

PERFORMANCE OF BIOFERTILIZER TREATMENTS AND VARIABILITY ANALYSIS FOR GROWTH, YIELD AND QUALITY TRAITS IN APICAL ROOTED CUTTING POTATO (*SOLANUM TUBEROSUM* L.)

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ABSTRACT

Potato (*Solanum tuberosum* L.) is an important vegetable crop contributing significantly to food and nutritional security. The present investigation was conducted during rabi 2023-24 and kharif 2023-24 at the College of Agriculture, Hassan, to assess variability parameters, heritability, genetic advance and treatment performance for growth, yield and quality traits in apical rooted cutting (ARC) potato under different biofertilizer applications. The experiment was laid out in a randomized complete block design with eight treatments and three replications using cultivar Kufri Himalini. Significant variation was observed among treatments for most of the studied traits during rabi, kharif and pooled seasons. Higher phenotypic coefficient of variation (PCV) values than genotypic coefficient of variation (GCV) for most traits indicated the influence of environmental factors on trait expression. High GCV and PCV along with high heritability and genetic advance as per cent of mean were observed for number of branches, plant spread, tuber yield and starch content, indicating the substantial variation and the potential usefulness of these traits for selection. Analysis of variance revealed significant treatment differences for most growth, yield and quality traits across seasons. Among the treatments, *Azotobacter* and *Trichoderma* recorded superior performance for important traits including plant spread, branching behaviour, leaf area, tuber yield and starch content. The pooled analysis further confirmed the consistency of these traits across seasons. Traits such as number of branches, number of haulms, plant spread, tuber yield and starch content were identified as important selection criteria for growth, yield and quality performance ARC potato. The results also highlighted the beneficial role of suitable biofertilizer applications in enhancing growth, productivity and quality in ARC potato cultivation under Hassan conditions.

KEYWORDS: Apical rooted cutting, potato, biofertilizers, variability, heritability, genetic advance, growth traits, tuber yield.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the most important vegetable crops cultivated worldwide and serves as a major source of carbohydrates, vitamins and minerals for human nutrition (Zaheer, K *et al.* 2016). Owing to its wider adaptability, high productivity and nutritional importance, potato occupies a prominent position in global food security. In India, potato cultivation plays a vital role in ensuring nutritional security and income generation for farming communities (Devaux *et al.* 2021). However, the availability of quality seed material remains one of the major constraints limiting higher productivity and profitability in potato cultivation.

To overcome the limitations associated with conventional seed tuber production, apical rooted cutting (ARC) technology has emerged as a promising alternative approach for rapid multiplication of disease free and healthy quality planting material in potato. The technology was standardised by ICAR-Central Potato Research Institute Shimla, India and has demonstrated considerable potential for production of quality planting material at lower cost with higher multiplication rates (Buckseth *et al.* 2019). ARC technology reduces the requirement of bulky seed tubers, facilitates efficient propagation and enables efficient seed production under both protected and open field conditions. Consequently, ARC based potato cultivation is gaining importance in modern potato seed production systems (Mohanty *et al.* 2020). Furthermore, apical rooted cutting gives a vigorous and uniform planting material similar to other transplanted solanaceous vegetables and offer a practical alternative for seed production programmes, particularly for processing-oriented potato cultivation and selection programmes, particularly for processing-oriented potato cultivation (Handayani *et al.* 2023).

The use of biofertilizers has gained importance in sustainable agriculture because of their ability to improve

nutrient availability, enhance soil biological activity and reduce dependence on chemical fertilizers. Beneficial microorganisms such as *Azotobacter*, *Azospirillum*, phosphate-solubilizing bacteria and *Trichoderma* play a major role in promoting plant growth, improving nutrient uptake and enhancing crop productivity (Yazdani *et al.* 2009). Recent plant-science studies have also highlighted the potential of biological and organic inputs to support plant growth and sustainable crop production (Arora *et al.*, 2025; Kumar *et al.*, 2025). Their integration with ARC potato cultivation may provide an environment friendly sustainable approach for improving growth, yield and tuber quality. Precision farming and improved resource management have been highlighted as approaches for enhancing agricultural productivity and promoting sustainable farming practices (Geetanjali and Singh, 2025).

