PART-II : CASE STUDIES

6. Azotobacter - A case study

Azotobacter is a free-living aerobic bacterium dominantly found in India soils. It is a non-symbiotic heterotrophic bacteria capable of fixing on an average 20 Kg N/ha/year. Besides, this it also produces growth promoting substances and is shown to be antagonistic to pathogens (Bhandari and Somani, 1990). Azotobacter are found in the soil and rhizoshpere of many plants and their population ranges from negligible to 10^4 g^{-1} of soil depending upon the organic matter, pH, temperature, microbial interactions etc. *Azotobacter chroococcum* is the most prevalent species found but other species described include *A. agilis*, A. *vinelandii*, *A. beijerinckii*, *A. insiginis*, *A. macrocytogenes* and *A. paspali.*

A large fraction of microbial population can dissolve insoluble inorganic phosphorus occuring in soil (Hayman, 1975). Amongst the fungi, the most efficient phosphate solubilizers were found in the *Aspergillus* (*A. awamori)* and the *Penicillium* (*P. digitatum*) group. Other genera include *Curvularia* and *Trichoderma.* Among the bacteria, the most efficient isolates were from *Pseudomonas (P. strioata, P rattonis*) and *Bacillus* (*B. subtilis*) group. A few species of cyanobacteria have also been reported to dissolve Mussorie rock phosphate (Roychoudhury and Kaushik, 1989). Microorganisms solubilizing phosphates are usually isolated from the rhizosphere portion and their ability to dissolve p is checked on to a medium containing phosphorus. The efficient cultures are selected after a series of tests with growth in specific media (Pikovskaya, 1948) containing isoluble phosphate source.

Our agriculture system depends on microbial activities and there appears to be a tremendous potential for making use of microorganisms in increasing crop production. There exists an immense diversity among microorganisms and even within a group of microorganisms. Conservation of this diversity is essentially needed to get continuous benefit of mirobes. The maintenance of this potent battery of prototype and new microorganisms is the very basis of impressive investment in long term basic and applied microbiological research. The importance of conservation is growing steadily as the number of preserved is continuously increasing by isolation and genetic manipulation but there is also need of awareness of the importance of proper preservation of microorganisms because important microbes preserved improperly may be lost forever or face genetic instability. A few attributes should be kept in mind while preserving the microbial cultures.

There has been little effort to develop type culture collections for microorganisms in India. At research institutions, as part of the research programmes, there exists a small collection of strains which might have been isolated during the course of research or obtained from some other collections. While such small collections have, no doubt, localized importance, they cannot serve the large national interest and the authenticity of the cultures obtained from such personal collections cannot be established or documented. Such an activity should be organized at the national level so that the whole scientific community has access to it. The deposit of personal cultures at an established culture collection centre or gene bank carries its own importance because these will be preserved in the best possible way(s) and be well characterized, authentic and recognized. Thus, the future of microorganisms is in conserving them and picking the best possible strains as per requirements. There is a good collection of bacteria established at IMTECH, Chandigarh and collection of blue-green algae, Fungi and Rhizobium at IARI, but there is a need to establish a repository of important microorganisms at National level to conserve these diverse microbial genetic resources.

Since there are other nitrogen fixers, phosphate solubilizers growth promoting rhizobacteria (PGPR) which play important role in improving the soil fertility and crop productivity, there is an urgent need to conduct fundamental as well as problem-oriented basic and applied research especially on the occurrence and distribution of strains and their isolation, maintenance and preservation; bionomics; physiology, genetics, biochemistry and economic utilization.

7. Potentials of Bees and Beekeeping for Increasing Fruit/crop Production through Pollination - A Case Study

Beekeeping forms an integral component of different farming systems such as agriculture, horticulture, animal husbandry and forest farming. The importance of beekeeping lies in the fact that it does not compete with farming systems for resources because the bees simply collect honey and pollen from the plants which otherwise would go waste. This enterprise can be taken up both at the households as well as commercial levels to generate substantially more profits and employment eliminating thereby the engulfing poverty in third world countries. The sustainability of agriculture warrants for reorientation of crop production technologies with much of the emphasis on yield enhancement through packages based on biological inputs. One such input, already practised and used is cross pollination of different crops through honeybees in increased yields.

