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Effect of Vermicompost and Microbial Inoculants on growth and nutrition of Tomato (*Lycopersicon esculentum*. M.) By D. Anusuya, Krishan Chandra and Neeraj Kumar	3
Growth Promotion in Different Paddy Varieties due to Application of Pseudomonas fluorescens. By Palaneeswar R., Rajapriya S and Neeraj Kumar*,	6
Response of Mulberry (Morus indica L.) to Liquid Formulations of Biofertilizer Inoculants By J. Sukumar, S.D. Padma and H. Thimma Reddy	8
Research Notes	11
Workshop, Seminar, Conferences	19
Advances in Biofertilizer Production Technology	21
Book Reviews	23

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Editorial

Dear Readers

Use of microbial technology in agriculture has increased tremendously during the past years. The major thrust areas of use of microbial technology in farming system are management of nutrients, pest and plant diseases. Thus it turns to be the segment of back bone to sustain the agricultural production. In the management of nutrients it plays a crucial and potential role by way of their transformations for growth of plants and fellow microbes. From rhizosphere to phyllosphere the microbes exist predominantly to help the plant system grow well and payback to soil fertility with protection from various pest and diseases. As a result of innovations in this technology, not only the major plant nutrients like Nitrogen, Phosphorous, Potash and Sulphur but also the micronutrients like Iron, Zink etc are being managed using this viable tool. Still, efforts are in progress to manage other nutrients exploiting its potential to maximum possible. The microorganisms being the nature sensitive can be easily affected with a slight change in ecosphere. Their population, action and overall effect on the crop may be influenced in such a situation to limit the effect of other inputs also, and may restrict the total production growth. The microbes are influenced by the external factors at two stages; one during the stage between final production and final use and the second after their invasion in to the soil. Both the stages are crucial and extremely difficult to control and manage. Researchers have inclined to explore the remedies and amendments to exploit the potential of these microorganisms under such circumstances. In the present issue both of these stages have been tried to be addressed. In one paper while the amended use of bacteria with vermicompost has been highlighted to increase the produce quantity and quality, in the second paper ecosphere has been maintained by the suiting crop to bacteria and vice versa. In the third paper the population of microbes before the use and their effect due to improved methods employed in the specific crop has been explained to enhance the production.

Besides above, the latest news on research and findings has been placed appropriately for the better and efficient use by all concerned. The events and programmes are also focused to give maximum publicity on the aspect. In addition, a new feature in the form of advances in biofertiliser technology has been introduced which will help the industrial sector. Hope the issue will attract many ones who have interest in the subject. We are obliged to all of our contributors of papers of this issue for their valuable works.

Ravindra Kumar
Editor and Assistant Director
RCOF, Bangaluru

Effect of Vermicompost and Microbial Inoculants on growth and nutrition of Tomato (*Lycopersicon esculentum*. M.)

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Introduction

Tomato *(Lycopersicon esculentum M.)* one of the most popular and widely used vegetable throughout the world belongs to family solanaceae. It is consumed as fresh or processed and is a good source of vitamins A and C. Over the past decades, phenomenal changes have been observed in the production of commercial crops owing to the innovative technologies in use of liquid biofertilizers, biopesticides and other innovative inputs resulting in better productivity. Hence, the present investigation was taken up to demonstrate the effect of Vermicompost and microbial inoculants with special reference to microbial Potassium mobilizer on growth and mineral elements of tomato plants.

Materials and Methods

A field experiments was carried out at Department of Botany, Bangalore University, Bangalore in replicated randomized block design. Tomato seedlings were transplanted in the field containing uniform doses of Vermicompost (3000 kg/acre applied as basal dose just before transplanting) enriched with different combinations of bio inoculants (biofertilizers) with three replications for each treatment. Treatments details were as follows;

T1 – Vermicompost (VC) + *Aspergillus awamorii (AA)*
T2 – VC + *Fraturia aurantia (FA)*
T3 – VC+ *Trichoderma viredi (TV)*
T4 – VC + Rock phosphate (RP)
T5 - VC + *AA + RP*
T6 – VC + *AA + FA + RP*
T7 – VC + *AA + TV + RP*
T8 – VC + *AA + FA + TV + RP*
T9 – VC + *FA + TV*
Control -VC alone

Tomato plants were harvested at different intervals viz 30, 60 and 90 day of transplanting and total plant biomass and nutrient contents viz: Phosphorus, (P) Calcium (Ca) Magnesium (Mg) and Potassium (K) and were estimated as per the standard methods.

Results and Discussion

Potassium uptake was the highest in T8 followed by T6 and T2. The uptake of K at flowering stage was maximum in T8 followed by T6 and T2 respectively. The maximum was computed with fruits and highest K uptake was recorded at T6 (1.76%) followed by T2 and T8, the lowest values were recorded in control. There was significant difference in available P, Ca, Mg and K content in enriched Vermicompost (Table 1). The P uptake by tomato plants increase with crop growth. The increase in dry matter production in vermicompost coupled with high N content might have enhanced phosphorus uptake. The uptake at vegetative stage was very less in all the treatments tried and among the treatment T2 had recorded the highest uptake value which was on par with values obtained for the treatments T3, T4 and T5. The lowest uptake value was noticed in control (0.16 %)

Higher Mg content (0.52%) was recorded in T8, and T2 and T6 respectively at 60 and 90 days. Lowest Mg content was recorded in

control (0.04 and 0.07%) followed by T4 (0.14)

At 90 days, highest Ca content of 2.41 percent was observed in T8 T6 and T2 compost treated and recorded 2nd and 3rd highest Mg content (2.38 and 2.37 %). Increase in dry matter production resulted in increased K absorption especially in tomato plants which received liquid bioinoculant as a source of K along with Vermi compost. The height of tomato plants inoculated with K mobilizer along with *Trichoderma viride* +*Aspergillus awamori* + Rock phosphate resulted in significant increase in shoot biomass than all other treatments (Table 2).

