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Influence of varying doses of inorganic fertilizers, humic acid, vermicompost and PGPR on growth and yield of potato (*Solanum tuberosum* L.)

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Abstract

The present investigation entitled “Influence of varying doses of inorganic fertilizers, humic acid, vermicompost and PGPR on growth and yield of potato (*Solanum tuberosum* L.)” was conducted during Rabi 2021-22 and 2022-23 at the College of Agriculture, Gwalior, Madhya Pradesh. The experiment was laid out in a Randomized Block Design with three replications comprising fifteen treatment combinations of 100% and 75% recommended dose of fertilizers (RDF) integrated with humic acid, vermicompost and PGPR (Azotobacter, PSB, KSB and SSB). The pooled results revealed that treatment T₁₅ (75% RDF + humic acid + vermicompost + Azotobacter + PSB + KSB + SSB) recorded significantly higher growth and yield parameters. Maximum plant height (26.30, 44.20 and 57.15 cm at 30, 60 and 90 DAP, respectively), number of compound leaves per plant (11.18, 13.49 and 18.16 at 30, 60 and 90 DAP), number of tubers per plant (8.93) and tuber yield (471.58 q/ha) were observed under T₁₅, which remained statistically at par with T₁₃, T₁₂, T₁₄ and T₁₁ in most cases. The minimum values for all parameters were recorded under T₁ (100% RDF). The enhanced performance under integrated treatments may be attributed to improved nutrient availability, better soil health, enhanced microbial activity and increased physiological efficiency of the crop. Thus, it can be concluded that application of 75% RDF along with humic acid, vermicompost and PGPR is an effective and sustainable nutrient management strategy for improving growth and yield of potato.

Keywords: Potato, inorganic fertilizers, humic acid, vermicompost, PGPR (Plant growth promoting rhizobacteria), azotobacter, PSB, KSB, SSB, growth and yield)

Introduction

Potato (*Solanum tuberosum* L.) is one of the most important tuber crops in the world and serves as a staple food for millions of people. It ranks fourth after rice, wheat and maize in terms of global food production and plays a crucial role in ensuring food and nutritional security (FAO, 2022) [7]. In India, potato is cultivated extensively due to its high yield potential, short duration and adaptability to diverse agro-climatic conditions. However, sustaining higher productivity while maintaining soil health remains a major challenge.

The productivity of potato largely depends on balanced nutrient management. Excessive reliance on inorganic fertilizers has led to deterioration of soil structure, nutrient imbalance and reduced microbial activity (Singh and Lal, 2012) [13]. Although chemical fertilizers provide readily available nutrients, their continuous use without organic supplementation adversely affects soil fertility and environmental sustainability (Tiwari, 2002) [14]. Therefore, integrated use of organic and inorganic nutrient sources has gained importance in modern agriculture.

Vermicompost is an organic amendment rich in macro and micronutrients, beneficial microbes and growth-promoting substances. It improves soil structure, enhances nutrient availability and increases crop productivity (Edwards *et al.*, 2004) [6]. Similarly, humic acid, a natural component of soil organic matter, plays a significant role in improving nutrient uptake, root growth and enzymatic activity in plants (Chen and Aviad, 1990) [5]. The application of humic substances has been reported to enhance plant growth and yield in several crops, including potato.

Plant Growth-Promoting Rhizobacteria (PGPR) are beneficial soil microorganisms that colonize plant roots and stimulate growth through various mechanisms such as nitrogen fixation,

phosphate solubilization and production of phytohormones (Kloepper *et al.*, 1980) ^[9]. PGPR not only improve nutrient use efficiency but also enhance plant resistance to biotic and abiotic stresses (Vessey, 2003) ^[15]. Their integration with organic and inorganic nutrient sources offers a sustainable approach to improving crop productivity.

Recent studies have emphasized the synergistic effect of combining inorganic fertilizers with organic amendments and biofertilizers. Integrated nutrient management (INM) has been shown to improve soil health, increase nutrient availability and enhance crop yield and quality (Chaudhary *et al.*, 2017) ^[4]. In potato, such integrated approaches have resulted in better tuber yield, improved quality parameters and enhanced economic returns.

