Need for Introducing the Concept of "PGPR" in Coconut Crop Production System for Improved Plant Growth and Establishment

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The concept of "PGPR" or "plant growth promoting rhizophere microorganisms" was first introduced by Kloepper in as early as 1980. He defined them as rhizosphere microorganisms that favourably influence plant growth and yield of commercially important crops. The PGPR concept essentially encompasses the isolation of microorganisms from soil and then their reintroduction into the appropriate habitat for stimulating plant growth. This microbial management in the soil means thus modifying the rhizosphere microflora with microbes that have been selected for their plant growth - and health - enhancing attributes. It has been found that these PGPRs contribute significantly to the control of pests and enhancement of plant growth.

Several groups of micro-organisms have been found to possess the potential to enhance the growth and health of agricultural crops, which was previously confined to inoculation of seeds of legumes by *Rhizobium*. These include a large array of bacteria that fit the bill of PGPRs and some of the well known examples are those belonging to the genera *Azotobacter, Azospirillum, Klebsiella, Bacillus, Pseudomonas, Enterobacteri, Serratia, Arthrobacter* and *Alcaligenes*. They are naturally occurring free-living soil microorganisms which are capable of colonizing roots and enhancing plant growth when added to seeds, roots or tubers. The direct mechanism of improving crop stand by many of these microorganisms is by producing and secreting plant growth promoting substances (phytohormones) such as auxins, gibberellins, cytokinins, ethylene and also vitamins; by stimulating root metabolic activities using bacterial surface components; by stimulation of phytoalexins in roots; by phosphate solubilization, by reducing the soil pH by production of organic acids or other acidic substances; and / or by supplying biologically fixed nitrogen. Consequently, germination, root development, mineral nutrition and water utilization are improved. PGPRs also influence plant growth by indirect mechanisms such as suppression of bacterial, fungal and nematode pathogens (biocontrol) by the production of various metabolites, by induced systemic resistance and / or by competing with the pathogen for nutrients or for colonization space. In fact these characters differentiate them from the many other micro-organisms that are also found in the rhizosphere.

Horticultural crops that are grown under a wide range of environmental conditions are targeted for successful application of PGPR management concepts. Among the micro organisms that are promising enough to fit well into the horticultural crop production systems are the mycorrhizal fungi and certain other free-living microorganisms with specific functions.

Mycorrhizal fungi

These are diverse groups of fungi that form a symbiotic relationship with the roots of the plants. Most of the plants form endomycorrhizae, the main type being the Vesicular - Arbuscular (VA) mycorrhizae. The VA-mycorrhizal fungi are members of the Endogonaceae and are obligate symbionts and can only be propagated in "pot culture" on living plant roots.

These mycorrhizal fungi aid plant growth by helping the plant acquire mineral nutrients from the soil, especially phosphorus, zinc, copper and others that may be quite immobile in soil. In field situations, a zone of nutrient depletion forms around roots which limits direct uptake of distant immobile nutrients by roots. This zone can be effectively bridged by mycorrhizal fungi since their hyphae can extend out into the soil and reach sources of nutrients available to nonmycorrhizal roots. In addition, mycorrhizal fungi alleviate drought stress, aid in transplanting and enhance rooting of cuttings which is desirable for horticultural plants.

The coconut, which is a perennial horticultural crop, is grown either as a sole crop (monocropping) or in combination with other compatible crops in the inter spaces between the coconut palms (mixed cropping). There exists an immense possibility for increasing the agricultural production through microbial manipulation of the soil. For example, inoculation with VA-mycorrhizal fungi can bring significant benefits to the coconut growers, as they colonize coconut and intercrops, *viz.* banana, pepper, clove, pineapple, coffee, colocasia, subabul, etc. very well. VA-mycorrhizal fungi commonly infecting coconut are *Gigaspora rosea, G. decipens, G. aurigloba, G. coralloidea, Glomus multicaulae* and *G. fasciculatum*. The *Glomus* species have been especially found to increase height of stem and number of leaves in field

planted coconut palms. VA-mycorrhizal colonization in roots of coconut is positively correlated with physiological indices associated with drought tolerance such as leaf water potential and stomatal resistance enabling the coconut plants to withstand water scarce conditions.

In the establishment of coconut seedlings in nurseries also, VA-mycorrhizae can play a significant role. It has been well established that introduction of species like *Glomus fasciculatum, G. macrocarpum , Scutellospora decipens, Gigaspora calospora, G. margarita,* etc. into coconut seedlings enhance their vigour apart from improving their fresh weight and nitrogen content. This helps the seedlings to withstand transplantation shock better.