Assessment of variability parameters such as genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability and genetic advance provides useful information regarding the nature and magnitude of genetic variation governing different traits. These parameters help breeders identify traits controlled predominantly by additive gene action and thereby improve the efficiency of selection. Similarly, analysis of variance helps determine the existence of significant variability among treatments for different growth, yield and quality traits. Growth parameters such as number of haulms, plant spread, branching behaviour and leaf area directly influence tuber development and final yield, whereas quality traits including starch content, tuber girth, specific gravity and total soluble solids are important for processing and consumer acceptability.

Therefore, the present study was carried out to evaluate the performance of different biofertilizer treatments and estimate variability parameters, heritability, genetic advance and analysis of variance for growth, yield and quality traits in apical rooted cutting potato during rabi and kharif seasons under Hassan conditions.

MATERIALS AND METHODS

Experimental location

The field experiment was conducted during rabi 2023-24 and kharif 2023-24 at the College of Agriculture, Hassan, University of Agricultural Sciences, Bengaluru, Karnataka, India. The experimental site is located at a latitude of 12.97263° and longitude of 76.268326° and is situated in southern dry zone (Zone VI) of Karnataka. The soil of the experimental field was red sandy loam in texture and the location is characterized by favourable climatic conditions for potato cultivation during both seasons.

Experimental details

The experiment was laid out in a Randomized Complete Block Design (RCBD) with eight treatments and three replications using apical rooted cutting potato cultivar Kufri Himalini. The treatments comprised T₁: Phosphate solubilizing bacteria (PSB), T₂: Potassium solubilizing bacteria (KSB), T₃: *Trichoderma*, T₄: *Azospirillum*, T₅: *Azotobacter*, T₆: Microbial consortium (MC-UASB), T₇: Arka Microbial Consortium (AMC) and T₈: Control. The crop was raised by following recommended package of practices for ARC potato cultivation. Observations were recorded during both rabi and kharif seasons, and pooled analysis was performed to evaluate the consistency of treatment performance across seasons.

Observations

Observations were recorded on important growth, yield and quality parameters at different stages of crop growth. Growth parameters included plant height, number of haulms per plant, plant spread, number of leaves per plant, number of branches per plant and leaf area at 45 and 60 days after transplanting (DAT). Yield parameters comprised number of tubers per plant, tuber weight per plant and tuber yield per plant. Quality traits included tuber girth, tuber length, specific gravity, chlorophyll content, starch content and total soluble solids (TSS). Observations were recorded from randomly selected plants in each treatment and replication, and the mean values were used for statistical analysis.

Statistical analysis

Variability parameters including genotypic coefficient of variation and phenotypic coefficient of variation, broad sense heritability (h^2) and genetic advance as per cent of mean were estimated following the methods proposed Burton (1952) Robinson *et al.* (1949) and Johnson *et al.* (1955), respectively. Analysis of variance (ANOVA) was carried out to determine the significance of differences among treatments for growth, yield and quality traits during rabi, kharif and pooled seasons. The significance of treatment effects was tested using critical difference (CD) values at the 5 per cent probability level of significance. The pooled analysis was performed by combining observations from both seasons to identify stable and superior biofertilizer treatments associated with enhanced growth, yield and quality performance in ARC potato.

RESULTS AND DISCUSSION

Variability studies

The magnitude of variability present in a population determines the scope for selection of superior genotypes for economically important traits such as crop growth, yield and quality attributes under different biofertilizer treatments. In the present investigation, substantial variation was observed among the treatments for several growth, yield and quality traits during rabi, kharif and pooled seasons. Variability parameters provide useful information regarding the extent of variation expressed by different traits and help identify characters exhibiting greater responsiveness under varying environmental conditions (Govindaraj *et al.* 2015). In general, PCV values

were slightly higher than the corresponding GCV values for most of the traits, indicating the influence of environmental factors on trait expression. However, the relatively narrow differences between PCV and GCV observed for several characters suggested comparatively lower environmental influence and greater consistency in their expression across seasons.

