Table 2: Solubilization zone produced on modified Aleksandrov medium amended with KCl, K_2SO_4, mica powder are the potassium sources

Bacterial isolate	KCl Solubilization zone diameter (mm)	K_2SO_4 Solubilization zone diameter (mm)	Mica powder solubilization zone (mm)
JS-17	13.2	9.2	4.0
JS-7	12.6	8.1	3.5
JS-3	12.2	7.2	3.1
JS-16	11.4	6.4	2.6
JS-31	10.5	5.2	2.2
JS-53	10.0	4.1	1.8

3.5 Zinc Solubilization Activity

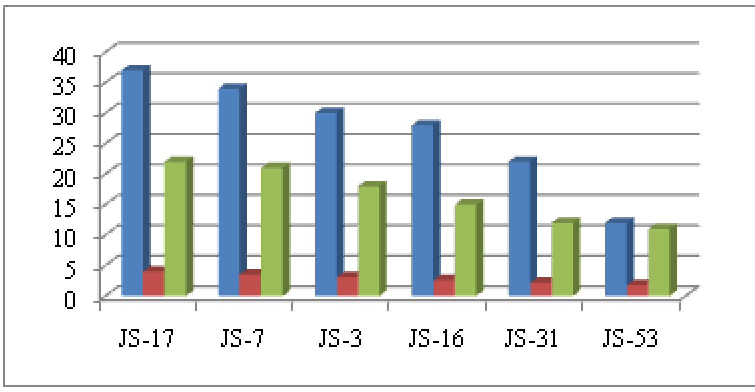
Zinc is one of the eight essential micronutrients required for healthy growth and reproduction of crop plants. From the data, it is obvious that the strains varied in their ability to solubilize different forms of insoluble zinc. Out of 55 strains, we could identify 14 strong Zn solubilizers. In the past also, efforts were made to identify zinc solubilizers with varying abilities. The demonstrated variation in the ability of solubilizing given zinc sources could be due to metabolic activity of a given strain [47].There are different mechanisms of solubilization which have been identified with proton excretion, production of organic acids and other chelating metabolites [48]. Organic acid production by microbial strains plays a major role in solubilization [49]. The zinc solubilization in our studies could be due to production of organic acids, like gluconic acids that is increased by the fall in pH of culture media noted in all cases. The transformation of glucose to gluconic acid by the glucose oxidative external pathway in *Pseudomonas* spp. and other bacteria has been interpreted as a competitive approach by microorganisms [50]. Zinc phosphate solubilization by a strain of *P. fluorescens* was also reported [51]. The supplementing medium with zinc sulphate resulted in more gluconic acid production. Plant growth parameters of legume crop increase when seedlings were inoculated with zinc solubilizing bacteria compared to uninoculated controls [52]. The potential of rhizobacteria to promote nutrient uptake and plant growth could be due to synergistic action of the growth promoting traits than individual effect [53]. This solubilization property is important in nutrient cycling. Zinc phosphate solubilization by a strain of *Pseudomonas fluorescens* was also investigated [54].

All the selected strains of *Pseudomonas* used could effectively solubilize the insoluble Zn compounds used namely $ZnCO_3$ and ZnO. It is apparent from the zinc solubilization data that the solubilization potential varied with each isolate. The zone of solubilization was comparatively high in ZnO amended medium as compared to $ZnCO_3$. Size of the solubilization zone ranged from 7 to 22mm in $ZnCO_3$ and from 9 to 33mm in ZnO incorporated medium. Among the cultures JS-16, and JS-17 showed the highest solubilization zone in $ZnCO_3$, where as JS-17 and JS-7 showed 31mm zone in ZnO amended medium (Table 3)

Table 3: Solubilization zones produced on modified PVK medium amended with ZnO, $ZnCO_3$

Bacterial isolate	ZnO Solubilization zone diameter (mm)	$ZnCO_3$ Solubilization zone diameter (mm)
JS-17	31	22
JS-7	31	21
JS-3	26	18
JS-16	22	15
JS-31	13	12
JS-53	12	11

Most of the soils are rich in total Zn, K and P. However, their availability to the plants when needed is very limited. Pseudomonads able to solubilize P, K and Zn and thus, offer best possible nutrient recycling mechanism at a low input cost where expensive inorganic fertilizers are becoming too expensive to small and marginal farmers. In the present study, bacteria when characterized by P, K and Zn solubilization was observed that some strains have high potential to solubilize the said essential nutrients. Pseudomonas isolate JS-17 showed TCP solubilization, and were also able to solubilize insoluble Zn sources. Interestingly, isolate JS-16 that could solubilize maximum Zn could not show any Pi solubilization. In this study we could find 6 isolates that could solubilize P, K and Zn. There are some PGPR that can fix nitrogen, solubilize mineral nutrients and mineralize organic compounds [55]. As we could screening for a potential PGPR strains on the basis of direct plant growth promoting traits *viz.*, IAA, solubilization of Phosphate, Zinc solubilization, Potassium solubilization.



Graph 5: Comparative solubilization zones of P, K&Zn minerals

4. Conclusion

The experiment performed under *invitro* condition showed that these isolates may promote plant growth promoting potentials. PGPR include facilitating the uptake of certain nutrient like nitrogen, phosphorus, potassium and zinc forms for nutrient avability from the soil and root environment by producing plant hormone indole-3-acetic acid and multinutrient solubilization. Such multiple positive PGP Traits isolates can be further explored as potential biofertilizer for the sustainable agriculture. The direct promotions of plant growth by such situation warrants for compatibility between such strains for formulating consortia and use in the field. However, if strains that possess ability to mobilize multi-nutrients could be a benefit as they could be deployed directly with minimum efforts without going through the formulation.

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