Enhancing the Efficacy of *Azotobacter chrococcum* and *Bacillus subtilis* by Dose Optimization and Immobilization within Organic Carrier for High Wheat (*Triticum aestivum* L.) Productivity

THESIS

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SUMMARY

Wheat (*Triticum aestivum* L.) is the most important cereal crop in the world, which is cultivated over a wide range of climatic conditions. Due to climatic constraints and shrinkage of per capita arable land wheat productivity has suffered loses worldwide. In India also wheat production has declined due to climate change and anthropogenic activities such as industrialization, urbanization, construction of roads, railway tracks, etc. It is estimated that in India the arable land will be reduced to 0.10 ha-1 by 2050. On the other hand India's population is growing at the rate of 1.9% per annum which has increased the demand for food production. To fulfil the needs of growing population, dependency on conventional fertilizers as a source of nutrients to enhance yield has increased. The excessive use of chemical fertilizers has caused drastic effects on environment, economy and public health, which has resulted in environmental pollution, ecological damage, degraded soil fertility and increased cost of cultivation. The conventional chemical fertilizers are more efficient for crop productivity in a given unit area, however, a significant amount of applied fertilizers i.e. 30-50% approximately get lost by leaching, runoff, volatilization and emission losses. These losses account economic losses and indeed, environmental degradation and health hazards. To reduce the impact and load of conventional chemical fertilizers there is a need for some alternative measures that can provide food security for growing population in ecologically sustainable and cost effective manner.

Sustainability in agriculture sector can be attained through developing an efficient nutrient management system with the use of organic manures and biofertilizers that holds potential to maintain soil fertility and crop productivity at lower cost. Among various organic management approaches, application of biofertilizers in agricultural field considered most efficient and cost effective practice. Biofertilizers are products containing living cells of different types of microorganisms, which have ability to convert nutritionally important elements nitrogen, phosphorus and potassium (N, P and K) from unavailable to available form through biological process such as atmospheric N fixation; and solubilisation and mineralization of rock phosphate, etc. Thus biofertilizers can decrease the dependency on use of chemical N and P fertilizers making them available to plants and significantly improving nutrient status of soil. They not only play major role in reducing use of chemical fertilizers but also reduce the rate of nutrient loss due to leaching, volatilization and fixation after fertilizer application to the soil and helps in improving yield in sustainable manner.

Biofertilizers when applied directly in soil or on seeds lose their efficacy as they fail to compete with existing microbial population and acclimatize themselves under prevailing environmental conditions. Their efficacy can be improved by immobilizing them with non-toxic, biodegradable materials which provide shelter and nutrients to survive and flourish in soil even under unfavourable conditions. Organic manures such as cow-dung, compost, vermicompost, poultry manure, farm yard manure (FYM), crop residue and green manure etc. which are recommended as an alternative to the chemical fertilizers in farming system are non-toxic, biodegradable materials that have capacity to provide a range of nutrients and improve physical and biological properties of soil. Immobilization of biofertilizers also delays their release in soil thereby extending time period for their availability. Thus immobilization of biofertilizers with organic manures as carrier is a sustainable strategy to enhance the efficiency of biofertilizer to increase crop productivity as well as soil fertility.

The present investigation entitled "Enhancing the Efficacy of *Azotobacter chroococcum* and *Bacillus subtilis* by Dose Optimization and Immobilization within Organic Carrier for High Wheat (*T. aestivum* L.) Productivity" was carried out to develop and study the optimal conditions for enhanced productivity of wheat (*T. aestivum* L.) using an efficient organic nutrient system based on basic principles of the plant nutrient and simple technological intervention.

From the present study following conclusions were drawn out:

 The experiment on assessment of effect of consortium of biofertilizers on wheat productivity and dose optimization when applied as seed coat and in free form in pot: study revealed that the threefold dose of biofertilizers (recommended dose) increased the growth and yield compared to crops grown in soil without fertilizer, with recommended dose and twofold of recommended dose on application in form of seed coat as well as in free form. However, when biofertilizer was applied as seed coat showed better results in comparison to free form application. Further increase in dose concentration does not produced significant effect on growth and productivity of wheat. At threefold dose the yield was recorded to be increased by 43.34, 19.93 and 17.57% when applied as seed coat and 17.46, 5.41 and 4.84% when applied in free form over no fertilizer, single dose, and twofold dose, respectively.

 The experiment on assessment of effect of consortium of biofertilizers on wheat productivity and dose optimization, applied as seed coat and free form in plots: study shown that the threefold dose of biofertilizers (recommended dose) was optimum to enhance the growth and yield of wheat crop compared to control (without fertilizer), recommended dose and twofold of recommended dose on both, seed coat and free form of application and increase in dose concentration beyond

threefold does not produced any significant effect on growth and productivity of wheat.

Similar to pot experiment in plot experiment when biofertilizers was applied as seed coat showed better results compared to free form of application. The yield productivity was recorded to be increased by 48.71, 17.71 and 8.45% on seed coat application and 20.18, 8.47 and 6.09% in case of free form of biofertilizers over no fertilizer, single dose and twofold dose, respectively.

 Formulation and Characterization of Super granules: The super granules were formulated by immobilizing biofertilizers with different organic matrix i.e. vermicompost, farm yard manure and cow dung with binders Acacia, molasses and Jaggery; clay soil as inert carrier and neem leaves. The super granules prepared in different combinations were analyzed through SEM-EDX and FTIR to determine elemental properties and functional groups of granules and the result obtained revealed that the super granules prepared with vermicompost with all three binders contains higher percentage of CHN ratio.

The microbial population in super granules was maintained in storage even at different temperature. The immobilization of biofertilizers in organic matrix and organic binder significantly supported and enhanced the microbial population. The highest microbial population was recorded in super granules prepared with vermicompost and jaggery at different storage time and varying temperature.

 Application of super granules for wheat cultivation in pots: All combination of organic matrix and binders immobilizing biofertilizers were applied in pots to enhance wheat productivity. The study showed super granules of biofertilizers immobilized with vermicompost and jaggery produced best results in terms of plant growth and yield in comparison to no fertilizer, chemical fertilizer, and other combinations of immobilized biofertilizers.

 Application of best performing super granules of biofertilizers immobilized with vermicompost and jaggery under environmental stress conditions: Under drought condition super granules of vermicompost and jaggery (IVJ-D) increased percentage of grain yield by 59.63, 43.51, 33.78, and 52.92% over no fertilizer (NF), free form biofertilizers (FBF), free form biofertilizers + free form of organic matrix (BFFOM) and free form of organic matrix (FOM). Under salinity super granules of vermicompost and jaggery (IVJ-SL) increased yield by 77.08, 11.27, 69.10 and 21.26% over no fertilizer (NF), free form chemical fertilizers (CF), free form biofertilizer + free form of organic matrix (BFFOM) and immobilized biofertilizers in vermicompost used jaggery as binder under stress condition in cadmium (IVJ-Cd). Under cadmium stress condition, super granules of vermicompost and jaggery (IVJ-Cd) increased percentage of grain yield by 51.09,

43.11 and 34.72% over no fertilizer; (NF), free form biofertilizers+free form of organic matrix; (BFFOM) and immobilized biofertilizers in vermicompost used *acacia* gum as binder under stress condition in cadmium and salinity; (IVJ-Cd+SL).

 Cost benefit analysis: From cost benefit analysis study it was concluded that the use of vermicompost as organic matrix and jaggery as binder for formulation of super granules of biofertilizer are cost effective in terms of their easy availability, low cost and potential to improve wheat productivity per hectare thereby reducing economic pressure over farmers and replacing dependency on costly chemical fertilizers.