During the rabi season, high GCV and PCV estimates were recorded for number of branches at 60 DAT (39.68 and 40.87%), tuber yield per plant (39.26 and 40.02%), plant spread at 60 DAT (36.80 and 37.78%) and starch content (33.57 and 33.89%), indicating the presence of substantial variation among treatments for these characters. Moderate to high variability was also observed for number of haulms, number of tubers per plant and tuber weight. Similar observations were reported by Sattar *et al.* (2007) in potato.

During the kharif season, higher GCV and PCV values were observed for number of branches at 45 DAT (40.04 and 41.06%), number of branches at 60 DAT (40.12 and 40.92%), number of haulms at 45 DAT (35.14 and 36.10%) and number of haulms at 60 DAT (31.79 and 32.00%). Plant spread and leaf area traits also exhibited moderate variability across treatments indicating differential responses of these traits to biofertilizer applications under seasonal environmental conditions.

The pooled analysis further confirmed the existence of considerable variability among treatments. High GCV and PCV estimates were recorded for number of branches at 60 DAT (38.36 and 38.74%), plant spread at 60 DAT (25.73 and 27.32%), starch content (19.18 and 20.32%) and tuber yield (19.09 and 20.70%). Similar findings have been reported by Asefa *et al.* (2016) and Hajam *et al.* (2018). The relatively narrow differences between GCV and PCV observed for several of these traits further indicated lower environmental influence and greater consistency in their expression across seasons. In contrast, traits such as plant height, specific gravity, chlorophyll content and total soluble solids exhibited comparatively lower variability across seasons, indicating relatively stable expression of these traits under different biofertilizer treatments (**Table 1**).

Table 1: Estimation of genetic parameters for various traits in Apical rooted cutting potato during 2023-24 season (Pooled)

Trait	GCV (%)	PCV (%)	h ² b (%)	GA @5%	GAM (%)
PH45P	3.13	6.44	23.58	1.00	3.13
PH60P	0.00	6.00	0.00	0.00	0.00
NH45P	15.44	16.22	90.58	0.49	30.28
NH60P	18.68	19.52	91.53	0.71	36.81
PS45P	17.84	19.41	84.55	92.01	33.80
PS60P	25.73	27.33	88.67	259.09	49.91
NL45P	11.86	14.09	70.83	4.17	20.56
NL60P	5.46	10.40	27.59	1.72	5.91
NB45P	18.06	18.91	91.15	0.95	35.51
NB60P	38.37	38.75	98.04	2.65	78.26
LA45P	9.35	12.52	55.79	249.03	14.39
LA60P	6.00	10.55	32.31	179.71	7.02
NTPP	9.06	11.01	67.77	1.28	15.37
WTPP	10.34	13.11	62.29	34.75	16.82
TYP	19.10	20.71	85.05	0.09	36.28
TGP	10.89	12.21	79.54	0.92	20.01
TLP	7.83	11.19	49.03	0.62	11.30
SGP	0.00	8.51	0.00	0.00	0.00
CHLP	6.06	8.07	56.38	0.12	9.37
STP	19.18	20.33	89.08	1.65	37.30
TSSP	7.95	10.65	55.75	0.97	12.23

Heritability and genetic advance

Heritability estimates together with genetic advance provide reliable information regarding the nature of gene action controlling different traits and help in identifying characters exhibiting greater consistency across environments. Variability parameters coupled with heritability estimates provide a clearer understanding of the extent of variation expressed by different traits and their potential usefulness in crop improvement studies (Burton, 1952; Swarup and Chaugle, 1962). In the present study, several growth, yield and quality traits exhibited high heritability coupled with high genetic advance as per cent of mean, indicating greater consistency in the expression of these traits across seasons and treatment combinations. Heritability indicates the proportion of observed variation attributable to inherited factors, whereas genetic advance predicts the expected improvement in trait performance. Therefore, heritability estimates together with genetic advance are considered more informative than heritability alone (Johnson *et al.* 1955).

