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Residual effect of humic acid, PSB and phosphorus nutrition on growth and yield attributing parameters of residual rice crop under subtropical condition of Jammu

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Abstract

A field investigation was carried out during the *Rabi* seasons of 2022-23 at the Research Farm, Water Management Research Centre, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu (SKUAST-J), Chatha, to assess the residual effect of humic acid source and dose, phosphorus solubilising bacteria (PSB) and phosphorus nutrition applied to a preceding black gram crop on the growth and yield attributing parameters of a succeeding residual rice crop (cv. IET-1410) grown in a black gram-rice cropping sequence. The experiment was laid out in a Factorial Randomised Block Design with three factors replicated thrice, comprising twenty treatment combinations of five humic acid treatments (control, and soil application of humic acid @ 2.5 and 5 kg/ha each from a market-ready source and from farm yard manure, FYM), two PSB treatments (with and without seed treatment) and two levels of phosphorus nutrition (100% recommended N: 100% recommended P at 15:40 kg/ha, and 100% recommended N: 75% recommended P at 15:30 kg/ha). The growth and yield attributes of the residual rice crop were numerically the highest under treatment H2 (soil application of humic acid @ 5 kg/ha, market ready; 227.75 effective panicles/m², 92.67 grains/panicle, 24.67 g test weight, 4212.73 kg/ha grain yield, 8005.35 kg/ha straw yield and 34.50% harvest index), followed by H4 (humic acid @ 5 kg/ha, FYM), with seed treatment using PSB (P1) and under 100% recommended N:100% recommended P nutrition (N1), while the lowest values were consistently recorded under the control (H5). However, none of the treatments, individually or in interaction, exerted a statistically significant residual influence on any growth or yield attribute of the succeeding rice crop. The beneficial residual effect of humic acid, PSB and phosphorus nutrition applied to the preceding legume crop was carried forward numerically but did not translate into significant differences in the growth or yield of the succeeding residual rice crop under the prevailing subtropical, puddled conditions of Jammu within a single cropping cycle.

Keywords: Residual effect, humic acid, PSB, phosphorus nutrition, growth parameters, rice, *Rabi* 2022-23

1. Introduction

Sustaining soil fertility and crop productivity under intensive cropping systems requires nutrient management practices that extend benefits beyond the crop to which they are directly applied. Humic substances, comprising humic and fulvic acids, are well recognised as natural biostimulants that enhance root proliferation, nutrient uptake and overall plant vigour, besides improving soil aggregation, aeration and water-holding capacity. Humic acid stimulates plant growth, thereby increasing yields by facilitating the uptake of plant nutrients and influencing various physiological mechanisms such as cellular respiration, photosynthesis and enzyme activities, in addition to regulating growth hormones through production of indole acetic acid or its precursors ^[1, 2]. Phosphorus solubilising bacteria (PSB) further complement this action by secreting organic acids that solubilise fixed soil phosphorus, thereby improving its availability not only to the crop to which they are applied but also, potentially, to the crop that follows in the rotation ^[3, 4].

In rice-based cropping systems of the subtropical Jammu region, black gram is frequently grown as a preceding legume crop, and any residual build-up of growth-promoting inputs applied to it may influence the growth and productivity of the succeeding rice crop. Since rice is a heavy feeder of nutrients and is cultivated under puddled, submerged conditions that considerably alter nutrient

dynamics, it becomes important to evaluate whether growth attributes of the residual rice crop, such as the number of effective panicles, grains per panicle, test weight and final yield, are influenced by treatments applied to the preceding crop. Against this background, the present investigation was undertaken during the *Rabi* season 2022-23 to assess the residual effect of humic acid source and dose, PSB and phosphorus nutrition on the growth and yield attributing parameters of a succeeding residual rice crop under the subtropical condition of Jammu.

2. Materials and Methods

2.1 Experimental site and soil characteristics

The field investigation was carried out during the *Rabi* season 2022-23 at the Research Farm, Water Management Research Centre, SKUAST-Jammu, Chatha (32.6529° N latitude, 74.8071° E longitude; elevation 332 m above mean sea level). The soil of the experimental site was sandy loam in texture, slightly alkaline in reaction (pH 7.54), and low in organic carbon (5.01 g/kg) and available nitrogen (214.12 kg/ha), but medium in available phosphorus (10.78 kg/ha) and potassium (128.01 kg/ha), with electrical conductivity within the safe range (0.33 dS/m).

