

# Developing a novel crop system with microbial inoculants for high income and multiple ecosystem services

**SUMMARY**

**of**

**THESIS**

SUBMITTED TO

BABASAHEB BHIMRAO AMBEDKAR UNIVERSITY



FOR THE DEGREE OF

**Doctor of Philosophy**

**IN**

**ENVIRONMENTAL SCIENCE**

Submitted by

***Roli Misra***

M.Sc. Environmental Science (UGC-JRF)

Enrollment Number: 1406/16

Under the Supervision of

***Dr. Rana Pratap Singh***

Professor

DEPARTMENT OF ENVIRONMENTAL SCIENCE

SCHOOL FOR ENVIRONMENTAL SCIENCES

BABASAHEB BHIMRAO AMBEDKAR UNIVERSITY

(A Central University)

LUCKNOW-226 025

**2022**

Increasing the income of crop growers per unit area and restoring the fertility of marginal soils are major emerging challenges of agricultural sustainability in Indian agrarian economy. Agriculture, as a whole has been suffering with the increasing difficulty of low income and ecosystem degradation. As a result, farmers are leaving the farming as occupation. One of the major cause of land degradation is to excessive use of chemical fertilizer and pesticides which are toxicating the land resources, resulting in large economic and associated environmental consequences. Nearly 80 percent of the farmers in India belong to the marginal or small land holding category with 1-2 ha land or even less. Approximately 6.73 million ha land categorized as marginal land due to high alkalinity/salinity which has lost its fertility for conventional agriculture. Rebuilding of such kind of degraded and marginal lands require sustained economic support to the farmers with better management of cropping patterns and product marketing. There are multiple biological and chemical practices are in use to improve the quality of marginal and degraded land. Several salt or alkali tolerant varieties of crops like rice, wheat, mustard, Acacia sps., date, palm, sorghum, biofuel crops and useful perennial grass species have been developed which can be grown on the marginal soil. The ecological and economic cultivation of Indian licorice, stevia and chilli as a highly paying cropping system in slightly alkaline land has been attempted in this study. Selection of species with its comparative commercial value, compatibility and the ability to withstand a variety of agroclimatic conditions including salt and drought stresses has recently made significant progress in reimagining, recreating and redesigning the degraded agroecosystems.

Our question was to assess the role of climate resilient plant growth promoters in supporting growth and productivity of high valued perennial and short - term crops like

Indian licorice, stevia and chilli in a suitable crop combination on a slightly alkaline soil (pH- 8.3, EC- 1.0 ds m<sup>-1</sup>, ESP – 19 percent) with economic and ecological benefits to the growers and soil fertility.

We hypothesized that assembling novel food and non-food crops in a cropping system and rhizo-engineering of soil inoculants can enhance the productivity of multiple crops at the same time and can improve soil fertility for sustainable agricultural production without use of agrochemicals. The increase in soil microbial biomass can increase carbon sequestration in soil and the same field can be utilized for different annual and perennial organic agriculture products.

Microbial communities are essential for healthy soil growth and biological interactions, as well as the construction of sustainable plant communities and the proper functioning of the ecosystem. These bacteria have the potential to replace agrochemicals, which have a variety of detrimental effects on agricultural output, human health, biodiversity, and ecosystem function. Beneficial soil bacteria can assist in fulfilling the United Nations' 2nd Sustainable Development Goal, which aims to boost agricultural output and incomes by 2030 in order to end poverty and malnutrition while also ensuring sustainable food production systems. Beneficial soil microorganisms derived from various ecological niches have been treated exogenously to boost plant output in agricultural fields. Due to rhizospheric pressures and variability in specific agro-climatic variables such as salinity, pH, and other abiotic stresses, the efficiency of these exogenously applied microbial inoculants is typically inconsistent. Though native soil microbes are often thought to be better soil inoculants because of their habitat suitability and stability. Hence, A good number of climate resilient agriculturally beneficial bacterial and fungal strains

have been isolated from dry plateau to Ralegarh Siddhi, Maharashtra and demonstrated for their plant growth promotion activities and high tolerance to salinity, drought, temperature variability and pesticide. The bioassay of the selected biostimulants as a consortium indicates that these microbes have good potential to develop climate resilient biofertilizers for enhanced plant growth, productivity and secondary metabolites (glycyrrhizic acid) production in Indian licorice. A successful climate resilient PGPM formulation for Indian licorice can help reduce a load of agrochemicals in the agroecosystems during its cultivation. The microbial bioinoculants developed by us have also improved soil fertility very significantly in pot conditions. Further its efficacy was assessed for changes in soil fertility of marginal land along with newly established crop community.