In recent years, a number of techniques have been developed for increasing the productivity of certain agricultural crops through cross pollination by honeybees. These include the use of pollen dispensers, pollen bombs, training of bees, development of high and low preference strains of honeybees for the pollination of specific crops through selective breeding, domestication and utilization of non-Apis pollinators and safeguard of bees against pesticides.

In view of the importance of bees for increasing the yield of cross pollinated crops, different species of honeybees and solitary bees are being utilized in northern India. Himachal Pradesh, Uttar Pradesh and Kashmir are the principle temperature fruit-growing regions of the country. In Himachal Pradesh, more than 75,000 hectares of Land is under temperate fruit cultivation and more than 20,000 colonies of honeybees are required against the present number of 10,000. The population of non-Apis pollinators is declining at an alarming rate, owing to growing deforestation, vast clearance of wasteland for cultivation, and increased use of pesticides. This makes domesticated honey bee essential for pollination. In addition to pollinate temperate fruits, both *Apis cerana* and *Apis mellifera* are also utilized for the pollination of vegetables, oil seed crops and clovers.

Considering the importance of bees in pollination, Himachal Pradesh has taken the lead in renting *Apis cerana* colonies to orchardists for the pollination of apple crips. This programme has created great awareness among orchaardists about the importance of honeybees for pollination.

7.1 Advantages of bees pollination

Honeybees are the most efficient pollinators of several cultivated and wild plants because of their following characteristics.

- Body parts are specially modified to pick up many pollengrains
- flower fidelity and constancy,
- potential for long working hours.
- Through micro-manipulation of flowers,
- Maintainability of high populations as and when needed, and
- Adaptability to different climates and niches.

7.2 Potentials of Bees and Beekeeping

Deodikar and Suryanarayana (1977) have reviewed the increase in seed or fruit yields in various crops due to pollination in India. As a result of cross pollination by bees, somatic, reproductive and adaptive hecterosis or hybrid effects occur in plant progeny either in a single way or in different combinations. Such hybrid effects bring the following qualitative changes in the economic and biological aspects of plants:

- Stimulate generation of pollen on stigmas of flowering and improve selectivity in fertilizer.
- increase viability of seeds, embryos and plants
- more nutritious and aromatic fruits are formed
- increase the vegetative mass and stimulate faster growth of plants
- increase number and size of seeds and yield of crops
- enhance resistance to diseases and other adverse climatic conditons
- increase nectar production in the nactaries of plants
- increase fruit set and reduces fruit drop
- increase oil content in oil seed crops

7.3 Native hive bee *Apis cerana*

This native species could potentially be of great importance to beekeeping and pollination even outside its range. New technologies in molecular biology will present opportunities to introduce genes that code for desirable characteristics of Apis cerana into population of European hive bee, Apis mellifera and vice-versa.

7.4 Genetic diversity of *Apis cerana* in India

Amongst different species of honeybees found in India, *Apis cerana* is equivalent to European honeybee *Apis mellifera*. Both these species build parallel combs and can be domesticated. The genetic diversity of *Apis mellifera* has been organized into 24 sub-species having varied economic usefulness. These sub-species are adapted to wider range of ecological conditions and occur at latitudes ranging from 0^0 N and 30 ^{0} S (Verma, 1991).

The Himalayan region is blessed with a great variety of climates supporting a wide range of flora and fauna including diverse wild species of non-Apis bees belonging to the families *Aphidae, Anthophoridae, Magchilidae, Melttidae, Andrenidae, Halictidae* and *Colletidae*. Throughout the world, more than 20,000 bee species have been estimated and classified into 200 genera, 9 families and 49 subfamilies (Michner , 1974). In the Indian sub-continent, Batra (1977) reported about 50 genera of bees belonging to 7 families. A survey conducted by Verma and Chauhan (1985) revealed 44 insect species (belonging to 15 families and 5 orders) visiting apple bloom in north-west Himalayas, and through pollination activity alone, yield goes up by 30 to 40 per cent beside remarkable improvement in fruit quality.