Biomass in terms of fresh weight of shoot was maximum in T6 (74 g) which was superior among all the treatments. Dry weight of shoot was higher in T8, T6 and T2 treatment. All the inoculated plants showed increased biomass compared to the control plants

Table 1 - Influence of Microbial Enriched Vermicompost on Chemical Characteristics of Tomato Plants

Treatments	P	Ca	Mg	K
T1	0.33	0.37	0.21	0.89
T2	0.56*	0.57*	0.26	1.74*
T3	0.31	0.34	0.18	0.71
T4	0.23	0.21	0.15	0.64
T5	0.32	0.39	0.20	1.11
T6	0.56*	0.56*	0.26*	1.76*
T7	0.46	0.48	0.23*	1.48
T8	0.59*	0.59	0.27*	1.73*
T9	0.41	0.44	0.24	1.57
Control	0.17	0.19	0.12	0.34

*Significant at P<0.0

Table 2 - Influence of Microbial Enriched Vermicompost on Growth Parameters of Tomato Plants

Treatments	**45 Days**			**60 Days**			**90 Days**		
	Root Cm	**Shoot cm**	**Dry Wt g**	**Root Cm**	**Shoot cm**	**Dry Wt g**	**Root Cm**	**Shoot cm**	**Dry Wt g**
T1	28*	71	31.0	38	90	39.5	43	108	59.5
T2	24	76*	48.0*	40*	92*	61.2*	48	116*	76.0*
T3	22	66	29.0	31	89	35.0	40	103	58.0
T4	20	65	22.0	29	87	30.8	39	100	51.5
T5	22	68	34.0	39	87	43.6	48	102	55.5
T6	26*	74	46.0*	39	98*	57.0	49*	118*	72.5*
T7	23	70	44.0	38	89	57.3*	49*	105	64.0
T8	26*	89*	50.6*	43*	104	65.0*	52*	128*	78.0*
T9	23	67	43.2	36	85	54.0	44	110	62.0
Control	19	65	26.5	31	80	33.6	36	96	50.5

*Significant at P < 0.05

Trichoderma was found to induce growth of various horticultural plants and increased shoot and dry weight of tomatoes and tobacco by producing growth regulating factor (Baker et al, 1987). Incorporation of various liquid bioinoculants to Vermicompost for tomato plants indicated a significant increase in nutrient availability especially in Potassium content in T6 and T8 treatments. The maximum available Phosphorus, Calcium, Magnesium and Potassium were recorded in T6 and T8 respectively and the results were similar to observations of Tester et al (1977) and Virendra and Mishra (1991). The highest mineralization has taken place in T6 and T8 treated Vermicompost at 90 days. Das et al (1995) and Saha et al (1995) also reported that Phosphorus extractability increased with decomposition reaction period and substantial portion of added Phosphorus was mineralized by 90th day of incubation.

Potassium availability also increased significantly by the incorporation of liquid bioinoculants to Vermicompost for tomato plants (Table 1). The highest value was recorded in T6 and T8 treatments probably due to liquid bioinoculant potassium mobilize. Chandra and Ramarethinum (2006) and Prasad et al (1991) also reported similar results on growth and yield of Brinjal. The amount of Potassium increase in T2 and T8 varied from that of other microbial inoculated Vermicompost. Lower values of Potassium and other mineral elements at 90 days may be due to reversion of part of water soluble and exchangeable form and cellular incorporation of microbes.

The results in Table 1 indicated that T2, T6 and T8 were superior to other combinations in almost all parameters for tomato plants, moreover, the enriched compost showed higher values of chemical characteristic than its corresponding combinations and control. According to Kostov et al (1995), compost has sharp impact over manure in respect of nutrient release, thus incorporation of enriched vermicompost with T2, T6 and T8 would give greater benefit to tomato plants. In the present studies, the low cost environmental friendly liquid bio inoculants have proved their potential as the cheapest inputs. Liquid biofertilizer technology is emerging as a promising future for biofertilizers and biocontrol agents. The quick response of liquid formulations compared to their carrier based counterparts are also creating high level of confidence among farming community.

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Growth Promotion in Different Paddy Varieties due to Application of *Pseudomonas fluorescens*

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Introduction

Bacteria that colonize plant roots and enhance plant growth by any mechanism are referred to as plant growth-promoting rhizobacteria (PGPR). PGPRs are being applied on various crops to enhance growth, seedling emergence, crop yield, disease control, and among them, some have been commercialized. The use of PGPR in sustainable agriculture is steadily increasing and offers an attractive way to complement and supplement chemical fertilizers. PGPR can promote plant growth indirectly or directly. *Pseudomonas fluorecens* is a PGPR that promises a wide role in Rice cultivation. Plant growth promotion by *Pseudomonas fluorecens* has been attributed to IAA production (Kochar et al 2011), Pyrroloquinoline quinine – PQQ (Okhee et al 2008), solubilisation of Phosphorous and Iron (De Freitas et al 1997), decreasing or preventing the deleterious effects of plant pathogenic micro organisms by production of siderophores (Kloepper et al 1980) and production of antibiotic 2,4, Diacetylphloroglucinol (DAPG) (Keel et. al 1992). To study the response of different paddy varieties to *Pseudomonas fluorescens* inoculation an experiment was conducted. Abstract findings are summarized here.

Materials and methods

The experiment was conducted at Virudhunagar during 2010. Three certified seeds of paddy varieties popularly cultivated in Tamil Nadu viz, ADT 45, ASD 16 and BPT 5204 were selected. The seeds were first surface sterilized with 50% bleach followed by several rinsing with sterile water and then treated with liquid formulation of *Pseudomonas fluorecens* developed by RCOF, Bangalore and having cell density in excess of $2x10^9$ cfu/ ml (Chandra K, 2010). 1ml of this formulation was suspended in 10ml of water and Paddy seeds were soaked in it. Surface sterilized paddy seeds soaked in sterile water were kept as control. Treated seeds were shade dried and twenty five seeds from each variety selected at random were sown in a tray containing the soils collected from Paddy field.

Five seedlings were selected at random from tray and the observations were made on 10^{th}, 20^{th} and 30^{th} day of sowing. The seedlings were uprooted gently without causing any damage to the root and shoot systems and washed well with water. The shoot and root lengths were measured with a metric scale. The shoot and root dry weight was determined using an electronic balance after drying to constant weight at $65^{O}C$.

Result and discussion

Pseudomonas fluorecens treated paddy seedlings showed positive response over the untreated ones. Percentage seed germination was found to be significantly higher in *Pseudomonas fluorecens* treated seeds compared to control (Table 1).

The inoculation of *Pseudomonas fluorecens* in variety ADT 45 showed considerable increase in seed germination than other varieties. It increased germination of ADT 45 variety from 74.5% to 88.3%. The observations made on 10^{th}, 20^{th} and 30^{th} days of sowing revealed that *Pseudomonas fluorecens* treated seeds had higher productivity in terms of length of shoot and root, total fresh weight and total dry weight

compared to control. Significant improvement in germination and overall growth attributes may be attributed to the release of hormones such as auxins by the bacteria under study (Table 2 and 3). Similar results have also been observed in other two paddy varieties under study but with slightly lesser response. Increased availability of auxins is known to induce development of numerous root branching, root hairs and primary and secondary lateral roots resulting into increased nutrient uptake and higher plant biomass. Similar effect of *Pseudomonas fluorecens* on increasing the vigour index of rice seedlings have also been reported by Saveetha et al 2009.