The objectives of the present study were aimed to find out the benefits of crops diversity levels among the selected crop species of high economic values in an ecological cultivation system in which beneficial soil microbes can be used as sole external amendments. In present study total seven crop combinations of Indian licorice (*Abrus precatorius* L.), Stevia (*Stevia rebaudiana* B.) and Chilli (*Capsicum annum* L.) were cultivated in all possible diversity levels with and without microbial application for two years and the benefits of these designed plant communities and microbial consortium of four plant growth promoting bacteria and fungi (*Bacillus pseudomycooides* RS6B, *Bacillus firmus* RS7B, *Aspergillus luchuensis* RS6F and *Aspergillus tamarisii* RS8F) were assessed on production of Plant growth, productivity, biomass generation, above ground and below ground carbon sequestration, income of growers and improvements in soil fertility in two years. The maximum increases in biomass (6.8 Mg ha<sup>-1</sup>), CEY (17765), LER (3.94) value and above ground carbon sequestration (3.2 Mg ha<sup>-1</sup>) were found in three species diversity

levels LSC (Indian licorice-stevia-chilli) with plant growth promoting microbes (PGPMs) whereas the highest below ground carbon sequestration ( $35 \text{ Mg ha}^{-1}$ ) and maximum soil fertility benefits e.g. pH (1.16 times), Electrical conductivity (7.53 times), Bulk density (1.84 times), soil total organic carbon (3.99 times), available nitrogen (5.95 times), dehydrogenase (6.16 times), microbial biomass carbon (4.06 times) and colony forming unit (4.44 times) were recorded at two species diversity level LC (Indian licorice-chilli) with and without PGPMs over the soil properties before cultivation of these plants. The highest net income ( $9.9 \text{ Lac ha}^{-1} \text{ Y}^{-2}$ ) was estimated for the two species diversity level possessing Indian licorice and stevia (LS) with effect of PGPMs. The highest productivity was recorded for chilli in two Species diversity LC (Indian licorice-chilli) and the highest microbial dependency was found for sole stevia cultivation i.e., 50.81%.

Indian licorice was first time cultivated with combination of other crops on marginal land which improved soil fertility along with multiple ecological and economic benefits. It is suggested that Indian licorice can be cultivated with other compatible crops like stevia and chilli with suitable microbial amendments of beneficial soil microbes. It will help in economic and ecological utilization of marginal and degraded land and give better productivity. The crop cultivation with increased crop diversity can be considered as an attempt to improve the delivery and stability of ecosystem services with enhanced crop productivity and income. Considering the experimental findings, it is concluded that cultivation of Indian licorice and stevia as combine cropping system may be the best combination for maximum economic return and highly diverse cropping pattern i.e., LSC would become a highly profitable cropping pattern for maximum biomass production,

above ground carbon sequestration as well as land equivalent ratio and crop equivalent yield over other less diverse crop pattern and sole crops. Designed diverse cropping practices are more efficient in the utilization of resources under stress conditions than the conventional monoculture crop practices.

### **Key findings of the study**

- Newly established plant community of *Abrus precatorius* L., *Stevia rebaudiana* Bertoni and *Capsicum annum* L. are highly effective for biomass generation, income of growers and soil fertility of marginal lands.
- The amended microbial consortium of bacteria and fungi to the plant community produces more income with enhanced soil fertility.
- Highest below ground and above ground carbon sequestration was recorded by two and three crop combination levels of LC and LSC, respectively.
- Three crop combination levels of LSC produced highest biomass, crop equivalent yield (CEY) and land equivalent ratio (LER).
- Two crop combination levels of LS benefited with maximum monetary advantages.
- The highest productivity was recorded for chilli crop in two crop combination of LC.
- The highest improvement in soil fertility was achieved by cultivation of two crop combination LC with and without microbial inputs.
- The highest microbial dependency was found for sole stevia cultivation.