During the rabi season, high heritability estimates were observed for tuber yield per plant (96.22%), number of tubers per plant (96.82%), plant spread at 60 DAT (94.90%) and number of branches at 60 DAT (94.24%). These traits also recorded high genetic advance as per cent of mean, particularly tuber yield (79.34%), number of branches at 60 DAT (79.36%), plant spread at 60 DAT (73.86%) and starch content (68.50%). Similar findings for yield related traits have been reported by Mishra *et al.* (2017).

Similarly, during the kharif season, high heritability estimates were recorded for number of haulms at 60 DAT (98.66%), number of branches at 60 DAT (96.12%) and number of branches at 45 DAT (95.10%). These traits also exhibited high genetic advance values, indicating their consistency across treatment combinations and environmental conditions.

The pooled analysis also revealed high heritability coupled with high genetic advance for number of branches at 60 DAT, plant spread at 60 DAT, starch content and tuber yield. Among the quality traits, starch content exhibited comparatively high heritability and genetic advance, suggesting its usefulness as an important quality parameter for improvement programmes. The occurrence of high heritability along with high genetic advance for these traits indicates that a substantial proportion of the observed variation was consistently expressed across seasons. In contrast, plant height, specific gravity, chlorophyll content and total soluble solids recorded comparatively lower heritability and genetic advance estimates, indicating greater environmental influence and limited scope for direct selection. Similar observations for tuber yield, plant height and tuber weight were reported by Luthra *et al.* (2001) (**Table 1**).

Analysis of variance

Analysis of variance revealed significant differences among treatments for most growth, yield and quality traits during rabi, kharif and pooled seasons, indicating substantial variation in the response of growth, yield and quality traits to different biofertilizer treatments in ARC potato. Significant treatment effects were observed for number of haulms, plant spread, number of leaves, number of branches, leaf area, number of tubers per plant, tuber weight, tuber yield, tuber girth and starch content. However, traits such as plant height at 60 DAT, tuber length and specific gravity were found to be non-significant, suggesting comparatively stable performance across treatments under rabi conditions. The occurrence of significant treatment effects for the majority of traits indicates differential responses of ARC potato to various biofertilizer applications under different seasonal conditions. The significant differences observed among treatments indicate the effectiveness of biofertilizer applications in influencing growth, yield and quality performance in ARC potato (**Supplementary Tables S1-S5**).

Effect of biofertilizer treatments on growth traits

The biofertilizer treatments significantly influence growth performance of ARC potato, the mean performance of treatments for growth traits revealed considerable variation during both rabi and kharif seasons. Among the treatments, *Azotobacter* recorded superior performance for several growth parameters including plant height (30.70 cm), number of haulms (2.40), number of leaves (34.02) and number of branches (5.60) during the rabi season. Similarly, *Azotobacter* recorded the highest plant spread at 60 DAT (641.083 cm²) and leaf area at 60 DAT (2936.580 cm²). In *Azotobacter* increase in biological nitrogen fixation, synthesis of plant growth promoting substances and improved nutrient uptake, which collectively enhanced canopy development and vegetative growth. Similar findings have been reported by Bhattacharya and Jha (2012) and Sharma *et al.* (2019) (**Supplementary Fig. S2**).

Trichoderma treatment also exhibited favourable effects on plant height, number of haulms and branching traits during both seasons (Harman, 2006). The improved growth performance under microbial inoculants may be associated with enhanced nutrient uptake, improved root growth and better microbial activity in the rhizosphere, which collectively promote vegetative growth and canopy development in ARC potato (**Supplementary Fig. S1**). The pooled mean performance further confirmed the superiority of *Azotobacter* and *Trichoderma* over the untreated control for most growth parameters (**Table 2**).

Plant growth responses to biological and organic inputs have also been documented in other crops. Arora *et al.* (2025) highlighted the potential roles of plant-associated microbial communities in growth and protection, supporting the importance of plant-microbe interactions in sustainable crop management.