Table 1:
Effect of *Pseudomonas fluorescens* inoculation on seed germination

Paddy variety	% germination	
	Control	Treated
ADT 45	74.5	88.3
ASD 16	72.5	85.5
BPT 5204	79.0	84.5

Table 2 - Effect of *P. fluorescens* treatment on shoot (S) and root length (R) of different paddy varieties

Paddy Variety	Control						Pseudomonas treated					
	10th		20th		30th		10th		20th		30th	
	S	R	S	R	S	R	S	R	S	R	S	R
ADT 45	14.7	7	19.6	14.5	27.1	16.9	18.5	8.8	22	15.2	28.8	19.8
ASD 16	12.3	5.2	15.3	10.9	20.3	14.5	17.6	7.8	19.9	14.9	26.4	15.8
BPT5204	14.2	6	17.6	12.6	20.5	15.9	17.3	8.4	20.5	13.2	26.2	18.0

Table 3 - Effect of *P. fluorescens* treatment on shoot (S) and root (R) dry mass of different paddy varieties

Paddy Variety	% increase in dry weight in treated plants over control					
	10th		20th		30th	
	S	R	S	R	S	R
ADT 45	20.0	19.81	15.06	43.9	13.26	26.89
ASD 16	25.7	29.0	13.58	37.64	25.53	14.08
BPT 5204	17.55	29.0	13.58	37.64	25.53	14.08

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Response of Mulberry (*Morus indica L.*) to Liquid Formulations of Biofertilizer Inoculants

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Introduction

Mulberry is the sole food plant of silkworm (*Bombyx mori* L.) The plant requires high doses of fertilizers amounting to substantial cost in cocoon production. Any reduction in their dosage and improvement in use efficiency contributes to reduction in cost of production. In this context biofetilizers play an important role. Liquid formulations of biofertilizer inoculants are gaining preference in contemporary agriculture as an alternative to carrier based inoculants to reduce N & P fertilizer application and increase their use efficacy. Recently potash mobilizing bacterial inoculants have also been identified and have been found to improve K mobility and availability to plants (Chandra, 2005). Liquid inoculants have a longer shelf life of up to two years, easy to produce, less bulky, contaminant free, cost effective and required in low doses, easy to transport, store and apply. Although lignite based *Azotobacter, Azospirillum* and *Bacillus* spp biofertilizers have been found to be highly efficient in mulberry cultivation by reducing 25% of N & P application with an additional increase of 4-5% in leaf yield. Combined application of these biofertilizers can increase leaf yield up to 12% resulting in similar improvement of cocoon yield fetching higher income to the sericulturists (Sukumar *et al* 2004 & 2005). However, the dosage of lignite based formulations of N & P biofertilizers is 8 and 10 kg/acre/yr. which costs Rs. 600 and 750/acre/yr. In the present study nitrogen fixing (NFB) and phosphate solubilizing (PSB) bacterial isolates (*Azospirillum brasilense, Azotobacter chroococcum, Bacillus megaterium*, *Pseudomonas fluorecens*) were developed as liquid formulations and evaluated against carrier (lignite) based formulations, both at the institute and farmers' field conditions. Brief results of study are presented here.

Highlights of findings

- Liquid formulations of NFB & PSB isolates had a shelf life of up to 18-24 months as compared to lignite based formulation (6 months- Table 1). From dosage point of view liquid formulations of PSB & NFB were required @ 1000 ml/acre/yr in two splits compared to 10 & 8 kg/acre/yr of lignite based inoculants.

- Leaf yield in presence of 75% N and *Azospirillum brasilense/Azotobacter chroococcum* were on par with control (100%N) while 3% increase in leaf yield was observed with liquid formulation in presence of 100%N (Table-2).

- Leaf N increased up to 10-15% in presence of liquid NFB compared to 8-13% in presence of carrier based formulation.
- Liquid formulation of PSBs (*Bacillus* spp. and *B. megaterium* – KSSRDI isolates) improved leaf yield by 8% with full dose of P as SSP, 5% in presence of SSP+MRP (50:50) as compared to 6 & 3% in presence of SSP 100% & SSP +MRP (50:50) with carrier based formulations respectively (Table-3).

- Leaf yield in presence of 75% P and inoculants was on par with control.

- Combined inoculation of PSB & NFB liquid formulation in presence of 100% N & P increased leaf yield by 13%

compared to 10% increase in presence of carrier based inoculants.

- N & P uptake increased by 15 & 22% in individual inoculations with liquid formulations (Table 2 & 3). With combined inoculations the uptake of P was 21% & 23% with powder and liquid formulations respectively

- Root volume increased by 30% with liquid formulation of PSB as compared to 23% with lignite based formulations.

Conclusion

Liquid formulation of biofertilizer inoculants were superior to carrier based inoculants in their influence on mulberry and per acre dose requirement. Liquid formulations may prove to be boon to sericulture in reducing the cost on PSB & NFB inoculants by Rs. 550 and Rs. 370/acre (cost of liquid inoculants was @ Rs. 200/litre) as compared to lignite based inoculants where the cost was Rs. 750 and 600 for 10 and 8 kg/acre/yr. They can also be applied with drip irrigation systems with little modifications in the dripping zone. These can be stored up to two years. While the lignite formulations are invariably associated with contaminants, liquid formulations are contaminant free. With many such benefits, the liquid formulations of biofertilizers are undoubtedly a new generation of bio-products highly beneficial in sericulture and are gaining importance and popularity.

Table-1. Shelf life of liquid and carrier based biofertilizer inoculants

Organism / formulation	Total viable count (cfu)per ml of liquid or per g of carrier based as observed after storage in months				
	0	6	12	18	24
Azotobacter chroococcum liquid formulation	10^9	10^9	10^8	10^8	10^7
Azospirillum brasilense liquid formulation	10^{10}	10^{10}	10^8	10^8	10^8
Azotobacter chroococcum Carrier based	10^9	10^7	10^4	-	-
Azospirillum brasilense Carrier based	10^9	10^8	10^4	10^2	-
PSB (*Bacillus* sp., *B. megaterium*, *Pseudomonas fluorescens* -KSSRDI isolates) liquid formulation	10^{10}	10^9	10^9	10^8	10^8
PSB (*Bacillus* sp., *B. megaterium*, *Pseudomonas fluorescens* -KSSRDI isolates) Carrier based	10^9	10^8	10^5	10^3	-

Table-2. Response of mulberry to liquid and lignite based formulations of NFB inoculant (average data of 10 harvests).