2.2 Experimental design and treatments

The experiment followed a black gram-rice cropping sequence and was laid out in a Factorial Randomised Block Design with three factors replicated thrice, giving twenty treatment combinations: five humic acid treatments - H1 (humic acid @ 2.5 kg/ha, market ready), H2 (humic acid @ 5 kg/ha, market ready), H3 (humic acid @ 2.5 kg/ha, FYM), H4 (humic acid @ 5 kg/ha, FYM) and H5 (control); two PSB treatments - P1 (with PSB seed treatment) and P2 (without PSB); and two phosphorus nutrition levels - N1 (100% recommended N:100% recommended P, 15:40 kg/ha) and N2 (100% recommended N:75% recommended P, 15:30 kg/ha).

2.3 Crop husbandry

All treatments were applied to the preceding black gram crop (cv. PU-31), sown in the third week of March at a spacing of 30 × 10 cm with a seed rate of 15-20 kg/ha. Rice (cv. IET-1410) was subsequently transplanted in mid-June at a spacing of 20 × 10 cm with two seedlings per hill, without altering the randomisation of treatments, in order to evaluate their residual effect. The recommended NPK dose for rice (50:30:20 kg/ha) was applied uniformly to all plots through urea, diammonium phosphate and muriate of potash; two-thirds of the nitrogen along with the full dose of phosphorus and potassium was applied as basal, and the remaining one-third of nitrogen was top-dressed in two splits, at the mid-tillering stage and prior to panicle initiation. Rice was harvested in the last week of September/first week of October.

2.4 Observations recorded and statistical analysis

Growth attributing parameters, viz. number of effective panicles/m², number of grains/panicle and 1000-grain weight, were recorded from five randomly tagged hills per plot at harvest,

while grain yield, straw yield and harvest index were recorded on a whole-plot basis after threshing, sun-drying and cleaning of the produce. Data were statistically analysed using analysis of variance (ANOVA) applicable to a Factorial Randomised Block Design, and F-tests of significance were applied to treatment means ^[11]. Standard errors of the mean (SEm±) and critical differences at 5% level of significance (CD 0.05) were computed to discern treatment effects.

3. Results and Discussion

3.1 Growth attributing parameters of residual rice crop

The data on growth attributing parameters of the succeeding residual rice crop, presented in Table 1, revealed that different treatments and their interactions exerted a non-significant influence on the number of effective panicles/m², number of grains/panicle and 1000-grain weight during the *Rabi* season 2022-23.

Among the humic acid treatments, the numerically highest number of effective panicles/m² (227.75) was recorded under H2 (soil application of humic acid @ 5 kg/ha, market ready), followed by H4 (226.67), H1 (221.58) and H3 (220.58), while the lowest value was recorded under the control, H5 (215.33). A similar trend was observed for the number of grains/panicle, which was numerically highest under H2 (92.67) and lowest under H5 (87.75), and for 1000-grain weight, which ranged between 23.46 g (H5) and 24.67 g (H2).

With respect to PSB application, treatment P1 (with PSB) recorded a numerically higher number of effective panicles/m² (223.97), grains/panicle (91.13) and 1000-grain weight (24.23 g) than P2 (without PSB; 220.80, 90.03 and 24.16 g, respectively). Likewise, among phosphorus nutrition levels, treatment N1 (100% recommended N:100% recommended P) recorded numerically superior growth attributes (222.90 panicles/m², 90.77 grains/panicle, 24.21 g test weight) over N2 (221.87, 90.40 and 24.18 g, respectively). None of the interactions among humic acid, PSB and phosphorus nutrition attained statistical significance for any of the growth attributing parameters studied. The numerical superiority of H2 and H4 over the control could be attributed to a carry-over effect of enhanced nutrient mineralisation, improved microbial activity and better nutrient-supplying power of soil induced by humic acid application to the preceding black gram crop, which might have improved residual nutrient availability during the reproductive phase of rice, favouring panicle initiation, spikelet fertility and grain filling ^[5, 6, 7]. Similarly, the marginal improvement associated with PSB seed treatment could be linked to enhanced phosphorus solubilisation carried over in the soil system ^[8, 9]. However, the failure of these numerical improvements to reach statistical significance may be ascribed to unfavourable temperature conditions during the kharif season in specific sub-regions of Jammu that could have adversely affected microbial populations, as well as to the practice of puddling for rice transplanting, which tends to reduce nutrient mineralisation and dilute the residual benefit of treatments applied to the preceding crop ^[10].

