two humps (Figure 3 *b*), one over the dyke and another along the SE end of the profile. The hump in the SE end may be due to shallow depth to the bedrock in this part or due to the concealed offshoots of another dyke, which is exposed at an offset of 100 m. The modelled depth to bedrock obtained is ~24 m. In general, the depth to bedrock obtained in the northern part of the watershed is ~17 m while in the northeastern part it ranges from 10 to 35 m. In the western part, the minimum counts to around 14 m but maximum depth of interface is about 18 m while in the eastern part it is estimated to be ~24 m. The interface between hard and fractured granite is estimated away from the dyke also. In profile-24 (Figure 3) the dyke is more weathered with respect to country rock as compared to offshoots that are less weathered. It is observed that within the dyke, there are variations in depth levels of the interface which behave as a groundwater potential zone. Thus, these dykes act as groundwater flow channels at shallow levels and barriers at deeper depth levels. The present study identified the thickness of the weathered/fractured zones and boundaries of the dyke intrusion and thus helped in selecting favourable groundwater potential zones. Hence the method suits well in the present conditions and could be used as a useful tool to be applied in similar geological environment, because it is fast and economical[5] as compared to other geophysical methods such as resistivity imaging and seismic technique in determining the depth to bedrock. Thus the present results are useful in identification of new potential well sites as well as in calibrating the numerical aquifer model of the groundwater flow.

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Suppression of deleterious bacteria by rhizobacteria and subsequent improvement of germination and growth of tomato seedlings

Saprophytic bacteria in soil include beneficial and deleterious species that have the potential to influence plant growth and crop yields significantly. The deleterious bacteria affect plant growth negatively through production of phytotoxins[1], but they do not necessarily parasitize the plant tissue. Other deleterious activities include alterations of the availability of water, ions and plant growth promoting substances by changing the root functions and/or by limiting root growth[2]. Beneficial bacteria on the other hand, promote plant growth and are referred to as 'plant growth promoting rhizobacteria' (PGPR)[3]. The PGPRs affect plant growth positively by enhancement of availability and uptake of plant nutrients[4], production of plant growth promoting substances[5] and suppression of deleterious bacteria[6].

In a field experiment, tomato seedlings in the nursery exhibited stunted growth. Microbiological analyses of the histosphere of such stunted plants yielded two predominant and distinct bacteria[7]. Based on morphological, physiological and biochemical tests[8], both were identified tentatively as *Bacillus* sp. and designated as DHBL and DHBS.

In order to study further the role of these bacteria, they were tested for the influence on germination and growth of tomato *in vitro*. Germination of tomato was tested following the petri plate pairing technique[9]. Interestingly, the histosphere bacteria were found to significantly inhibit seed germination as evidenced by the reduced length of radicle of tomato, presumably by producing volatile metabolites. *Bacillus* DHBL inhibited radicle length by 37% while *Bacillus* DHBS inhibited it by 48%. When examined, both the deleterious bacteria did not produce

Table 1. Plant growth response of tomato after bacterization with DBHS in an axenic culture at 30 days after sowing

Treatment	Germination (%)	Mean root length (cm)	Mean shoot length (cm)	Vigor index
Uninoculated control (UIC)	92	5.9	8.4	13.16
PGPR (RDV 108)	100	8.8 (+49.15)	8.9 (+5.95)	17.70
DHBS	90	5.1 (–13.56)	4.4 (–47.6)	08.55
PGPR + DHBS	98	7.6 (+28.8)	8.3 (–1.19)	15.58
CD at 1%	1.88	2.37	2.28	

Values in parentheses indicate per cent increase or decrease over UIC.

Table 2. Recovery of DHBS and PGPR from tomato seedlings grown in axenic culture at 30 days after sowing

Treatment	Bacteria recovered (CFU × 10^2 per g plant tissue)	
	PGPR	DHBS
PGPR (RDV 108)	4.68	–
DHBS	–	5.30
PGPR + DHBS	2.80 (71.1%)	1.05 (28.9%)

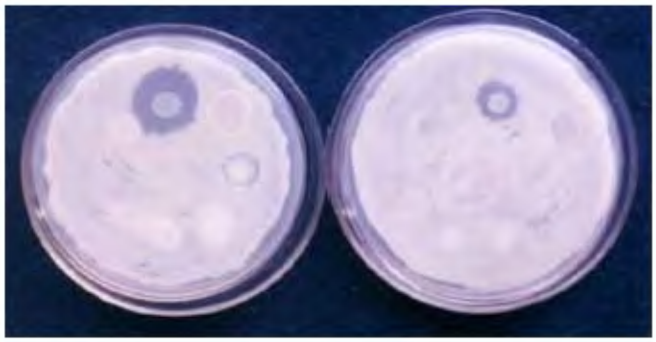

Figure 1. *In vitro* inhibition of *Bacillus* DHBS and DHBL respectively, by *Pseudomonas* sp. RDV 108.

any HCN *in vitro*. Therefore, it is possible that some other gaseous metabolite produced by the bacteria under conditions has inhibited radicle development. Bacteria producing phytotoxic gaseous metabolites from the endorhizosphere of tomato plants that are deleterious to plant growth have been isolated earlier[10]. These metabolites are known to be entrapped in the root tissue and do not diffuse easily and exhibit dramatic effects on the plant physiology than the metabolites produced on the root surface[2].

Effect of deleterious bacteria on the growth of tomato plants was tested by growing seedlings in an axenic culture using vermiculite moistened with Hoagland's nutrient solution. Tomato bacterized with *Bacillus* DHBS demonstrated significant reduction in root and shoot length by 13.5 and 47.6% respectively, over the uninoculated control (UIC) treatment (Table 1). However, dual inoculation of DHBS and fluorescent *Pseudomonas* sp. RDV 108, a plant growth promoting rhizobacterial (PGPR) strain[5], available in the microbial culture collection at the Department of Agricultural Microbiology, UAS, Dharwad, reduced the plant growth-inhibiting effect of DHBS. In fact, it increased root length by 28.8% and produced a shoot length statistically on par with that of the uninoculated control. And, this could be correlated to the reduced population of DHBS recovered from the plant tissue (Table 2). The PGPR strain used here was kanamycin-resistant and hence enumerated on King's B medium containing Kan (50 µl/ml). Histosphere bacterial counts were obtained by deducting these counts from those on King's B medium. When the interaction was further studied in a dual culture assay *in vitro*, the PGPR strain inhibited both *Bacillus* DHBS and DHBL on NA glucose medium, evidently by producing metabolites antagonistic to DHBS (Figure 1).

Such a phenomenon was earlier noticed in a study where the dual inoculation of seed with a PGPR and a DRB strain resulted in the inhibition of DRB colonization of roots and increasing plant growth[11]. They also observed that the mode of action of PGPR in increasing plant growth was, in part, related to the *in vitro* inhibition of DRB. Thus, in case of appearance of stunted growth, the presence of such DRBs needs to be tested for (as shown by our observation herein) and the inoculation of PGPRs capable of inhibiting the DRBs may be observed. The choice of such bacteria can further augment their utility as bioinoculants in sustainable organic farming.

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