Table 2: Mean performance of treatments for growth traits in ARC Potato during rabi season

Trait	Mean	Min	Max	CV (%)	SEm	CD @ 5%	CD @ 1%
PH45R	28.47	25.27	30.53	5.77	0.95	2.88	3.99
PH60R	30.70	27.33	32.87	8.19	1.45	4.40	6.11
NH45R	1.92	1.40	2.40	7.26	0.08	0.24	0.34
NH60R	2.41	1.80	3.53	7.33	0.10	0.31	0.43
PS45R	256.57	149.50	373.67	8.31	12.31	37.35	51.84
PS60R	641.08	401.67	1163.40	8.53	31.57	95.75	132.89
NL45R	25.31	16.13	31.60	5.70	0.83	2.52	3.50
NL60R	34.03	28.53	40.73	8.71	1.71	5.19	7.21
NB45R	4.17	3.33	5.43	5.07	0.12	0.37	0.51

NB60R	5.60	2.73	9.60	9.81	0.32	0.96	1.34
LA45R	2147.31	1457.20	2653.33	5.23	64.80	196.54	272.78
LA60R	2936.58	2623.67	3245.67	4.01	67.95	206.10	286.06

Effect of biofertilizer treatments on yield and quality traits

Considerable variation was also observed among treatments for yield and quality parameters traits. During rabi season, *Azotobacter* recorded the highest tuber yield per plant (0.42 kg) and tuber yield per hectare (22.17 t/ha), followed by *Trichoderma* and MC-UASB treatments. The increases in tuber yield under *Azotobacter* treatment may be attributed to enhanced vegetative growth, increased leaf area and improved photosynthesis rate, which ultimately contributed to greater assimilate production and development of tubers. Similar findings were reported by Vessey (2003), Kumar et al. (2017), and Singh et al. (2020).

Among the quality parameters, *Azotobacter* treatment recorded higher starch content during rabi season, whereas *Trichoderma* and MC-UASB treatments showed comparatively better performance for tuber length, tuber girth and total soluble solids. Specific gravity exhibited relatively lower variation among treatments, indicating comparatively stable response under different biofertilizer applications. Verma *et al.* (2016) also reported significant improvement in potato yield following application of beneficial microbial inoculants due to improved nutrient use efficiency. Sustainable crop production also depends on efficient resource use and appropriate agronomic practices. Kumar *et al.* (2025) highlighted the role of resource-efficient cropping systems in supporting agricultural sustainability, providing broader context for evaluating biological inputs in potato production.