Table 1: Effect of humic acid source and dose, PSB and phosphorus nutrition on growth attributing parameters of succeeding residual rice crop (Rabi 2022-23)

Treatment	No. of effective panicles/m ²	No. of grains/panicle	1000-grain weight (g)
Humic acid source and dose			
H1 - Humic acid @ 2.5 kg/ha (market ready)	221.58	90.25	24.15
H2 - Humic acid @ 5 kg/ha (market ready)	227.75	92.67	24.67
H3 - Humic acid @ 2.5 kg/ha (FYM)	220.58	89.92	24.06
H4 - Humic acid @ 5 kg/ha (FYM)	226.67	92.33	24.63
H5 - Control	215.33	87.75	23.46
SEm±	5.07	2.13	0.37
CD (0.05)	NS	NS	NS
Phosphorus solubilising bacteria (PSB)			
P1 - With PSB (seed treatment)	223.97	91.13	24.23
P2 - Without PSB	220.80	90.03	24.16
SEm±	3.20	1.35	0.24
CD (0.05)	NS	NS	NS
Phosphorus nutrition			
N1 - 100% RN:100% RP (15:40 kg/ha)	222.90	90.77	24.21
N2 - 100% RN:75% RP (15:30 kg/ha)	221.87	90.40	24.18
SEm±	3.20	1.35	0.24
CD (0.05)	NS	NS	NS
Interactions			
H × P	NS	NS	NS
P × N	NS	NS	NS
N × H	NS	NS	NS
H × P × N	NS	NS	NS

Note: NS = Non-significant at 5% level of probability; RN = Recommended nitrogen; RP = Recommended phosphorus; FYM = Farm yard manure

3.2 Grain yield, straw yield and harvest index of residual rice crop

The data presented in Table 2 and Fig. 1 indicated that different treatments and their interactions exerted a non-significant effect on grain yield, straw yield and harvest index of the succeeding residual rice crop during the study period.

Treatment H2 (soil application of humic acid @ 5 kg/ha, market ready) recorded the numerically highest grain yield (4212.73 kg/ha) and straw yield (8005.35 kg/ha), followed by H4, H1 and H3, while the lowest grain and straw yields were recorded under the control (H5). Harvest index followed a similar, though narrower, trend, ranging from 33.94% (H5) to 34.50% (H2) across humic acid treatments. Among PSB treatments, P1 (with PSB) recorded a numerically higher grain yield (4086.13 kg/ha), straw yield (7864.54 kg/ha) and harvest index (34.30%) than P2 (without PSB; 4052.29 kg/ha, 7770.62 kg/ha and 34.04%, respectively), while among phosphorus nutrition levels, N1 (100% recommended N:100% recommended P) outperformed N2

numerically for all three parameters (4080.86 vs. 4057.56 kg/ha grain yield; 7847.57 vs. 7787.59 kg/ha straw yield; 34.40% vs. 34.14% harvest index).

The higher grain and straw yield associated with H2 and H4 could be linked to the improved growth attributes, viz. more effective panicles/m², grains/panicle and test weight, arising from a favourable residual carry-over of nutrients and improved soil microbial activity, which together might have supported greater dry matter accumulation and its translocation to economic yield [5]. Similar residual improvements in yield of a succeeding rice crop through humic acid and PSB application to a preceding legume have been reported by Biswas *et al.* [8] and Ghosal *et al.* [9]. Nevertheless, as with the growth attributes, the observed differences did not attain statistical significance, most likely on account of the puddled and submerged soil environment of rice cultivation limiting the mineralisation and availability of residual nutrients, corroborating the findings of Bochalaya *et al.* [10].

Table 2: Effect of humic acid source and dose, PSB and phosphorus nutrition on grain yield, straw yield and harvest index of succeeding residual rice crop (Rabi 2022-23)

Treatment	Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)
Humic acid source and dose			
H1 - Humic acid @ 2.5 kg/ha (market ready)	4063.73	7790.57	34.35
H2 - Humic acid @ 5 kg/ha (market ready)	4212.73	8005.35	34.50
H3 - Humic acid @ 2.5 kg/ha (FYM)	4025.68	7722.24	34.32
H4 - Humic acid @ 5 kg/ha (FYM)	4141.06	7958.48	34.45
H5 - Control	3902.85	7611.26	33.94
SEm±	93.06	169.85	0.74
CD (0.05)	NS	NS	NS
Phosphorus solubilising bacteria (PSB)			
P1 - With PSB (seed treatment)	4086.13	7864.54	34.30
P2 - Without PSB	4052.29	7770.62	34.04
SEm±	58.86	107.42	0.47
CD (0.05)	NS	NS	NS
Phosphorus nutrition			
N1 - 100% RN:100% RP (15:40 kg/ha)	4080.86	7847.57	34.40
N2 - 100% RN:75% RP (15:30 kg/ha)	4057.56	7787.59	34.14

