CHAPTER-VI
SUMMARY
AND
CONCLUSION
6- SUMMARY AND CONCLUSION

In the last two decades, the quantum of research done on the members of microbial community particularly their role in the habitat/eco-system, and nature's prosperity, fluorescent pseudomonads possibly have major share for their unique quality of being simultaneously the producer (PGPR) and destructor as biocontrol agents (Antibiosis, siderophores, HCN and other metabolites).

Laboratory and glass house experiments were carried out to study various soil and plant factors, on rhizosphere competence (colonization of root system) and the growth of paddy wheat and tomato by isolates of Pseudomonas fluorescens having high antagonistic and plant growth promoting potential.

1. The isolates of Pseudomonas fluorescens developed well in all the textural groups of soils tested. However, sandy loam soil was distinctly and significantly superior followed by clay loam, clay, loam and silty loam.

2. Suitability of soil's textural groups was further assessed through estimation of rhizosphere populations. The results revealed that crops grown in sandy loam soil favoured maximum root colonization by the PGPR isolates.

3. Soil's moisture holding capacity affected development and persistence of the inoculum of the isolates of Pseudomonas fluorescens introduced in soil. Invariably soil moisture regulated at field capacity favourable maximum development and persistence of the inoculum. Rhizosphere population in crops grown in soil adjusted to field capacity was also highest.

4. Soil reaction (pH) is an important ecosystem factor affecting activities of flora
and fauna. It was observed that neutral (pH 7.0) or slightly alkaline (pH 8.0) supported maximum development and persistence of all the isolates of *Pseudomonas fluorescens*. Soil's acid reaction was unfavourable for development of *Pseudomonas fluorescens*.

5. It is well established that soil for major period remains deficient for energy building compounds and thus for microbial activities. Addition of decomposable material reverses this trend. The results of organic amendments on population of *Pseudomonas fluorescens* were-

(a) Population increased and persisted for longer durations.

(b) Among the amendments used, chicken manure caused maximum stimulation of the populations that too for longer durations.

(c) FYM and wheat straw also increased populations of the isolates significantly.

6. The combined effects of organic amendments and *Pseudomonas fluorescens* that subsequently developed under the influence of decomposable crop residues were studied on plant growth promotion. Fresh weight of roots and shoots of paddy increased significantly in pots amended with chicken manure, FYM and wheat straw. Similarly, the weight of roots and shoots of wheat and tomato was also increased. Neem cake was least effective.

7. Besides weight, the length of the roots and shoots also increased. Most organic amendments with in association with *Pseudomonas fluorescens* increased the length of roots and shoots. Presence of inoculum that developed with chicken
manure and FYM affected the length more appreciably and significantly.

8. Organic amendment of soil did affect the population dynamics of *Pseudomonas fluorescens*. What effects such changes in the soil environment will have on colonization of roots, were also studied. It was recorded that organic amendments had no negative effect on root colonizing capacity of the organism. Rather, presence of high population of the antagonistic bacteria in amended soil resulted in invariably high counts in rhizosphere of plants. Among the amendment used, spent compost was inferior.

9. *Pseudomonas fluorescens* though popularly called PGPR, are also implicated as “emergence promoting rhizobacteria” (EPR). Seeds of paddy, wheat and tomato when bacterized with isolates individually and/or combinations stimulated germinability, reduced time taken for seedling appearance and the total plant emergence- 

(a) Combined use of two isolates TR 13 (tomato isolate) and PR 8 (paddy isolate) caused highest plant emergence of paddy.

(b) In case of wheat, isolate WR 62 (wheat isolate) was highly effective in improving plant emergence. It was followed by TR 13 + WR 62 and TR 13 + PR 8.

(c) In tomato WR 62 + PR 8 were highly effective.

10. In interactions between different levels of inoculum of TR 13 (tomato isolate) and paddy (plant species), emergence, height and plant canopy were significantly improved particularly when inoculum mixed in soil was high. Development of
bacterium in rhizosphere was also very high, thus indicating positive and compatible interaction.

11. In interactions between paddy isolate (PR 8) and paddy plant, the results revealed positive compatible and durable interactions between plant genotype, isolated of *Pseudomonas fluorescens* and the amount of inoculum mixed in soil.

12. Paddy (Pant Dhan-10) and WR 62 (wheat isolate) also interacted positively. The bacterium colonized plant roots very appreciably and improved plant growth substantially.


(a) FYM inoculated with WR 62 and mixed in soil @ 300g/kg soil increased rhizosphere counts in wheat by about 185 per cent over to that of check. Emergence, height, tillers and canopy was also improved appreciably.