By following coconut based mixed farming or agroforestry system, VA-mycorrhizal colonization can still be enhanced in comparison to coconut monocropping. Coconut can be intercropped with subabul, casuarina, mango, jack, eucalyptus, etc. all of which are mycorrhizal and enhance VA - mycorrhizal infection and also yield of coconut.

Free-living microbes with specific functions

These microorganisms can also have significant effects on plant growth. These effects may either be exerted directly on the host plant, or indirectly via some effect on other microorganisms in the rhizosphere. For example, some organisms are pathogen antagonists, auxin producers, ethylene producers, hormone producers, nitrogen fixers, chitinase producers, or phosphate solubilizers.

The root regions of coconut palm are inhabited by a number of associative symbiotic nitrogen - fixing bacteria having dehydrogenase uptake activity. The association of N_2-fixing *Azospirillum amazonense* with the roots of coconut palm has recently been confirmed by Prabhu and co-workers (1998). Some endorhizospheric bacteria have also been observed that fix more nitrogen than rhizoplane associated *Azospirillum* spp. Some of these are capable of fixing nitrogen even in the presence of nitrogenous fertilizer. These organisms may have additive or synergistic effects on plant growth and health if they function in concert in the rhizosphere of coconut palms.

Soil amendments as well as farming practices also bring about a protracted change in rhizosphere microflora, which favour the growth of specific microorganisms, thus leading to better plant growth and crop yield. For example, organic amendments like cowdung increase VA-mycorrhizal colonization as well as the population of phosphate solubilizing bacteria in the root zone of coconut palms. Other organic amendments such as farm yard manure, coir pith, neem cake and green manures, etc. can be combined with microbial inoculants like *Beijerinckia indica* for improving the nitrogen fixation by indigenous diazotrophs in coconut soils.

The activities and positive effects of these beneficial microorganisms become more tangible in crop mixing or mixed farming in coconut as the component crops continually add plant rsideues to the soil which undergo organic recycling. This leads to alterations in the composition of the rhizosphere and has important and exciting implications in the manner that could possibly promote the growth and number of beneficial microorganisms. Also in mixed cropping, nitrogen - fixing bacteria dominated by the *Beijerinckia* group and phosphate - solubilizers such as *Pseudomonas* sp., *Bacillus* sp., *Aspergillus* sp. and *Penicillium* sp. are higher in numbers. Not only this, higher inhibition potential of resident soil bacteria to phytopathogens is observed, as compared to coconut monocropping. When coconut is grown with cacao, rhizosphere activity increases and a better mobilization of phosphate coupled with fixation of nitrogen and production of growth substances (GLS and IAA) in rhizosphere, is reflected in terms of enhanced yield. An indole-acetic-acid (IAA) producing *Escherichia* sp. is associated with the root surface of coconut and the rhizospheric *Aspergillus flavus* and *A. fumigates,* produce gibberellin like substances (GLS).

While raising coconut seedlings in coir dust-soil mixture, *Beijerinckia indica* is a promising microbiological inoculant which enhances the growth and performance of seedlings. The use of PGPRs in such specialized situations, where the environment can be manipulated to favour their establishment and proliferation is going to be more rewarding in terms of economy and in protecting the wholesomeness of the environs.

Combining microbes

Microbial combinations may have very great potential for plant growth enhancement. Additive growth benefits can be obtained by inoculating both VA-mycorrhizal fungi and a plant growth - promoting bacterium or VA-mycorrhizae in combination with phosphate - solubilizing bacteria or associative nitrogen - fixing *Azospirillum.* For additive effects, the compost prepared from coir-pith and other coconut wastes can be enriched with nitrogen - fixing bacteria like *Beijerinckia indica* and also phosphate - solubilizing bacteria, for application in coconut basins. Some rhizosphere microorganisms may have multiple functions, as mycorrhizal fungi have the capability to absorb phosphate from soil, are ethylene and hormone producers and are also effective antagonists against root pathogens. Such plant growth promoters could be

exploited to their full potential for use in coconut - based crop production systems. Wherever the coconut growers are drip irrigating their crops, such situations are ideally suited for easy application of these PGPRs.

Thus, the use of microbiological in agriculture, particularly horticultural crops is gaining momentum and it is time to explore the possibility of including these microscopic agents of vast potentials in coconut farming, with a view of facilitate the reconstitution of rhizosphere microflora dominated by already proven beneficial organisms for a sustainable coconut farming.

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