Treatments	**Leaf yield kg/ha/yr**	**% increase**	**Leaf N %**	**% increase**
Control	28,700	-	2.60	-
NFB(L)+ N 100%	29,561	3	2.99	15
NFB(P) + N 100%	29,274	1	2.90	13
NFB (L) + N 75%	29,100	1	2.86	10
NFB (P) + N 75%	28,843	0.5	2.89	08
CD @ 5%	**863**		**0.27**	

(L – Liquid formulation P- (powder) lignite based formulation)

Table-3. Response of mulberry to liquid and lignite based formulations of PSB and combined inoculations with PSB & NFB inoculants (average data of 10 harvests).

Treatments	**Leaf yield kg/ha/yr**	**% increase**	**Leaf P %**	**% increase**
Control	29,000	-	1.60	-
PSB (L)+P 100%(SSP)	31,320	8	1.95	22
PSB (L)+P 75% (SSP)	29,580	2	1.90	19
PSB(P)+P 100%(SSP)	30,740	6	1.92	20
PSB (P)+P 75% (SSP)	29,290	1	1.62	17
PSB (L)+P 100% (SSP+MRP)	30,450	5	1.68	18
PSB (P)+P 100% (SSP+MRP)	29,870	3	1.86	16
PSB (L)+NFB(L) N & P(SSP) 100%	32,770	13	1.97	23
PSB (P)+NFB(P) N & P (SSP)100%	31,900	10	1.99	21
CD @ 5%	**880**	**-**	**0.08**	**-**

L – Liquid formulation P- (powder) lignite based formulation

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Research Notes

Interactions between *Bacillus mucilaginosus* and silicate minerals (weathered adamellite and feldspar): Weathering rate, products, and reaction mechanisms - *Bacillus mucilaginosus* is a common soil bacterium, and usually used as a model bacterium in studying microbe-mineral interactions. Several reaction mechanisms of *B. mucilaginosus* weathering silicate minerals were proposed. However, the molecule mechanisms and detailed processes were still unclear. In this paper, bacterium mineral interactions were studied in terms of variations in pH value over the experimental period, variations in mineral composition, weathering rates of silicate minerals and volatile metabolites in the culture medium, etc., to further explore the bacterium-mineral interaction mechanisms. The results showed that *B. mucilaginosus* could enhance silicate mineral weathering. The weathering rates were quite different for various kinds of silicate minerals, and the weathering rate of weathered adamellite could reach 150 $mg/m^2/d$. Although *B. mucilaginosus* produced little acidic substance, pH in the microenvironment of bacterium-mineral complex might be far lower than that of the circumjacent environment; a large amount of acetic acid was found in the metabolites, and was likely to play an important role as a ligand. These results appear to suggest that acidolysis and ligand degradation are the main mechanisms of *B. mucilaginosus* dissolving silicate minerals, the formation of bacterium-mineral complexes is the necessary condition for the bacteria weathering silicate minerals, and extracelluar polysaccharides played important roles in bacterium-mineral interaction processes by forming bacterium-mineral complexes and maintaining the special physicochemical properties of microenvironment. (Source - Binbin and Bin Lian, 2007, Chinese Journal of Geochemistry, 30 (2) : 187-192)

Effect of *Bacillus mucilaginosus* on weathering of phosphorite and a preliminary analysis of bacterial proteins - The authors investigated the effect of *Bacillus mucilaginosus* on weathering of phosphorite. Analysis of different proteins was of significance in exploring the molecular biological mechanism in the bacterial weathering process. The concrete methods are described as follows: Mineral powder was put into liquid culture medium and *B. mucilaginosus* was incubated in the medium. The control had no mineral powder in the medium. The treatments and controls were cultured simultaneously under the same condition. In a few days, the supernatant was filtrated, the main cations (Ca^{2+}, Mg^{2+}, Na^{+}, Mn^{2+}, Al^{3+}, Fe^{3+}, K^{+}) were measured by ICP-OES, and the contents of water soluble phosphorus (Pws) and silicon (Siws) were determined by colorimetry. The residual solid was weighed on the filter paper, followed by digestion with concentrated HNO_3. The concentrations of the main cations and Pws, Siws in the digest liquid were measured by using the method mentioned above. After the supernatant was centrifuged, the precipitation was used to analyze the protein differences between the treatment groups and the control groups by 2-dimentional gel electrophoresis (2-DE). The experimental results showed that apatite and quartz were partially weathered, but kaolinite was dissolved completely. The population of bacteria increased when mineral powder was added in the liquid medium. Software analysis and comparison of the 2-DE pictures of bacterial proteins revealed 1134 visible protein spots in the treatment group, and 729 visible protein spots in the control group. To compare the bacterial protein expression contents of the treatment group with those of the control group, there were 496 different protein spots, including 214 protein spots which indicated that the protein contents increased, 75 protein spots were indicative of a decrease, and 207 proteins were newly synthesized. It is proposed that the increased bacterial contents may be related to some protein expression and activation after the input of mineral powder. Newly

synthesized proteins, the increase of expression contents and the reduction of proteins may be connected with bacterial metabolic regulations, cell activation and signal transmission. (Source – Chen et al, Chinese J. Geochemistry 27 (2) : 209-216)

Mobilization of potassium from waste mica by plant growth promoting rhizobacteria and its assimilation by Maize (*Zea mays*) and wheat (*Triticum aestivum L.*) - A Hydroponics study under phytotron growth chamber - A hydroponics study was carried out to evaluate the effect of three plant growth promoting rhizobacteria (PGPR) namely, *Bacillus mucilaginosus*, *Azotobacter chroococcum*, and *Rhizobium* spp. on their ability to mobilize potassium from waste mica using maize and wheat as the test crops under a phytotron growth chamber. Results revealed that PGPR significantly improved the assimilation of potassium by both maize and wheat, where waste mica was the sole source of potassium. This was translated into higher biomass accumulation, potassium content and uptake by plants as well as chlorophyll and crude protein content in plant tissue. Among the rhizobacteria, *Bacillus mucilaginosus* resulted in significantly higher mobilization of potassium than *Azotobacter chroococcum* and *Rhizobium* inoculation. Overall, inoculation of maize and wheat plants with these bacteria could be used to mobilize potassium from waste mica, which in turn could be used as a source of potassium for plant growth. (Source – Singh et al 2010 Journal of Plant Nutrition 33, (8) 1236-1251)