Throughout the developing countries of Asia, after green revolution where major thrust has been upon cereal production, farmers are currently being encouraged to find other uses of their limited land including alternative crops, high value crops; extensification and forestry schemes. This specially holds true for mountain areas where green revolution hardly made any impact because new miracle varieties of wheat and rice were not suitable and the technologies that went with them were inappropriate for mountain areas. The current trend of diversification from traditional cereal crops to alternative high value cash crops such as fruits, off-season vegetables. Fodder and oil seed çrops will need insect pollination. Hence the demand of bees and other insect pollinators to pollinate crops is expected to increase in future:

- Fruits and nuts
- Vegetables and pulses
- Cereals
- Drugs, beverages, condiments and spice plants
- Oil crops
- Forage crops
- Timber trees and natural vegetation

Many of the mountain crops grown in Himalayan region benefit through pollination by bees in several ways. More fruit or seed is perhaps the most commom benefits, in clovers, fruit quality can be improved, in apple or seed ripening can be synchronized, in oil seed rape, oil content of seed can be improved, in sunflower hybrid vigour with better germination and seedling establishment can be incorporated.

The pollination of crops and wild flowers by bees and conservation of "natural" environment are inter dependent. Crops and wild flowers need bees to pollinate them, bees need succession of forage from crops and wild flowers to sustain them and the natural environment to supply them with nesting sites. The seed produced ensures the potential for survival of plant species. If the seed results from cross-pollination, the potential for survival of the plant species is further enhanced because the genetic interchange involves all adaptation to new and changing environments. Furthermore, seeds and plants form parts of the food chain for seed eating and herbivorous insects, birds and mammals.

a repository of important microorganisms at National level to conserve these diverse microbial genetic resources.

Since there are other nitrogen fixers, phosphate solubilizers growth promoting rhizobacteria (PGPR) which play important role in improving the soil fertility and crop productivity, there is an urgent need to conduct fundamental as well as problem-oriented basic and applied research especially on the occurrence and distribution of strains and their isolation, maintenance and preservation; bionomics; physiology, genetics, biochemistry and economic utilization.

7. Potentials of Bees and Beekeeping for Increasing Fruit/crop Production through Pollination - A Case Study

Beekeeping forms an integral component of different farming systems such as agriculture, horticulture, animal husbandry and forest farming. The importance of beekeeping lies in the fact that it does not compete with farming systems for resources because the bees simply collect honey and pollen from the plants which otherwise would go waste. This enterprise can be taken up both at the households as well as commercial levels to generate substantially more profits and employment eliminating thereby the engulfing poverty in third world countries. The sustainability of agriculture warrants for reorientation of crop production technologies with much of the emphasis on yield enhancement through packages based on biological inputs. One such input, already practised and used is cross pollination of different crops through honeybees in increased yields.

In recent years, a number of techniques have been developed for increasing the productivity of certain agricultural crops through cross pollination by honeybees. These include the use of pollen dispensers, pollen bombs, training of bees, development of high and low preference strains of honeybees for the pollination of specific crops through selective breeding, domestication and utilization of non-Apis pollinators and safeguard of bees against pesticides.

In view of the importance of bees for increasing the yield of cross pollinated crops, different species of honeybees and solitary bees are being utilized in northern India. Himachal Pradesh, Uttar Pradesh and Kashmir are the principle temperature fruit-growing regions of the country. In Himachal Pradesh, more than 75,000 hectares of Land is under temperate fruit cultivation and more than 20,000 colonies of honeybees are required against the present number of 10,000. The population of non-Apis pollinators is declining at an alarming rate, owing to growing deforestation, vast clearance of wasteland for cultivation, and increased use of pesticides. This makes domesticated honey bee essential for pollination. In addition to pollinate temperate fruits, both *Apis cerana* and *Apis mellifera* are also utilized for the pollination of vegetables, oil seed crops and clovers.

Considering the importance of bees in pollination, Himachal Pradesh has taken the lead in renting *Apis cerana* colonies to orchardists for the pollination of apple crips. This programme has created great awareness among orchaardists about the importance of honeybees for pollination.

7.1 Advantages of bees pollination

Honeybees are the most efficient pollinators of several cultivated and wild plants because of their following characteristics.