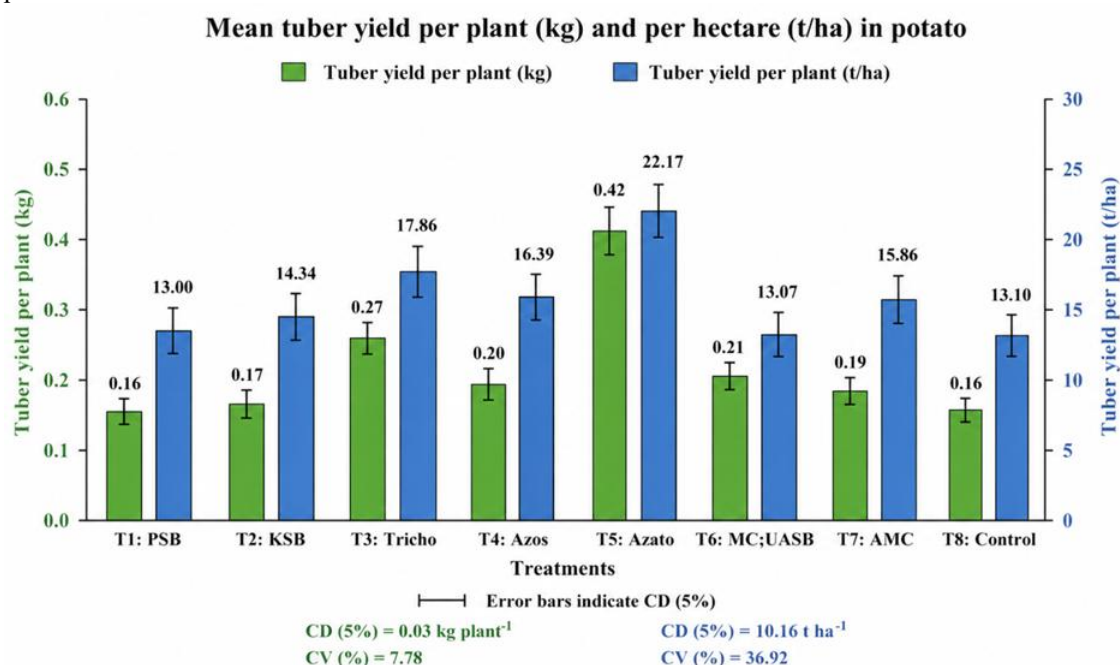


Fig.1: Mean performance of treatments for yield traits in ARC Potato during rabi season

Overall, *Azotobacter* and *Trichoderma* emerged as the most effective biofertilizer treatments for enhancing growth, yield and quality traits in ARC potato. The superior performance of these treatments highlights their potential for enhancing productivity and quality under ARC based potato cultivation systems (Table 3 and Fig. 1).

Table 3: Mean performance of treatments for yield and quality traits in ARC Potato during rabi season

Trait	Mean	Min	Max	CV (%)	SEm	CD @ 5%	CD @ 1%
NTPR	8.96	5.67	12.60	5.07	0.26	0.80	1.10
WTPR	160.28	105.53	214.33	9.57	8.86	26.86	37.28
TYR	0.22	0.16	0.42	7.78	0.01	0.03	0.04
TGR	2.61	2.23	3.21	4.61	0.07	0.21	0.29
TLR	3.56	3.24	3.89	6.84	0.14	0.43	0.59
SGR	1.07	1.05	1.09	7.11	0.04	0.13	0.19
CHLR	1.22	1.11	1.43	7.36	0.05	0.16	0.22
STR	4.96	2.68	8.63	4.65	0.13	0.40	0.56
TSSR	7.83	7.00	8.67	8.69	0.39	1.19	1.66

CONCLUSION

The present investigation revealed the considerable variation among biofertilizer treatments for growth, yield and quality traits in apical rooted cutting potato during rabi, kharif and pooled seasons. Higher estimates of GCV and PCV coupled with high heritability and genetic advance were observed for traits such as number of branches, plant spread, tuber yield and starch content, indicating substantial variation and the consistency of these traits across seasons. Analysis of variance further confirmed significant differences among treatments for most of the studied traits, demonstrating the influence of biofertilizer applications on growth, yield and quality performance in ARC potato. Among the treatments, *Azotobacter* and *Trichoderma* exhibited superior performance for several growth, yield and quality parameters including branching behaviour, plant spread, tuber yield and starch content. Overall, traits such as number of branches, number of haulms, plant spread, tuber yield and starch content were identified as important selection criteria for ARC potato improvement programmes, while suitable biofertilizer applications may contribute to enhance productivity and quality under varying seasonal conditions.

Summary for short note: Eight biofertilizer treatments were evaluated in apical rooted cutting (ARC) potato cv. Kufri Himalini during rabi and kharif seasons for growth, yield and quality traits. Significant differences among treatments were observed for most of the characters studied. Among the treatments, *Azotobacter* and *Trichoderma* consistently recorded superior performance for growth parameters, tuber yield and quality traits. Higher values of variability parameters were observed for number of branches, plant spread, tuber yield and starch content, indicating greater responsiveness of these traits under different biofertilizer applications. The study demonstrated the potential of *Azotobacter* and *Trichoderma* for improving productivity and quality in ARC potato cultivation under Hassan conditions.

Author contributions: RB, VA, and KK conceptualized the problem and designed the experiments. RB conducted the experiments and collected data. RB and SVP analysed the data and RB wrote a manuscript. NA, SVP, KP and VA edited the manuscript. The manuscript was finalized by all the authors.

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