Chapter-6

Summary
SUMMARY

The present thesis entitled "Impact of microbial inoculants on cadmium stress in selected leguminous plants." comprises of six chapters.

➤ **Chapter 1** deals with the importance of the problem and justifications for the present work undertaken were emphasized.

➤ **Chapter 2** is the review of the literature. It includes the literature available on the aspects of the physiological analysis of various growth, biochemical characteristics, and stress markers, components of antioxidant systems and yield of various crop plants under cadmium (Cd) stress. The importance of inoculation of *Rhizobium* and application of Arbuscular mycorrhizal (AM) fungi in the alleviation and in the regulation of plant growth and development under stress conditions were also reviewed. The chapter has been divided in sections and subsections for the better understanding of the work of other research reports in this field of study. In addition, the critical appraisal of the review of literature has also been included to identify the gap in the field of the study.

➤ **Chapter 3** includes the details of the material used in the study and the methodology adopted to determine various characteristics recorded in the four experiments have been described in the chapter 3. In addition, also mentions the relevant information on the location of the study and the environmental conditions during the data sampling times.

➤ **Chapter 4** includes the results of the four experiments. Variation among leguminous crops for sensitivity and non-sensitivity were studied to select Cd-sensitive and non-sensitivite legumes. Details of physiological and biochemical processes occurring in Cd-sensitive and non-sensitive legume and the role of microbes in regulating physiological processes under influence of microbes were studied. The data were statistically analyzed and level of significance was determined at $P<0.05$ using analysis of variance (ANOVA).

➤ **Chapter 5** discuss the results obtained in the Experiments, in the light of the observations recorded and supported with earlier findings, if available, and also with the help of correlations. This chapter also presents the possible
explanations of the data obtained to reach a conclusion and possible future aspects.

Experiment 1:

This Experiment was performed to study the effect of five concentrations of Cd viz., 0, 25, 50, 75 and 100 mg Kg\(^{-1}\) soil on Cd accumulation in plants stress markers, growth, biochemical and yield characteristics of five legume plants viz. methi, broad bean, chick pea, pea and lentil. The treatments in this Experiment were arranged in a factorial randomized block design. Cadmium accumulation in plant, stress markers, growth and biochemical characteristics were studied at pre-flowering (30DAS), flowering (60DAS) and post-flowering (90DAS) stages, while yield characteristics were noted at harvest (120DAS). Tolerance index of five legumes was calculated and the plants were designed as Cd-sensitive and Cd non-sensitive on the basis of their performance under Cd stress. The effects of Cd on growth, biochemical and yield characteristics were found significant at all sampling times. The increase in Cd levels decreases the growth, biochemical and yield characteristics of all the five plants at all sampling stages. The observations showed similar pattern of plants responses to Cd treatments. Maximum reduction in growth, biochemical and yield characteristics was noted with 100 mg Cd Kg\(^{-1}\) soil followed by 75, 50 and 25 mg Cd Kg\(^{-1}\) soil. Among legumes, methi showed lesser decrease in growth, biochemical and yield characteristics followed by methi, broad bean and chick pea, whereas, pea and lentil exhibited greater reduction in growth characteristics under Cd stress. The tolerance index of cultivars was, methi> broad bean> chick pea> pea> lentil.

Experiment 2:

Experiment 2 was performed on the basis of findings of Experiment 1. As observed in Experiment 1, methi emerged as Cd-least sensitive and lentil as Cd-most sensitive. Among Cd levels, 100 mg Cd Kg\(^{-1}\) soil was found to be most toxic and caused maximum reduction in characteristics studied. In the present Experiment, the aim was to study the alleviation potential of *Rhizobium* on the effects of 50 and 100 mg Cd Kg\(^{-1}\) soil. The treatments in this Experiment were arranged in a factorial randomized block design. The assessment was done by studying the changes in Cd accumulation in root and shoot, stress markers (MDA and proline content), growth and biochemical characteristics, components of antioxidant defense system and yield characteristics of
non-sensitive (methi) and sensitive (lentil) plants. The sampling stages for Cd accumulation, growth and biochemical characteristics, stress markers, components of antioxidant defense system were determined at pre-flowering (30DAS), flowering (60DAS), and post-flowering (90DAS) stages. The yield characteristics were recorded at the time of harvest (120 DAS). The growth, biochemical characteristics and yield decreased maximally in both the plants treated with 100 mg Cd Kg\(^{-1}\) soil. There was significant increase in the Cd accumulation, MDA as well as proline content and components of enzymatic antioxidant system.

