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Long-term effect of *Pseudomonas aeruginosa* GRC_1 on yield of subsequent crops of paddy after mustard seed bacterization

Worldwide, the population depends on rice as staple food. Demand for rice is gradually increasing day-by-day. To meet demand, growers apply additional nutrient input in the form of chemical fertilizers[1]. But these chemicals disturb the environment, subvert ecology, degrade soil and mismanage water resources[2]. Nowadays, it is an endeavour to blend ecology and economy in a cost–benefit framework; hence considerable attention has been paid to use plant growth promoting rhizobacteria (PGPR) in the field[3].

Pseudomonads are well-known PGPR, which control deleterious pathogens through production of siderophore, antibiotics and HCN[4]. Gu and Mazzola[5] reported the improved root colonization of non-legumes by pseudomonads. Lumsden *et al.*[6] reported that rhizosphere-competent antagonistic microorganisms are ideal biological control agents, as the rhizosphere provides the frontline defence for roots against infection by the pathogens, which results in increased plant growth and productivity[7]. The objective of this work was to assess the residual effect of *Pseudomonas aeruginosa* $GRC_1^{rif+str+}$ on crops of paddy grown for two subsequent years.

Plant growth promoting activities of *P. aeruginosa* GRC_1 such as phosphate solubilization, production of IAA, HCN and siderophore, and biological control activity against *Macrophomina phaseolina* were evaluated earlier[8]. When *P. aeruginosa* $GRC_1^{rif+str+}$ bacterized mustard seeds were sown in the field during 2000, it enhanced the growth and yield of *Brassica campestris* compared to control. *Pseudomonas*-bacterized seeds increased 151% mustard grain yield per plant (Table 1). At that time rhizosphere population of *P. aeruginosa* $GRC_1^{rif+str+}$ was 4.5 ($\log_{10}$ cfu). After one year (2001) of harvesting, paddy seedlings were raised in the same field. The field was not given any exogenous treatment of fertilizer, except irrigation whenever required. To determine root colonization, paddy plants were carefully uprooted with shovel and 1 g of the root segments was serially diluted in sterile distilled water (SDW) to determine cfu per gram. The serially diluted root suspension was spread on tryptic soy agar medium (TSM) containing streptomycin (100 $\mu g\ ml^{-1}$) and rifampicin (100 $\mu g\ ml^{-1}$). The plates were incubated at 28 ± 1°C for 24 h. Plates without antibiotics were used to determine the total indigenous bacterial population. All vegetative parameters of the plant, such as seedling fresh weight, dry weight, shoot length, root length and grain yield per plant were recorded at the time of harvesting. Data were analysed statistically using analysis of variance (ANOVA) and LSD.

Residual effect of *P. aeruginosa* $GRC_1^{rif+str+}$ after a period of one year significantly enhanced fresh weight, dry weight of seedlings, shoot and root length of paddy compared to control. After a gap of two years (2002), *P. aeruginosa* GRC_1 also showed significant increase in seedlings of paddy compared to control. Grain yield per plant was enhanced by 105 and 267% respectively, more in the first year and second year compared to respective control (Table 1).

Root colonization study revealed that the population of *P. aeruginosa* GRC_1 and indigenous bacteria increased by 17.7 and 18.3%, respectively, in paddy compared to mustard crops. There was 15% more grain yield per paddy plant compared to the yield during the first year. Cfu of *P. aeruginosa* GRC_1 in the second year (2002) population was 11.3% greater than the first year (2001) population. Indigenous bacterial population in rhizosphere also increased by 8.6% compared to the first year population (Figure 1).