(b) Spent compost inoculated with WR 62 and applied @ 400g/kg soil improved plant health appreciably and increased rhizosphere counts by over 80 per cent over to that of check.

14. Health of wheat crop and root colonization by bacteriuim raised in soil inoculated with different amounts of inoculum of WR 62, revealed positive and direct relationship. Higher the inoculum better the plant vigour and significant improvement in root colonization.

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15. Isolate PR 8 (paddy isolate) when used in varying doses improved health of wheat and also rhizosphere population of the bacterium. Increase in inoculum concentrations caused simultaneous increase in plant health and rhizosphere populations.

16. Results of glass house studies have revealed that isolates of *Pseudomonas fluorescens* used singly or in mixtures, affected plant growth response (PGR) positively. In general, fresh and dry weight of roots and shoots, in wheat plants as well as their length was increased. Isolate PR 8 (paddy isolate) did not increase fresh shoot weight. Mixture of WR 62 + TR 13 and WR 62 + TR 13 + PR 8 caused mostly significant increase in most growth parameters measured. Treatment having a mixture of TR 13 + WR 62 + PR 8 was significantly superior in improving root length, shoot length, fresh root weight, fresh shoot weight, dry root weight and dry shoot weight of tomato. Treatment having a mixture of PR 8 + WR 62 was best for shoot length, WR 62 + TR 13 and PR 8 + WR 62 + TR 13 for root length, PR 8 + WR 62 + TR 13 and PR 8 + TR 13 for fresh root weight, WR 62 and PR 8 + TR 13 for dry shoot weight and PR 8 + WR 62 + TR 13 for dry root weight of paddy.

17. *Pseudomonas fluorescens* in rhizosphere soil of wheat plants raised from seeds bacterized with isolates of *Pseudomonas fluorescens* individually or in combinations colonized root zones with almost similar magnitude and extent. The differences between the treatments were narrow.

18. Fungicidal seed (wheat, paddy) treatments increased rhizosphere counts of *Pseudomonas fluorescens*. Bavistin and Vitavax increased counts

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non-significantly but Thiram did so significantly.

19. Amounts of nitrogen affect plant growth, which in turn might affect root colonization by *Pseudomonas fluorescens*. The results have revealed that higher the amount of nitrogen given to plants, correspondingly higher rhizosphere counts of the bacterium 160 to 200 kg N/ha looked highly favorable for root colonization by the antagonist.

20. Amide-N source of nitrogen favoured growth and root colonization of *Pseudomonas fluorescens* substantially and significantly as compared to NO$_3$-N and NH$_4$-N.

21. Crop rotation (sequence) did affect the population of *Pseudomonas fluorescens* in root zone. The rhizosphere of wheat plants grown after rice, maize and urd, the increase of *Pseudomonas fluorescens* (WR 62) was substantial and significant. These rotations improved population counts (cfu) by 104-125 per cent over to that of non-rhizosphere soil (check-no crop). The positive effect of rotations continued upto 100 days.

22. The host genotypes affected rhizosphere counts of *Pseudomonas fluorescens*. In wheat genotypes UP 262 followed by PBW 343 and PBW 154 supported significantly higher root colonization by WR 62. In paddy cultivar Pant Dhan-10 supposed highest rhizosphere counts of PR 8.

23. Foliar application of micronutrients persistently increased rhizosphere population of *Pseudomonas fluorescens* (isolate WR 62). Spray of ZnSO$_4$.7H$_2$O and
MnSO\textsubscript{4} were distinctly and significantly superior over others.

24. Frequent watering of pots reduced root colonization by WR 62 and also caused poor plant vigour. Watering once a fortnight improved plant health as well as root colonization by the bacterium.

25. Foliar application of urea caused significant improvement in rhizosphere counts.

26. Root colonization or rhizosphere competence of the isolate of \textit{Pseudomonas fluorescens} was evaluated using towel paper method. In general, the isolates either applied singly or in mixtures colonized the spermosphere and initial parts of the radical. Root segments measuring up to 1 cm. were heavily colonized. Further extension of root system resulted in reduced population of the isolates. Recovering from 1-2 cm segments was relatively low over the 0-1 cm. segments. Finally from 4-5 cm. segments populations amounting to about 80% were reduced. The isolates also differed in their root colonizing capacity. In totality, colonization and movement of inoculum of \textit{Pseudomonas fluorescens} was somewhat positive of mixtures of the isolates were used.