- Body parts are specially modified to pick up many pollengrains
- flower fidelity and constancy,
- potential for long working hours.
- Through micro-manipulation of flowers,
- Maintainability of high populations as and when needed, and
- Adaptability to different climates and niches.

7.2 Potentials of Bees and Beekeeping

Deodikar and Suryanarayana (1977) have reviewed the increase in seed or fruit yields in various crops due to pollination in India. As a result of cross pollination by bees, somatic, reproductive and adaptive hecterosis or hybrid effects occur in plant progeny either in a single way or in different combinations. Such hybrid effects bring the following qualitative changes in the economic and biological aspects of plants:

- Stimulate generation of pollen on stigmas of flowering and improve selectivity in fertilizer.
- increase viability of seeds, embryos and plants
- more nutritious and aromatic fruits are formed
- increase the vegetative mass and stimulate faster growth of plants
- increase number and size of seeds and yield of crops
- enhance resistance to diseases and other adverse climatic conditons
- increase nectar production in the nactaries of plants
- increase fruit set and reduces fruit drop
- increase oil content in oil seed crops

7.3 Native hive bee *Apis cerana*

This native species could potentially be of great importance to beekeeping and pollination even outside its range. New technologies in molecular biology will present opportunities to introduce genes that code for desirable characteristics of Apis cerana into population of European hive bee, Apis mellifera and vice-versa.

7.4 Genetic diversity of *Apis cerana* in India

Amongst different species of honeybees found in India, *Apis cerana* is equivalent to European honeybee *Apis mellifera*. Both these species build parallel combs and can be domesticated. The genetic diversity of *Apis mellifera* has been organized into 24 sub-species having varied economic usefulness. These sub-species are adapted to wider range of ecological conditions and occur at latitudes ranging from 0^0 N and 30 ^{0}S (Verma, 1991).

The Himalayan region is blessed with a great variety of climates supporting a wide range of flora and fauna including diverse wild species of non-Apis bees belonging to the families *Aphidae, Anthophoridae, Magchilidae, Melttidae, Andrenidae, Halictidae* and *Colletidae*. Throughout the world, more than 20,000 bee species have been estimated and classified into 200 genera, 9 families and 49 subfamilies (Michner , 1974). In the Indian sub-continent, Batra (1977) reported about 50 genera of bees belonging to 7 families. A survey conducted by Verma and Chauhan (1985) revealed 44 insect species (belonging to 15 families and 5 orders) visiting apple bloom in north-west Himalayas, and through pollination activity alone, yield goes up by 30 to 40 per cent beside remarkable improvement in fruit quality.

Throughout the developing countries of Asia, after green revolution where major thrust has been upon cereal production, farmers are currently being encouraged to find other uses of their limited land including alternative crops, high value crops; extensification and forestry schemes. This specially holds true for mountain areas where green revolution hardly made any impact because new miracle varieties of wheat and rice were not suitable and the technologies that went with them were inappropriate for mountain areas. The current trend of diversification from traditional cereal crops to alternative high value cash crops such as fruits, off-season vegetables. Fodder and oil seed crops will need insect pollination. Hence the demand of bees and other insect pollinators to pollinate crops is expected to increase in future:

- Fruits and nuts
- Vegetables and pulses
- Cereals
- Drugs, beverages, condiments and spice plants
- Oil crops
- Forage crops
- Timber trees and natural vegetation

Many of the mountain crops grown in Himalayan region benefit through pollination by bees in several ways. More fruit or seed is perhaps the most commom benefits, in clovers, fruit quality can be improved, in apple or seed ripening can be synchronized, in oil seed rape, oil content of seed can be improved, in sunflower hybrid vigour with better germination and seedling establishment can be incorporated.

The pollination of crops and wild flowers by bees and conservation of "natural" environment are inter dependent. Crops and wild flowers need bees to pollinate them, bees need succession of forage from crops and wild flowers to sustain them and the natural environment to supply them with nesting sites. The seed produced ensures the potential for survival of plant species. If the seed results from cross-pollination, the potential for survival of the plant species is further enhanced because the genetic interchange involves all adaptation to new and changing environments. Furthermore, seeds and plants form parts of the food chain for seed eating and herbivorous insects, birds and mammals.