**Experiment 3:**

Experiment 3 was performed on the basis of the findings of Experiment 1. In Experiment 2, it was observed that the application of *Rhizobium* to plants treated with 50 mg Cd Kg\(^{-1}\) soil alleviated Cd-induced toxicity in both the plants. Inoculation of *Rhizobium* maximally overcome the toxic effects of 50 mg Cd Kg\(^{-1}\) soil in methi (nonsensitive plant) while, the same microbe lowered the Cd-induced toxic effects in lentil to some extent. The present experiment was aimed to study the effect of application of AM fungi for the alleviation of adverse effects of 50 mg Cd Kg\(^{-1}\) soil and 100 mg Cd Kg\(^{-1}\) soil. The treatments in this Experiment were arranged in a factorial randomized block design. The assessment was done by analyzing the changes in Cd accumulation in root and shoot, growth and biochemical characteristics, stress markers, components of antioxidant defense system were done at pre-flowering (30DAS), flowering (60DAS), and post-flowering (90DAS) stages and yield characteristics was determined at harvest. The alteration in Cd accumulation, growth, biochemical characteristics, stress markers, components of antioxidant defense system and yield characteristics caused by 50 mg Cd Kg\(^{-1}\) soil alleviated by AM fungi in methi (nonsensitive plant) and lentil (sensitive plant). Application of AM fungi not only ameliorated the Cd-induced effects but also increased growth, biochemical characteristics, components of antioxidant defense system and thus yield characteristics in methi. In lentil, application of this symbiont only lowered the adverse effects of Cd.

**Experiment 4:**

Experiment 4 was conducted on the basis of the findings of Experiment 1. In Experiment 2 and 3, it was observed that the application of *Rhizobium* and AM fungi
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singly to plants treated with 50 mg Cd Kg\textsuperscript{-1} soil alleviated Cd-induced toxicity in both the plants. Inoculation of both the symbionts maximally overcome the toxic effects of 50 mg Cd Kg\textsuperscript{-1} soil in methi (non-sensitive plant) while, the same microbes lowered the Cd-induced toxic effects in lentil to some extent but it was more than their single inoculation. The present experiment was aimed to study the synergistic effect of dual inoculation of AM fungi and Rhizobium for the alleviation of adverse effects of 50 mg Cd Kg\textsuperscript{-1} soil and 100 mg Cd Kg\textsuperscript{-1} soil. The treatments in this Experiment were arranged in a factorial randomized block design. The assessment was done by analyzing the changes in Cd accumulation in root and shoot, growth, biochemical characteristics, stress markers, components of antioxidant defense system and sampling was done at pre-flowering (30DAS), flowering (60DAS), and post-flowering (90DAS) stages and yield characteristics was recorded at harvest (120DAS). The alteration in Cd accumulation, growth, biochemical characteristics, stress markers, components of antioxidant defense system and yield characteristics caused by 50 mg Cd Kg\textsuperscript{-1} soil were alleviated in methi (non-sensitive plant) and lentil (sensitive plant), but the alleviation potential of co-inoculation both the symbionts varied between plants. Combined application of AM fungi and Rhizobium not only ameliorated the Cd-induced effects but also increased growth, biochemical characteristics, components of antioxidant defense system and thus yield characteristics in methi. In lentil, application of these symbionts only lowered the adverse effects of Cd. The dual inoculation in all its effects was additive, synergistic and proved superior to their single inoculation.

The present Chapter 6 (Summary) is the resume of the current thesis and followed by the up-to-date references cited in the text. An appendix, containing the methodology employed for the chemical/biochemical analysis, has been described at the end of the thesis.
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