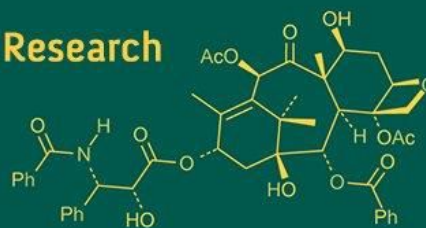


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Impact of integrated nutrient management using inorganic fertilizers, humic acid, vermicompost, and PGPR on growth and yield of potato (*Solanum tuberosum* L.)

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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 treatments involving 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 superior performance in terms of growth, biomass and yield attributes. Maximum stem diameter (9.12, 10.45 and 11.69 mm at 30, 60 and 90 DAP, respectively), fresh weight of shoots (195.07 g), dry weight of shoots (30.59 g), average tuber diameter (7.12 cm) and tuber yield (42.45 kg/plot) 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 improved performance under integrated treatments may be attributed to enhanced nutrient availability, improved soil health, increased microbial activity and better 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 globally and serves as a staple food for millions. It ranks fourth after rice, wheat and maize in total food production and plays a vital role in ensuring food and nutritional security (FAO, 2022). In India, potato is widely cultivated due to its high yield potential, short crop duration and adaptability to diverse agro-climatic conditions. However, achieving sustained productivity while maintaining soil health remains a major challenge. Crop productivity in potato is largely influenced by balanced nutrient management, whereas continuous and excessive use of inorganic fertilizers has led to soil degradation, nutrient imbalance and decline in microbial activity (Kumar *et al.*, 2015) [6]. Although chemical fertilizers supply nutrients in readily available forms, their indiscriminate use without organic supplementation adversely affects soil fertility and environmental sustainability (Sharma and Singh, 2018). In this context, the integration of organic and inorganic nutrient sources has emerged as a sustainable approach. Vermicompost, being rich in macro- and micronutrients, beneficial microorganisms and growth-promoting substances, improves soil structure, enhances nutrient availability and increases crop productivity (Patel *et al.*, 2016) [6]. Likewise, humic acid, an important component of soil organic matter, plays a key role in enhancing nutrient uptake, root development and enzymatic activities in plants (Verma and Prasad, 2017) [12]. In addition, Plant Growth-Promoting Rhizobacteria (PGPR) are beneficial microbes that colonize plant roots and promote growth through mechanisms such as nitrogen fixation,

phosphate solubilization and phytohormone production (Meena *et al.*, 2017) [7]. They also improve nutrient use efficiency and enhance plant tolerance to various stresses (Yadav *et al.*, 2019) [14].

Recent research highlights the synergistic effects of integrating inorganic fertilizers with organic amendments and biofertilizers, which improve soil health, nutrient availability and crop productivity (Gupta *et al.*, 2020) [4]. In potato, such integrated nutrient management practices have been reported to enhance growth, tuber yield, quality and economic returns. However, the optimum combination and levels of inorganic fertilizers, humic acid, vermicompost and PGPR under specific agro-climatic conditions are still not well defined. Therefore, the present study was undertaken to evaluate the influence of varying doses of these inputs on the 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.

The pooled data on 30 DAP, the maximum stem diameter (9.12 mm) was recorded under treatment T₁₅, which was statistically at par with T₁₃ (8.86 mm), T₁₂ (8.62 mm), T₁₄ (8.07 mm) and T₁₁ (7.86 mm). The minimum pooled stem diameter (6.67 mm) was recorded under T₁ (100% RDF).

The mean of two year data at 60 DAP, the maximum stem diameter (10.45 mm) was recorded under treatment T₁₅, which was statistically at par with T₁₃ (9.22 mm) and T₁₂ (8.96 mm). The minimum pooled stem diameter (7.10 mm) was recorded under T₁ (100% RDF).

After 90 DAP, the maximum stem diameter (11.69 mm) was recorded under treatment T₁₅, which was statistically at par with T₁₃ (11.43 mm), T₁₂ (11.35 mm), T₁₄ (11.21 mm), T₁₁ (11.12 mm), T₉ (11.00 mm), T₈ (10.90 mm), T₁₀ (10.78 mm), T₇ (10.37 mm), T₅ (10.30 mm) and T₄ (10.16 mm). The minimum pooled stem diameter (8.27 mm) was recorded under T₁ (100% RDF). On pooled basis, the maximum fresh weight of shoots per plant (195.07 g) was recorded under treatment T₁₅, which was statistically at par with T₁₃ (191.29 g), T₁₂ (186.90 g), T₁₄ (186.25 g), T₁₁ (181.72 g), T₉ (181.09 g), T₈ (180.04 g), T₁₀ (175.99 g), T₇ (171.85 g) and T₅ (168.05 g). The minimum pooled fresh weight of shoots per plant (143.61 g) was recorded under T₁ (100% RDF).

The mean of the both year experimental data, the maximum dry weight of shoots per plant (30.59 g) was recorded under treatment T₁₅, which was statistically at par with T₁₃ (29.65 g), T₁₂ (29.17 g), T₁₄ (28.07 g), T₁₁ (27.66 g), T₉ (27.34 g), T₈ (27.00 g), T₁₀ (26.77 g), T₇ (26.44 g) and T₅ (26.23 g). The minimum pooled dry weight of shoots per plant (21.63 g) was recorded under T₁ (100% RDF). On pooled basis, the maximum average diameter of tubers per plot at harvest (7.12 cm) was recorded under T₁₅. It was statistically at par with T₁₃ (6.66 cm), T₁₂ (6.41 cm), T₁₄ (6.28 cm) and T₁₁ (6.19 cm). The minimum pooled value (5.09 cm) was recorded under T₁ (100% RDF).