Solubilization of potassium-bearing minerals by a wild-type strain of *Bacillus edaphicus* and its mutants and increased potassium uptake by wheat - Two potassium (K)-bearing minerals, Nanjing feldspar and Suzhou illite, were used to investigate K mobilization by the wild-type strain NBT of *Bacillus edaphicus*, also labeled MPs^{+}, selected for high activity in mobilizing potassium from minerals, and by four of its UV + LiCl mutants, MPs^{++}, $MPs^{+}1$, $MPs^{+}2$, and MPs^{-}. In liquid cultures, the five bacterial strains showed better growth on Suzhou illite than on Nanjing feldspar. Suzhou illite was the better potassium source for the growth of the wild type and the MPs^{++}, $MPs^{+}1$, and $MPs^{+}2$ mutants. Solubilization of K from its sources by the wild-type NBT and the MPs^{++} mutant resulted mostly from the action of organic acids and capsular polysaccharides. Oxalic acid seemed to be a more active agent for the solubilization of Nanjing feldspar. Oxalic and tartaric acids were likely involved in the solubilization of Suzhou illite. The MPs^{-} mutant did not produce any organic acid or capsular polysaccharide when grown on the above two K sources. In a pot experiment wheat (*Triticum aestivum* L.) 'Yangmai-158' was grown in a yellow–brown soil that had low available K. After inoculation with bacterial strains, *B. edaphicus* NBT and its four mutants, MPs^{++}, $MPs^{+}1$, $MPs^{+}2$, and MPs^{-} (in separate tests), the root growth and shoot growth of wheat were significantly increased by *B. edaphicus* NBT and the mutants MPs^{++} and $MPs^{+}1$. Bacterial inoculation also resulted in significantly higher N, P, and K contents of plant components. The bacteria were able to survive in the wheat rhizosphere soils after root inoculation. (Xia and He 2006 Canadian Journal of Microbiology, 52:(1) 66-72)

Co-inoculation of potassium solubilizing and nitrogen fixing bacteria on solubilization of waste mica and their effect on growth promotion and nutrient acquisition by a forage crop - Waste mica, a potassium-bearing mineral, is a by-product of mica industry; however, its potassium (K)-supplying capacity for crop production is not well understood. A greenhouse trial was made to study the effect of co-inoculation of potassium solubilizing (*Bacillus mucilaginosus*) and nitrogen (N) fixing (*Azotobacter chroococcum* A-41) bacteria on solubilization of waste mica (a potassium-bearing mineral) and their effects on growth promotion and nutrient uptake by a forage crop of sudan grass (*Sorghum vulgare* Pers.) in a Typic Haplustalf. Results revealed that significantly higher biomass accumulation and nutrient acquisition were obtained in all the pots treated with mica and/or bacterial strain as compared to control. Data indicated that co-inoculation of waste mica with *B. mucilaginosus* and *A. chroococcum* A-41 resulted in highest

biomass production and nutrient acquisition. Co-inoculation of bacterial strains maintained consistently highest amounts of available K and N in soils even at 150 days of crop growth than other treatments. *B. mucilaginosus* strain was more effective and potent K solubilizer than *A. chroococcum* A-41. Thus, co-inoculation of potassium solubilizing and nitrogen fixing bacteria to waste mica could be a promising and alternative option for utilizing this potent source as K fertilizer to crops and maintaining greater nutrients availability in soil. Further studies are necessary to see the effects of these bacterial strains on mobilization of potassium-bearing minerals under field conditions. (Source - Basak and Biswas, 2010, Biol Ferility Soils 46(1) : 641-648)

Sulfur-oxidizing Bacteria: A Novel Bioinoculant for Sulfur Nutrition and Crop Production - Sulfur is an essential nutrient for plant growth as sulfur-deficient conditions cause severe losses in crop yield. Sulfur nutrition has received little attention for many years, since fertilizers and atmospheric inputs have provided adequate amounts. However, recent reductions in sulfur inputs from atmospheric depositions have resulted in a negative sulfur balance in agricultural soils, making crop plants increasingly dependent on the soil to supply sulfur. Thus to alleviate this deficiency, sulfur fertilizers are invariably added to soils, usually in a reduced form, such as elemental sulfur. Yet, reduced sulfur fertilizers must be oxidized to sulfate before they become available to the plant, a process that is mediated by microorganisms. Sulfur and sulfur fertilizers and physiological role of sulfur in crop plants and interaction of sulfur with other elements along with ecological niches for isolation of sulfur-oxidizing bacteria and their role in sulfur oxidation in soil and sulfur nutrition to crop plants are discussed. (Source - Anandham, et al 2011,Bacteria in Agrobilogy: Plant Nutrient Management, 81-10)

Studies on Potassium Solubilizing Bacteria – Attempts were made to isolate potassium solubilizing bacteria from rhizosphere soil of different crops from Dharwad and Belgaum Districts of Karnataka State. A total of 30 bacteria isolates were tested for K-solubilization and characterized up to genus level based on morphological and biochemical characters. The mechanism involved in K solubilization and other agronomical beneficial traits were also analysed for selected efficient strains. In-vitro K solubilization by bacteria ranged from 2.41 µg/ml to 44.49 µg/ml. Oxalic acid, citric acid were chief organic acids produced by the KSB isolates. All the isolates tested for other beneficial traits like solubilization of insoluble phosphate and production of growth promoting substances. The amount of Pi released by the isolates from TCP ranged from 5.72 to 12.27 percent. The amount of IAA produced by the strains ranged from 1.10 to 16.50 and that of GA ranged from 0.60 to 3.29 µg/25ml broth. Nine efficient gram positive K solubilizing bacteria were also examined for their influence on growth, K uptake and yield of maize plants under glass house condition. All the inoculated treatment with bacteria was found to increase growth parameters and yield components compared to absolute control and 25% of RDK control. Bacillus sp KSB 11 recorded the highest yield (51.33 g/plant) and other parameters followed by KSB 62 and KSB 42. Three strains of present study viz KSB 11, KSB 62 and KSB 42 showed high potential among the KSB isolates. Thus it can be inferred that potassium solubilizing bacteria have the potential to use as bioinoculants. (Sourcre – Archana, DS, 2007, M.Sc Thesis submitted to Department of Soil Science, University of Agricultural Sciences, Dharwad, Karnataka)

Solubilization of Potassium containing Minerals by Bacteria and their effect on plant Growth – Potassium solubilizing bacteria isolated from soil, rock and mineral samples and their effects on solubilization from microcline, orthoclase and muscovite minerals and ground nut plant growth were examined. One of the bacteria Bacillus mucilaginous MCRCpl, had particularly strong ability to form slime. The maximum solubilization (4.29 mg/L) was found in muscovite mica. MCRCpkl bacterium could colonise and develop in soil than the control. Total number of bacteria increased due to inoculation from $8.4x10^3$ cfu g^{-1} to $9.6x10^6$ cfu g^{-1}. Phosphorus (P) and potassium (K)

nutrition status in the soil were markedly improved through inoculation of this bacterium. The result showed that available P and K was increased from 6.24 to 9.28 mg kg^{-1} and 86.57 to 99.60 mg kg^{-1} in soil. Ground nut plant dry matter increased by 125% and the oil contents were increased by 35.41% through inoculation of MCRCpl bacterium. (Source – Sugumaran and Janardhanam 2007, World Journal Agricultural Sciences 3(3) : 350-355)

