.86	4.00	2.85	206.04	698.22	916.47	970.33
T ₄ : PH @ 2 g L ⁻¹ at PI	1.83	3.92	2.81	201.75	690.57	908.45	961.37
T ₅ : PH @ 2 g L ⁻¹ at T and PI	2.00	4.30	3.14	220.65	748.77	982.48	1039.59
T ₆ : PH @ 3 g L ⁻¹ at PI	1.93	4.03	2.88	210.44	707.20	935.83	991.20
T ₇ : PH @ 3 g L ⁻¹ at T and PI	2.22	4.41	3.28	226.96	772.41	1015.50	1079.11
T ₈ : PH @ 4 g L ⁻¹ at PI	1.98	4.04	2.91	216.61	715.78	937.13	993.62
T ₉ : PH @ 4 g L ⁻¹ at T and PI	2.07	4.34	3.19	225.18	758.20	989.71	1049.71
SE (m) ±	0.089	0.120	0.090	4.668	18.019	22.896	18.739
CD (P=0.5)	0.27	0.36	0.27	13.99	54.01	68.63	56.17

PH: potassium humate; T: tillering; PI: panicle initiation.

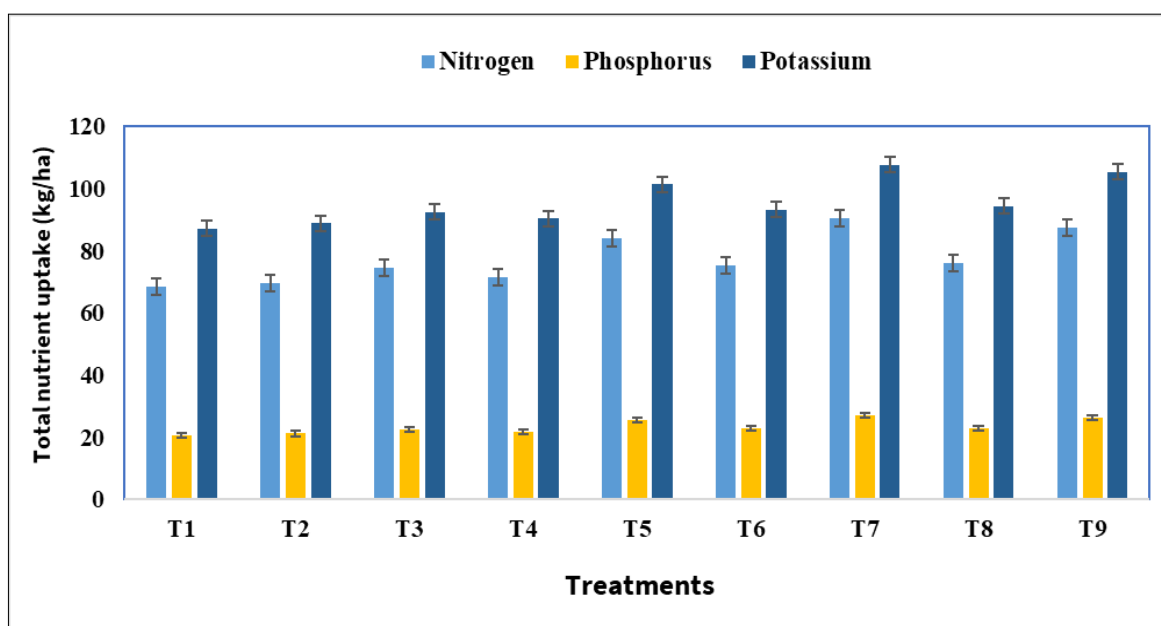
Table 4. Effect of varied rate of potassium humate application on crop growth rate and relative growth rate of rice