The mean of the both year experimental data, the maximum tuber yield per plot at harvest (42.45 kg/plot) was recorded under T₁₅. It was statistically at par with T₁₃ (40.07 kg/plot), T₁₂ (39.22 kg/plot), T₁₄ (38.61 kg/plot) and T₁₁ (37.77 kg/plot). The minimum pooled value (23.72 kg/plot) was recorded under T₁ (100% RDF).

Table 1: Effect of varying dose of fertilizer, humic acid, vermicompost and rhizobacteria on growth and yield of potato

S. No.	Diameter of stem (mm) (Mean of two years)			Fresh weight of shoots per plant (g) at harvest (Mean of two years)	Dry weight of shoots per plant (g) at harvest (Mean of two years)	Average diameter of tubers per plot (cm) at harvest (Mean of two years)	Tuber yield per plot (kg) at harvest (Mean of two years)
	At 30 DAP	At 60 DAP	At 90 DAP				
T ₁	6.67	7.10	8.27	143.61	21.63	5.09	23.72
T ₂	6.69	7.30	9.50	151.35	23.96	5.11	25.05
T ₃	6.75	7.41	9.57	157.40	24.73	5.25	25.87
T ₄	7.01	7.73	10.16	164.14	25.63	5.53	30.23
T ₅	7.12	7.94	10.30	168.05	26.23	5.69	30.74
T ₆	6.83	7.62	9.89	163.83	25.22	5.44	26.88
T ₇	7.26	8.08	10.37	171.85	26.44	5.86	31.48
T ₈	7.50	8.35	10.90	180.04	27.00	5.99	33.39
T ₉	7.63	8.49	11.00	181.09	27.34	6.07	36.37
T ₁₀	7.35	8.23	10.78	175.99	26.77	5.91	32.63
T ₁₁	7.86	8.63	11.12	181.72	27.66	6.19	37.77
T ₁₂	8.62	8.96	11.35	186.90	29.17	6.41	39.22
T ₁₃	8.86	9.22	11.43	191.29	29.65	6.66	40.07
T ₁₄	8.07	8.75	11.21	186.25	28.07	6.28	38.61
T ₁₅	9.12	10.45	11.69	195.07	30.59	7.12	42.45
SEm (±)	0.51	0.55	0.63	10.10	1.59	0.37	2.08
C.D. @ 5%	1.45	1.57	1.80	28.80	4.53	1.05	5.93

Discussion

The results revealed that integrated application of inorganic fertilizers, humic acid, vermicompost and PGPR had a significant effect on stem diameter, biomass accumulation and yield attributes of potato. The maximum stem diameter recorded under T₁₅ at 30, 60 and 90 DAP indicates enhanced vegetative vigor due to balanced and continuous nutrient supply. This may be attributed to the combined effect of humic acid and vermicompost in improving soil structure, moisture retention and root proliferation, which ultimately enhanced nutrient uptake. Humic substances are known to stimulate cell division and elongation, resulting in increased stem girth and overall plant robustness (Chen and Aviad, 1990) [2]. The presence of PGPR such as Azotobacter, PSB, KSB and SSB further contributed through biological nitrogen fixation, solubilization of phosphorus, potassium and sulfur, and production of growth-promoting hormones (Kloepper *et al.*, 1980; Vessey, 2003) [5, 13].

The higher fresh and dry weight of shoots observed under T₁₅ may be due to improved photosynthetic efficiency and greater accumulation of assimilates. Vermicompost provides essential macro- and micronutrients in available forms and enhances microbial activity, which leads to better nutrient mineralization and uptake (Edwards *et al.*, 2004) [3]. The combined use of organic and biofertilizers likely increased chlorophyll content and enzymatic activity, thereby promoting higher biomass production. These findings are in agreement with Singh and Lal (2012) and Chaudhary *et al.* (2017) [61, 10], who reported increased plant biomass under integrated nutrient management in potato.

The significant increase in average tuber diameter and tuber yield per plot under T₁₅ can be explained by improved source-sink relationship and efficient translocation of photosynthates from shoots to tubers. Adequate supply of nutrients throughout the growth period, coupled with enhanced microbial activity, likely promoted better tuber bulking and development. Humic acid also improves membrane permeability and nutrient transport, while vermicompost ensures sustained nutrient release, both of which contribute to increased tuber size and yield. In

contrast, the lowest values recorded under T₁ (100% RDF) suggest that sole reliance on chemical fertilizers limits nutrient use efficiency and does not support optimal soil biological activity.

Overall, the superior performance of T₁₅ highlights the importance of integrating chemical fertilizers with organic amendments and PGPR for improving plant growth, biomass accumulation and yield attributes in potato. These results support the concept of balanced fertilization and sustainable nutrient management as emphasized by Tiwari (2002) [11], demonstrating that partial substitution of inorganic fertilizers with organic and biological inputs enhances crop productivity and soil health.

Conclusion

The study concludes that integrated application of 75% RDF along with humic acid, vermicompost and PGPR (T₁₅) significantly improved stem diameter, shoot biomass, tuber size and yield of potato. The enhanced performance is attributed to better nutrient availability, improved soil properties and increased microbial activity, leading to efficient photosynthesis and assimilate translocation. Thus, partial substitution of inorganic fertilizers with organic and biofertilizers is an effective and sustainable strategy for enhancing potato productivity.

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