Decomposition of silicate minerals by Bacillus mucilaginosus in liquid culture - The extraction of K+ and SiO_2 from silicate minerals by Bacillus mucilaginosus in liquid culture was studied in incubation experiments. B. mucilaginosus was found to dissolve soil minerals and mica and simultaneously release K+ and SiO_2 from the crystal lattices. In contrast, the bacterium did not dissolve feldspar. B. mucilaginosus also produced organic acids and polysaccharides during growth. The polysaccharides strongly adsorbed the organic acids and attached to the surface of the minerals, resulting in an area of high concentration of organic acids near the minerals. The polysaccharides also adsorbed SiO_2 and this affected the equilibrium between the mineral and fluid phases and led to the reaction toward SiO_2 and K+ solubilization. These two processes led to the decomposition of silicate minerals by the bacterium (Source – Liu et al 2006 Environmental Geochemistry and Health 28:133–140)

Phosphate and Potassium Solubilizing Bacteria Effect on Mineral Uptake, Soil Availability and Growth of Eggplant - Experiments were conducted to evaluate the potential of phosphate solubilizing bacteria (PSB) *Bacillus megaterium* and potassium solubilizing bacteria (KSB) *Bacillus mucilaginosus* inoculated in nutrient limited soil planted with eggplant. Results showed that rock P and K materials either applied singly or in combination did not significantly enhance soil availability of P and K. PSB increased higher soil P availability than KSB, which was recommended as a K-solubilizer. Inoculation of these bacteria in conjunction with amendment of its respective rock P or K materials increased the availability of P and K in soil, enhanced N, P and K uptake, and promoted growth of eggplant. **(**Source Han and Lee, 2005 Research Journal of Agriculture and Biological Sciences 1(2): 176-180)

Efficiency of K-feldspar Combined with Organic Materials and Silicate Dissolving Bacteria on Tomato Yield - Potassium is one of the three essential elements viz., NPK, for the growth and reproduction of the plants and it plays many vital roles in its nutrition. The crop production in Egypt relies completely on imports to meets its annual requirement of potash fertilizers besides; the high cost of conventional, water soluble K fertilizers constrains their use by most of the farmers in the country. In order to reduce the dependence on imported potash, feldspar a potash mineral, contains 11.25 % K_2O and therefore it could be a potential K-source for crop production. Novel approaches are needed to unlock K from the silicate structure of this mineral in order to render K more available for plant nutrition. A strain of silicate dissolving bacteria SDB (*Bacillus cereus*) was used as bioinoculant. These studies were undertaken to evaluate the effectiveness of bacterial inoculation in combination with feldspar and rice straw on K-releasing capacity as well as the effect of feldspar charged compost (F-compost) as biofertelizer on tomato yield in field experiment. F-compost prepared through rice straw significantly enhanced the content of total K in the final product as organic materials decreased during composting process. However, incorporation of feldspar with organic materials at different rates had no or little effect on the degradation. Concentration of available K released from feldspar increased markedly through composting process and the maximum increase was observed with 40% feldspar addition. Inoculation with SDB into the composting mass appears to enhance the percent of available K in the mature compost compared to its counterpart without inoculation. Similarly, the response of tomato plants to the F-compost inoculated with SDB was dramatic when added to sandy soil of low K content and its effect was higher than potassium sulphate. The conjunctive use of F-compost plus SDB also produced maximum potassium use

efficiency (KUE), total K uptake and considerable higher K recovery than potassium sulphate. Application of organic K-sources considerably improved the fertility status of the soil as measured by organic C and available NPK contents of the soil after harvest, while feldspar and potassium sulphate had no or little effect on fertility build up. The effect of compost prepared through rice straw only on organic C was more pronounced, while available P and K were higher under F-compost plus SDB. The benefit of this compost however, demonstrated the validity and possibility of sustained agronomic performance of tomato and reduces the cost of cultivation through the use of cheep feldspar. (Source – Badr Journal of Applied Sciences Research, 2(12): 1191-1198, 2006)

Effectiveness of phosphate and potash rocks with Acidithiobacillus on sugarcane yield and their effects on soil chemical attributes – Experiments were conducted to evaluate the effectiveness of biofertilizers produced from phosphate and potash rocks mixed with sulfur inoculated with Acidithiobacillus oxidizing bacteria on sugarcane yield and their effects on some chemical attributes of a Brazilian tableland soil. The experiment was arranged in a completely randomized factorial design 2 9 4 9 3 + 1, with four replicates. Two varieties of sugarcane, four rates of three sources of P and K (apatite + biotite, P + K biofertilizers with Acidithiobacillus, and soluble fertilizers—triple superphosphate and potassium chloride) were tested. A control without P and K fertilization was applied. A significant reduction in soil pH was observed with biofertilizers, especially when applied at higher rates, although no harmful effect on sugarcane yield was observed. Available P and K and exchangeable Ca and Mg increased with biofertilizer application compared to mineral fertilizers and P and K rocks. Biofertilizers may be used as an alternative source of P and K for sugarcane grown in soils with low available P and K. (Source - Stamford et al 2008 World J Microbiol Biotechnol 24:2061–2066)

Growth promotion and increased potassium uptake of cotton and rape by a potassium releasing strain of Bacillus edaphicus - A potassium-releasing bacterial strain Bacillus edaphicus NBT was examined for plant-growth-promoting effects and nutrient uptake on cotton and rape in K-deficient soil in pot experiments. Inoculation with bacterial strain B. edaphicus NBT was found to increase root and shoot growth of cotton and rape. Strain NBT was able to mobilize potassium efficiently in both plants when illite was added to the soil. In cotton and rape growing in soils treated with insoluble potassium and inoculated with strain NBT, the potassium content was increased by 30 and 26%, respectively. Bacterial inoculation also resulted in higher N and P contents of above ground plant components. The bacterial isolate was also able to colonize and develop in the rhizosphere soil of cotton and rape after root inoculation. (Source – Sheng et al 2005 Soil Biology & Biochemistry 37 : 1918–1922)

Assessing the Zinc solubilization ability of *Gluconacetobacter diazotrophicus* in maize rhizosphere using labelled ^{65}Zn compounds - Solubilization of insoluble zinc compounds like $ZnCO_3$ and ZnO by *G. diazotrophicus* was confirmed using radiotracers. The zinc compounds ($ZnCO_3$ and ZnO) tagged with ^{65}Zn. $^{65}ZnCO_3$ and ^{65}ZnO were effectively solubilized and the uptake of Zn by the plants was also more in *G. diazotrophicus* inoculated treatments compared to the uninoculated treatments. Three types of soils (Zn deficient sterile, Zn deficient-unsterile, and Zn sufficient-sterile) were used in experiment. Among the three soils, Zn deficient-unsterile soil registered maximum zinc solubilization compared to other two soils. This may be due to other soil microorganisms in unsterile soil. Application of ZnO with *G. diazotrophicus* showed better uptake of the nutrient. (Source - Sarathambal et al 2010, Indian J. Microbiology 50(1) : 103-109).