Despite the known benefits, the optimum combination and dose of inorganic fertilizers, humic acid, vermicompost and PGPR for maximizing potato growth and yield under specific agro-climatic conditions is still not well established. Therefore, the present study was undertaken to evaluate the influence of varying doses of inorganic fertilizers, humic acid, vermicompost and PGPR on growth and yield of potato.

Materials and Methods

The present investigation entitled “Influence of varying doses of inorganic fertilizers, humic acid, vermicompost and PGPR on growth, yield and quality of potato (*Solanum tuberosum* L.)” was conducted during the Rabi seasons of 2021-22 and 2022-23 at the Research Field, College of Agriculture, Gwalior, Madhya Pradesh, situated at 26°13' N latitude and 76°14' E longitude with an altitude of 211.52 m above mean sea level. The region experiences a semi-arid, sub-tropical climate with hot summers, cold winters, and an average annual rainfall of 700-800 mm. The soil of the experimental field was slightly alkaline (pH 7.6), low in organic carbon and available nitrogen, medium in phosphorus and low in potassium. The experiment was laid out in a Randomized Block Design with three replications and fifteen treatment combinations involving T₁-100% RDF; T₂-75% RDF + Humic acid 25 kg/ha; T₃-75% RDF + Vermicompost 12 t/ha; T₄-75% RDF + Humic acid + Azotobacter + PSB + KSB; T₅-75% RDF + Humic acid + Azotobacter + PSB + SSB; T₆-75% RDF + Humic acid + PSB + KSB + SSB; T₇-75% RDF + Humic acid + Azotobacter + PSB + KSB + SSB; T₈-75% RDF + Vermicompost + Azotobacter + PSB + KSB; T₉-75% RDF + Vermicompost + Azotobacter + PSB + SSB; T₁₀-75% RDF + Vermicompost + PSB + KSB + SSB; T₁₁-75% RDF + Vermicompost + Azotobacter + PSB + KSB + SSB; T₁₂-75% RDF + Humic acid + Vermicompost + Azotobacter + PSB + KSB; T₁₃-75% RDF + Humic acid + Vermicompost + Azotobacter + PSB + SSB; T₁₄-75% RDF + Humic acid + Vermicompost + PSB + KSB + SSB; T₁₅-75% RDF + Humic acid + Vermicompost + Azotobacter + PSB + KSB + SSB. Standard agronomic practices including land preparation, seed treatment with Mancozeb (0.2%), planting at 60 × 20 cm spacing, irrigation, nutrient management, intercultural operations and plant protection measures were followed uniformly in all treatments. Observations on growth parameters (plant height, number of leaves, stem diameter, fresh and dry

weight), yield attributes (number of tubers, tuber size, weight and yield) and quality parameters (dry matter, TSS and starch content) were recorded at appropriate stages. Economic analysis was carried out in terms of cost of cultivation, gross and net returns, and benefit-cost ratio. The data obtained were statistically analyzed using analysis of variance (ANOVA) for Randomized Block Design as per standard procedures.

Results

The pooled data on 30 DAP, the maximum plant height (26.30 cm) was recorded under treatment T₁₅, which was statistically at par with T₁₃ (25.70 cm), T₁₂ (24.97 cm), T₁₄ (23.96 cm), T₁₁ (23.63 cm), T₉ (23.11 cm), T₈ (22.98 cm) and T₁₀ (22.55 cm). The minimum pooled plant height (16.29 cm) was recorded under T₁ (100% RDF).

The mean of two year data at 60 DAP, the maximum plant height (44.20 cm) was recorded under treatment T₁₅, which was statistically at par with T₁₃ (41.97 cm), T₁₂ (41.66 cm), T₁₄ (40.88 cm), T₁₁ (40.38 cm), T₉ (40.09 cm), T₈ (39.26 cm), T₁₀ (39.13 cm), T₇ (38.66 cm), T₅ (38.48 cm) and T₄ (38.08 cm). The minimum pooled plant height (17.45 cm) was recorded under T₁ (100% RDF).