IAA production and phosphate solubilization activities of *P. aeruginosa* $GRC_1^{rif+str+}$ have increased the importance of these bacteria because such activities improved plant growth as well as productivity of non-legumes[9]. Better root colonization confirmed that *Pseudomonas* GRC_1 has capability to survive in rhizosphere of paddy and increase its population successively for two years. Also, it enhanced growth and grain yield of paddy every year. De La Fuente *et al.*[10] reported that inoculation with *Pseudomonas fluorescens* did not affect the symbiosis between rhizobia and forage legumes. They also reported that *Mesorhizobium loti* B816 with UP16 increased dry weight of lotus plant compared to *M. loti* B816 as control. Such observations give support that biocontrol *Pseudomonas* strains may be unaffected by other beneficial bacteria.

Rewari[11] observed that substantial increase in yield was often obtained with

Table 1. Residual effect of *Pseudomonas aeruginosa* $GRC_1^{rif+str+}$ on paddy (*Oryza sativa*) after bacterization of mustard seeds

	Mustard (year-2000)		Paddy (year-2001)		Paddy (year-2002)	
Vegetative parameter	Treatment $GRC_1^{rif+str+}$	Control	Treatment $GRC_1^{rif+str+}$	Control	Treatment $GRC_1^{rif+str+}$	Control
Seedling fresh weight (g)*	79**	33	15.8**	7.6	17.2**	5.92
Seedling dry weight (g)*	45**	19	10.5**	3.2	10.7**	2.1
Shoot length (cm)*	185**	97	111**	63.7	113**	49.2
Root length (cm)*	18.2**	11.3	13.1**	9.2	13.6**	7.8
Grain yield $plant^{-1}$ (g)*	18.3**	7.3	11.5**	5.6	13.2**	3.6

Values are mean of ten randomly selected plants; *Significant at $P > 0.01$ level of ANOVA; **Significant at 0.01 level of LSD compared to control.

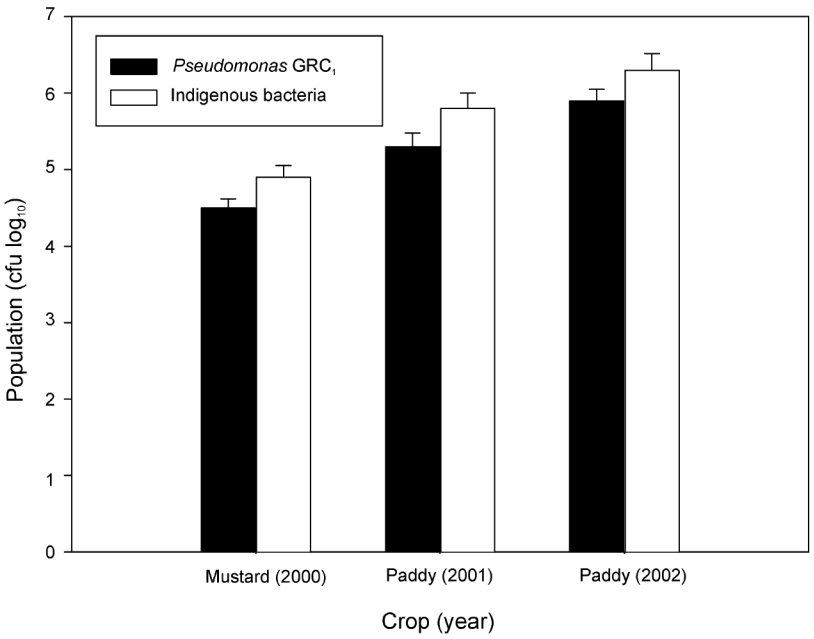

Figure 1. Root colonization study of mustard and paddy crop by *Pseudomonas aeruginosa* GRC_1.

Rhizobium inoculation with many leguminous crops (mung bean, urd bean, pigeonpea and lentil) for several years. Subba Rao and Tilak[12] observed that maximum residual effect was seen in soybean, which increased the yield of the subsequent crop of wheat by 65.9% in *Rhizobium*-inoculated series than the uninoculated control. It is concluded that not only *Rhizobium*, but *Pseudomonas* also survives in rhizosphere for several years and casts its growth-promoting effects on subsequent crops. Thus, *P. aeruginosa* GRC_1 is one of the potential PGPR with long-term residual effect.

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