Solubilization of zinc compounds by the diazotrophic, plant growth promoting bacterium *Gluconacetobacter diazotrophicus* - *Gluconacetobacter diazotrophicus* an endophytic diazotroph also encountered as rhizosphere bacterium is reported to possess different plant growth promoting characteristics. In this study,

authors assessed the zinc solubilizing potential of *G. diazotrophicus* under *in vitro* conditions with different Zn compounds using glucose or sucrose as carbon sources. *G. diazotrophicus* showed variations in their solubilization potential with the strains used and the Zn compounds tested. *G. diazotrophicus* PAl5 efficiently solubilized the Zn compounds tested and ZnO was effectively solubilized than $ZnCO_3$ or $Zn_3(PO_4)_2$. The soluble Zn concentration was determined in the culture supernatant through Atomic Absorption Spectrophotometer. Gas chromatography coupled Mass Spectrometry analysis revealed 5-ketogluconic acid, a derivative of gluconic acid as the major organic acid produced by *G. diazotrophicus* PAl5 cultured with glucose as carbon source. This organic anion may be an important agent that helped in the solubilization of insoluble Zn compounds. (Source - Saravanan et al 2007 Chemosphere, 66(9) : 1794-1798)

Assessing in-vitro Solubilization Potential of Different Zinc Solubilizing Bacterial (ZSB) Isolates - Zinc solubilizing ability of Bacillus sp. and Pseudomonas sp. was assessed using zinc oxide, zinc sulphide (sphalerite) and zinc carbonate in both plate and broth assays. ZSB-O-1 (Bacillus sp.) showed highest dissolution in the zinc sulphide (Sphalerite ore), with 2.80 cm of dissolution zone and 14.50 cm2 of area in the plate assay and 13.60 mg kg -1 of zinc in the broth assay on the 15th day after inoculation. The ZSB-S-2 (Pseudomonas sp.) showed more solubilizing ability in the zinc oxide, with 3.30 cm clearing zone and 20.43 cm2 area in the plate assay and 16.40 mg kg -1 of zinc in the broth assay over the same inoculation period. The isolate ZSB-S-4 (Pseudomonas sp.) has highest solubilizing potential in zinc carbonate with 6.20 cm of dissolution zone and 13.40 cm2 area in the plate assay and 13.40 mg kg-1 of zinc in the broth assay. Thus, the solubilization potential varies among different cultures. The solubilization might be due to production of acids by the culture, since the pH of the culture broth has been shifted form 7.0-7.3 to 4.8-6.5 after 15 days of inoculation. The zinc tolerance limit for two cultures (ZSB-O-1 and ZSB-S-2) was studied and determined to be upto 100 mg kg -1 of zinc in the in vitro broth assay (Source – Saravanan et al Brazilian Journal of Microbiology (2003) 34:121-125)

Effect of various parameters on the efficiency of zinc phosphate solubilization by indigenous bacterial isolates - Zinc phosphate solubilization efficiency of ten soil bacteria were studied for various parameters like carbon sources, temperature, pH, variable concentration of sodium chloride and glucose. For majority of the isolates 20oC was appeared to be the optimum temperature for solubilization of zinc phosphate. Glucose was the most favorable carbon source for solubilization while lactose is the least favourable carbon source. pH 7 was the most favorable pH for solubilization while at pH 4 no growth and solubilization was seen. Except CMG859, no isolate solubilized at pH 8 and 9. CMG851 (Acinetobacter lwoffi) and CMG852 showed enhanced solubilization in presence of 1% sodium chloride. 1% glucose is required for the solubilization of zinc phosphate and no solubilization was appeared in presence of 0.1% glucose. CMG851 (A. lwoffi), CMG 860 (pseudomonas aeruginosa) CMG 857 (Bacillus thuringiensis) were found to be the most promising isolates. (Source - Sadaf Shahab* and Nuzhat Ahmed 2008, African Journal of Biotechnology Vol. 7 (10), pp. 1543-1549)

Solubilization of Phosphates and Micronutrients by the Plant-Growth-Promoting and Biocontrol Fungus Trichoderma harzianum Rifai 1295-22 - We investigated the capability of the plant-growth-promoting and biocontrol fungus Trichoderma harzianum Rifai 1295-22 (T-22) to solubilize in vitro some insoluble or sparingly soluble minerals via three possible mechanisms: acidification of the medium, production of chelating metabolites, and redox activity. T-22 was able to solubilize MnO_2, metallic zinc, and rock phosphate (mostly calcium phosphate) in a liquid sucrose-yeast extract medium, as determined by inductively coupled plasma emission spectroscopy. Acidification was not the major mechanism of solubilization since the pH of cultures never fell below 5.0 and in cultures containing MnO_2 the pH rose from 6.8 to 7.4. Organic acids were not detected

by high-performance thin-layer chromatography in the culture filtrates. Fe_2O_3, MnO_2, Zn, and rock phosphate were also solubilized by cell-free culture filtrates. The chelating activity of T-22 culture filtrates was determined by a method based on measurement of the equilibrium concentration of the chrome azurol S complex in the presence of other chelating substances. A size exclusion chromatographic separation of the components of the culture filtrates indicated the presence of a complexed form of Fe but no chelation of Mn. In liquid culture, T. harzianum T-22 also produced diffusible metabolites capable of reducing Fe(III) and Cu(II), as determined by the formation of Fe(II)-Na_2-bathophenanthrolinedisulfonic acid and Cu(I)-Na_2-2,9-dimethyl-4,7-diphenyl-1,10-phenanthrolinedisulfonic acid complexes. This is the first report of the ability of aTrichoderma strain to solubilize insoluble or sparingly soluble minerals. This activity may explain, at least partially, the ability of T-22 to increase plant growth. Solubilization of metal oxides by Trichoderma involves both chelation and reduction. Both of these mechanisms also play a role in biocontrol of plant pathogens, and they may be part of a multiple-component action exerted by T-22 to achieve effective biocontrol under a variety of environmental conditions. (Source - Altomare et al Appl. Environ. Microbiol. July 1999 vol. 65 no. 7 2926-2933)