SEm±	58.86	107.42	0.47
CD (0.05)	NS	NS	NS
Interactions			
H × P	NS	NS	NS
P × N	NS	NS	NS
N × H	NS	NS	NS
H × P × N	NS	NS	NS

Note: NS = Non-significant at 5% level of probability; RN = Recommended nitrogen; RP = Recommended phosphorus; FYM = Farm yard manure.

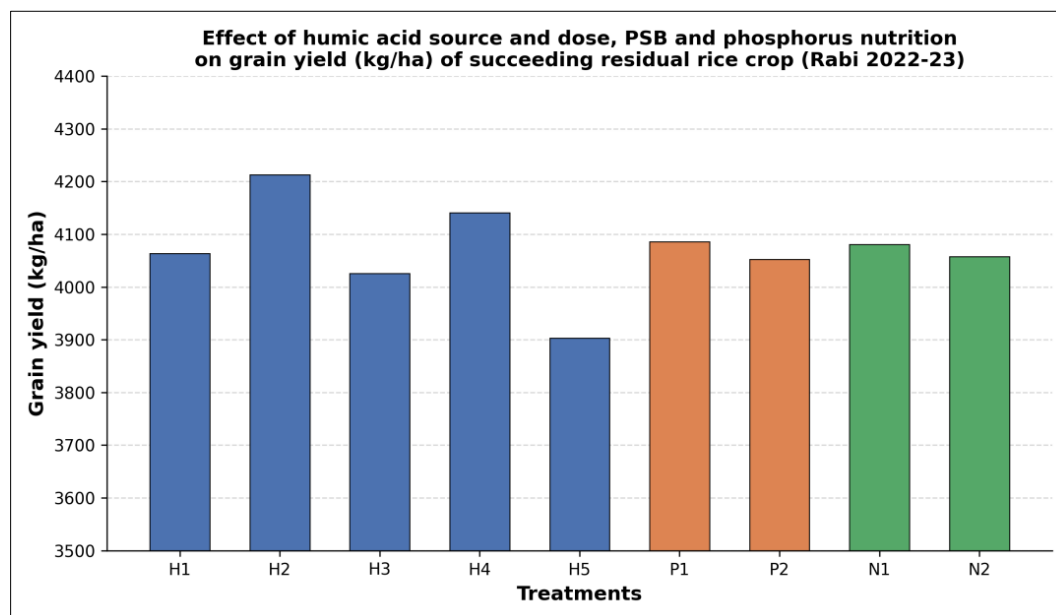


Fig 1: Effect of humic acid source and dose, PSB and phosphorus nutrition on grain yield (kg/ha) of succeeding residual rice crop during Rabi 2022-23

4. Conclusion

The field investigation conducted during the *Rabi* season 2022-23 revealed that soil application of humic acid @ 5 kg/ha, whether sourced from a market-ready formulation or from farm yard manure, along with seed treatment using PSB and a nutrient schedule of 100% recommended nitrogen and 100% recommended phosphorus (15:40 kg/ha) applied to a preceding black gram crop, exerted a numerically favourable residual effect on the growth attributing parameters - number of effective panicles/m², grains/panicle and 1000-grain weight - as well as on grain yield, straw yield and harvest index of the succeeding residual rice crop. However, these improvements remained statistically non-significant, suggesting that under the puddled, subtropical conditions of Jammu, the residual influence of humic acid, PSB and phosphorus nutrition applied to a preceding legume crop, while numerically beneficial, does not translate into a significant enhancement of growth or yield in the succeeding rice crop within a single cropping cycle. Multi-season evaluation is recommended to confirm whether the observed numerical trends stabilise into significant residual benefits over time.

5. Disclaimer

The products used for this research are commonly and predominantly used in the region, and no assumption is made about their suitability beyond the scope of this study. The authors declare that generative AI technologies were used solely for language refinement and formatting of this manuscript; all data, analysis, interpretation and scientific content are the original work of the authors.

6. Competing Interests

Authors have declared that no competing interests exist.

7. Authors' Contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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