After 90 DAP, the maximum plant height (57.15 cm) was recorded under treatment T₁₅, which was statistically at par with T₁₃ (54.05 cm), T₁₂ (53.80 cm), T₁₄ (53.02 cm), T₁₁ (52.74 cm), T₉ (52.22 cm), T₈ (52.06 cm) and T₁₀ (51.89 cm), T₇ (51.49 cm), T₅ (51.19 cm) and T₄ (50.73 cm). The minimum pooled plant height (22.93 cm) was recorded under T₁ (100% RDF).

On pooled basis data on 30 DAP, the maximum number of compound leaves per plant (11.18) was recorded under treatment T₁₅, which was statistically at par with T₁₃ (10.69), T₁₂ (10.49), T₁₄ (10.25), T₁₁ (10.15), T₉ (9.88) and T₈ (9.59). The minimum pooled number of compound leaves per plant (4.48) was recorded under T₁ (100% RDF).

The data on 60 DAP, the maximum number of compound leaves per plant (13.49) was recorded under treatment T₁₅, which was statistically at par with T₁₃ (13.22), T₁₂ (12.70), T₁₄ (12.51), T₁₁ (12.20), T₉ (12.08), T₈ (11.89) and T₁₀ (11.56). The minimum pooled number of compound leaves per plant (9.90) was recorded under T₁ (100% RDF).

Based on pooled data at 90 DAP, the maximum number of compound leaves per plant (18.16) was recorded under treatment T₁₅, which was statistically at par with T₁₃ (17.68), T₁₂ (17.14), T₁₄ (16.97), T₁₁ (16.74), T₉ (16.25), T₈ (15.81), T₁₀ (15.60) and T₇ (15.40). The minimum pooled number of compound leaves per plant (13.08) was recorded under T₁ (100% RDF).

On pooled basis, the maximum number of tubers per plant at harvest (8.93) was recorded under T₁₅. It was statistically at par with T₁₃ (8.45), T₁₂ (8.29), T₁₄ (8.17), T₁₁ (7.86), T₉ (7.74) and T₈ (7.65). The minimum pooled value (5.94) was observed under T₁ (100% RDF).

The mean of the both year experimental data, the maximum tuber yield per hectare at harvest (471.58 q/ha) was recorded under T₁₅. It was statistically at par with T₁₃ (445.16 q/ha), T₁₂ (435.69 q/ha), T₁₄ (428.99 q/ha) and T₁₁ (419.68 q/ha). The minimum pooled value (263.58 q/ha) was recorded under T₁ (100% RDF).

Table 4.1: Effect of varying dose of fertilizer, humic acid, vermicompost and rhizobacteria on growth and yield of potato

S. No.	Days to Sprout (Pooled)	Plant Height (Mean of two years)			Number of compound leaves per (Mean of two years)			Number of tubers per plant at harvest (Mean of two years)	Tuber yield per hectare (q) at harvest
		At 30 DAP	At 60 DAP	At 90 DAP	At 30 DAP	At 60 DAP	At 90 DAP		
T ₁	12.45	16.29	17.45	39.43	4.48	9.90	13.08	5.94	263.58
T ₂	12.07	21.21	36.69	49.12	7.93	10.50	13.54	6.26	278.36
T ₃	11.89	21.47	37.12	49.64	8.08	10.69	13.79	6.47	287.42
T ₄	11.54	21.97	38.08	50.73	8.35	11.02	14.50	6.99	335.83
T ₅	11.29	22.20	38.48	51.19	8.55	11.19	14.86	7.10	341.52
T ₆	11.72	21.90	37.74	50.00	8.26	10.83	14.19	6.73	298.60
T ₇	11.09	22.39	38.66	51.49	8.73	11.36	15.40	7.26	349.78
T ₈	10.75	22.98	39.26	52.06	9.59	11.89	15.81	7.65	371.01
T ₉	10.60	23.11	40.09	52.22	9.88	12.08	16.25	7.74	404.07
T ₁₀	10.89	22.55	39.13	51.89	9.28	11.56	15.60	7.50	362.57
T ₁₁	10.38	23.63	40.38	52.74	10.15	12.20	16.74	7.86	419.68
T ₁₂	9.93	24.97	41.66	53.80	10.49	12.70	17.14	8.29	435.69
T ₁₃	9.78	25.70	41.97	54.05	10.69	13.22	17.68	8.45	445.16
T ₁₄	10.15	23.96	40.88	53.02	10.25	12.51	16.97	8.17	428.99
T ₁₅	9.58	26.30	44.20	57.15	11.18	13.49	18.16	8.93	471.58
SEm (±)	0.68	1.33	2.27	2.48	0.56	0.72	1.00	0.47	22.56
C.D. @ 5%	NS	3.80	6.46	7.06	1.60	2.04	2.85	1.33	64.29