Treatments	Crop growth rate (g m ⁻² day ⁻¹)			Relative growth rate (mg g ⁻¹ day ⁻¹)		
	30-60 DAT	60-90 DAT	90 DAT -Harvest	30-60 DAT	60-90 DAT	90 DAT - Harvest
T ₁ : Control	15.79	6.68	2.14	40.74	8.70	2.45
T ₂ : PH @ 1 g L ⁻¹ at PI	15.99	7.09	2.31	40.96	9.10	2.53
T ₃ : PH @ 1 g L ⁻¹ at T and PI	16.41	7.33	2.45	40.62	9.06	2.68
T ₄ : PH @ 2 g L ⁻¹ at PI	16.29	7.25	2.41	41.01	9.14	2.56
T ₅ : PH @ 2 g L ⁻¹ at T and PI	17.60	7.79	2.60	40.73	9.06	2.58
T ₆ : PH @ 3 g L ⁻¹ at PI	16.56	7.09	2.52	40.39	9.35	2.61
T ₇ : PH @ 3 g L ⁻¹ at T and PI	18.18	8.14	2.89	40.82	9.12	2.74
T ₈ : PH @ 4 g L ⁻¹ at PI	16.64	6.83	2.57	39.85	8.98	2.64
T ₉ : PH @ 4 g L ⁻¹ at T and PI	17.77	7.72	2.73	40.50	8.88	2.68
SE (m) ±	0.523	0.269	1.042	0.711	0.328	1.101
CD (P=0.5)	1.57	0.81	NS	NS	NS	NS

PH: potassium humate; T: tillering; PI: panicle initiation.

T₇ yielding 5234 kg ha⁻¹ grains recorded the highest NPK uptake in grains (61.24 kg N ha⁻¹, 18.73 kg P ha⁻¹ and 21.46 kg K ha⁻¹). T₇ was at par with T₉ and T₅ in terms of grain NPK uptake. Similarly, the highest NPK uptake in straw to the tune of 29.07 kg N ha⁻¹, 8.39 kg P ha⁻¹, 86.25 kg K ha⁻¹ accompanied by the highest straw yield (6201 kg ha⁻¹) was observed in T₇. Nutrient uptake data are provided in the Supplementary Table S1. Total NPK uptake followed a similar pattern with T₇ recording the highest uptake and remained at par with T₉ and T₅. T₇, T₉ and T₅ recorded 27.8 %, 24.5 % and 19.7 % increase in total nutrient uptake over the control, respectively (Fig. 2). The increased uptake of nutrients with

foliar application of potassium humate might have been attributed to increased concentration of nutrients in plant parts along with higher biomass. The nutrient concentration was improved with the application of humic acid due to enhanced permeability of membranes and interaction with phospholipid of cell membrane, thereby acting as a carrier of nutrients (8). Nutrient solubilisation and transport were also enhanced due to the application of humic acid because of its chelating property, which facilitates and aids in the protection and uptake of available forms of nutrients (25). Similar results were noticed in previous finding with wheat (26).

**Fig. 2.** Effect of varied rate of potassium humate application on total nutrient uptake of rice.

Conclusion

The results of our study indicate that foliar application of potassium humate at a concentration of 3 g L⁻¹ at both the tillering and PI stages in rice has a significant effect on the enhancement of growth parameters by recording 9.7 % taller plant, 23.3 % higher tiller m⁻², 17.4 % higher dry matter accumulation, 13.2 % higher yield and, subsequently recording 27.8 % higher total nutrient uptake than control. The combined application, along with the recommended dose of fertilizer at these critical phenological stages, ensured sustained nutrient availability, leading to enhanced physiological performance and biomass accumulation. Future research should assess the long-term impacts of potassium humate on soil nutrient dynamics, crop sustainability through multi-location trials evaluating different concentrations, application timings and synergist effect with other biostimulants/nutrient sources for enhancing rice productivity and resilience under diverse production systems for improving rice productivity.

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Authors' contributions

MK, HKS and SKD conducted the field experiment, collected data and performed the statistical analysis. MK drafted the manuscript, while SAA, SP and KK contributed to its editing and SKP, TS and TJ did critical review of the manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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