Discussion

The results of the present investigation clearly indicated that integrated application of inorganic fertilizers, humic acid, vermicompost and PGPR significantly influenced the growth and yield parameters of potato. The maximum plant height recorded under T₁₅ at 30, 60 and 90 DAP might be attributed to the synergistic effect of reduced inorganic fertilizer (75% RDF) combined with humic acid, vermicompost and multiple PGPR strains (*Azotobacter*, *PSB*, *KSB* and *SSB*). This integrated nutrient supply likely enhanced nutrient availability, particularly nitrogen, phosphorus and potassium, along with improved soil physical properties and microbial activity. Humic substances are known to stimulate root growth, cell elongation and enzymatic activity, thereby improving nutrient uptake and plant vigor (Canellas *et al.*, 2002) [3]. Similarly, vermicompost acts as a slow-release nutrient source and improves soil structure, aeration and water-holding capacity, leading to better root proliferation and growth (Arancon *et al.*, 2005) [1]. The role of PGPR in enhancing plant growth through biological nitrogen fixation, phosphate solubilization, potassium mobilization and production of growth-promoting substances such as auxins and gibberellins has also been well documented (Glick, 2012; Bhattacharyya and Jha, 2012) [8, 2].

The significantly higher number of compound leaves per plant under T₁₅ across all growth stages further supports the improved vegetative growth due to better nutrient assimilation and hormonal stimulation. Increased leaf production enhances photosynthetic surface area, thereby improving assimilate production and overall plant growth. The combined use of organic and biofertilizers might have increased chlorophyll content and photosynthetic efficiency, leading to enhanced biomass accumulation. These findings are in agreement with those of Kumar *et al.* (2018) [10] and Singh *et al.* (2020) [12], who reported improved vegetative growth in potato under integrated nutrient management practices.

The higher number of tubers per plant and tuber yield under T₁₅ can be explained by improved source-sink relationship and efficient translocation of photosynthates from leaves to developing tubers. Adequate and balanced nutrient supply throughout the crop growth period likely promoted stolon formation and tuber initiation, while improved soil microbial activity ensured continuous nutrient availability. Humic acid also enhances membrane permeability and nutrient transport,

while vermicompost provides micronutrients and beneficial microbes, all contributing to better tuber development. The significantly lower values observed under T₁ (100% RDF) indicate that sole reliance on chemical fertilizers may not sustain soil health and nutrient use efficiency, resulting in comparatively poor growth and yield.

Overall, the superior performance of T₁₅ demonstrates that integration of inorganic fertilizers with organic amendments and PGPR not only improves plant growth and yield but also enhances nutrient use efficiency and soil health. These findings are in close conformity with the concept of balanced fertilization and integrated nutrient management as suggested by Mahajan *et al.* (2017), highlighting the importance of combining chemical, organic and biological sources of nutrients for sustainable potato production.

Conclusion

The study concludes that integrated use of 75% RDF along with humic acid, vermicompost and PGPR (T₁₅) significantly enhanced growth and yield of potato compared to sole application of inorganic fertilizers. The improvement is attributed to better nutrient availability, soil health and microbial activity. Thus, partial substitution of chemical fertilizers with organic and biofertilizers is an effective and sustainable approach for higher potato productivity.

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