Zinc Phosphate and Pyromorphite Solubilization by Soil Plant-Symbiotic Fungi - Acidolysis, complexolysis and metal accumulation were involved in solubilization of zinc phosphate and pyromorphite by a selection of soil fungi representing ericoid and ectomycorrhizal plant symbionts and an endophytic/entomopathogenic fungus,Beauveria caledonica. Zinc phosphate was much more readily solubilized than pyromorphite. According to the relationship between metal mobilization and pH, acidolysis (protonation) was found to be the major mechanism of both zinc phosphate and pyromorphite dissolution for most of the fungi examined. In general, the more metal tolerant fungal strains yielded more biomass, acidified the medium more and dissolved more of the metal mineral than less tolerant strains. However,B. caledonica4 excreted a substantial amount of oxalic acid (nvsim0.8 mM) in the presence of pyromorphite that coincided with a dramatic increase in lead mobilization providing a clear example of complexolysis. Organic acid excretion by fungi was inter- and intraspecific and was strongly influenced by the presence of the toxic metal minerals. When grown on zinc phosphate or pyromorphite,Hymenoscyphus ericaeDGC3 (UZ) accumulated the lowest metal concentration, but Thelephora terrestrisaccumulated the highest metal concentration in the biomass. The ability to accumulate water-soluble lead species, representing mainly cytosolic and vacuolar pools, seemed to be connected with pyromorphite-solubilizing ability. B. caledonica4, which demonstrated the highest ability to dissolve pyromorphite, accumulated the highest water-soluble fraction and total lead concentration in the mycelium. Generally, isolates with a higher zinc-tolerance accumulated significantly less total zinc from zinc phosphate (including the sum of water-soluble and NaCl-extractable zinc) than non-tolerant strains. (Source - M Fomina et al Geomicrobiology Journal (2004) : 21, Issue: 5, Pages: 351-366).

Plant Root Associated Bacteria for Zinc mobilization in Rice - The activity of Plant Growth Promoting Rhizobacteria (PGPR) to mobilize indigenous soil zinc (Zn) in rice (Oryza sativa L.) rhizosphere was observed in a net house micro plot experiment and compared with available form of chemical Zn source as Zn–EDTA. The inoculum used for this study was carrier based biofertilizer (BioPower) containing a mixed consortia of five PGPR strains viz., Azospirillum lipoferum (JCM-1270, ER–20), Pseudomonas sp (K–1, 96-51) and Agrobacterium sp. (Ca–18). The PGPR application alleviated the deficiency symptoms of Zn and invariably increased the total biomass (23%), grain yield (65%) and harvest index as well as Zn concentration in the grain. The inoculation had a positive impact on root length (54%), root weight (74%), root volume (62%), root area (75%), shoot weight (23%), panicle emergence index (96%) and showed the highest Zn

mobilization efficiency as compared with the un-inoculated control. The PGPR colonized rice plants were more efficient in acquiring Zn from either added or indigenous source, than non-colonized plants. Zinc mobilization by PGPR was also confirmed in liquid culture medium. It was concluded that, selected PGPR strains can serve as efficient solubilizer of Zn, allowing farmers to avoid the use of costly chemical Zn fertilizer in rice crop. (Source – Tariq et al Pak. J. Bot., 39(1): 245-253, 2007)

Effect of zinc-phosphate-solubilizing bacterial isolates on growth of *Vigna radiata* - This study examined the effects of five bacterial isolates (U, 8M, 36, 102, and 111) on the growth of *Vigna radiata*. Bacterial isolates were applied alone, or together with zinc phosphate [$Zn_3(PO_4)_2 \cdot 4H_2O$]. The maximum increase in all plant growth parameters was seen when seedlings were inoculated with isolate 102. Isolate 36 with 1 mM zinc phosphate showed the maximum increase in seedling length (35.1 cm) as compared to controls. Isolate 111 was the best phosphate solubilizer, releasing 13.29 ppm phosphorous (P) in soil when used in combination with 1 mM salt, whereas isolate 36 showed maximum uptake of P, leaving only 4.63 ppm in soil. (Source - Uzma Iqbal et al Annals of Microbiology 60(2) : 243-248)

Plant growth promoting rhizobacteria as biofertilizers - Numerous species of soil bacteria which flourish in the rhizosphere of plants, but which may grow in, on, or around plant tissues, stimulate plant growth by a plethora of mechanisms. These bacteria are collectively known as PGPR (plant growth promoting rhizobacteria). The search for PGPR and investigation on their modes of action are increasing at a rapid pace as efforts are made to exploit them commercially as biofertilizers. After an initial clarification of the term biofertilizers and the nature of associations between PGPR and plants (i.e., endophytic versus rhizospheric), this review focuses on the known, the putative, and the speculative modes-of-action of PGPR. These modes of action include fixing N_2, increasing the availability of nutrients in the rhizosphere, positively influencing root growth and morphology, and promoting other beneficial plant–microbe symbioses. The combination of these modes of actions in PGPR is also addressed, as well as the challenges facing the more widespread utilization of PGPR as biofertilizers (Source - Vessey *2003, Plant and Soil* 255: 571–586)

Impact of pseudomonas inoculation on the biodiversity and function of phytosphere microbiota - *Pseudomonas fluorecens* SBW25 is a natural isolate typical of the fluorescent pseudomonads that colonise rhizosphere soil and the plant phytosphere. This isolate was collected from the leaves of field grown sugar beet and has been the subject of intensive field and laboratory investigations to understand its ecology, population genetics and the molecular basis of the activity of this bacterium and associated horizontal gene pool. Modified variants of this bacterium and its natural plasmids have been constructed that allow the study of the factors that influence competition, survival and horizontal gene transfer in the natural environment. A single copy of the operon that directs the biosynthesis of phenazine carboxylic acid (PCA) derived from *P. fluorescens* 2-79 has been modified to remove the *phz*I and *phz*R regulators and inserted as a single copy into the chromosome of *P. fluorescens* SBW25. Chromosomal insertion of the phenazine biosynthetic pathway (*phz*ABCDEFG) enhances the efficacy of damping-off disease control by *Pseudomonas fluorescens*. MPMI. In laboratory and glasshouse studies PCA expression significantly enhanced the control of damping-off disease in sugar beet, pea and wheat. Measures of soil enzyme activity, bacterial and fungal diversity revealed that competition and community succession in the phytosphere were more strongly influenced by plant type than either the presence of inocula or disease. (Source Baille et al)

Workshop, Seminar, Conferences

National Conference on Mycodiversity with its Sustainable Exploration and Biotechnological Applications and 38th Annual Meeting of Mycological Society of India 6TH - 7TH FEBRUARY 2012 at SHRI SHIVAJI SCIENCE COLLEGE, AMRAVATI - Mycology plays a vital role in the basic as well as applied field of studies such as fermentation, ecology, pathogenesis, antibiotic production, toxicities, mushroom and mycorrhizal technology. The past six decades have witnessed phenomenal progress in mycology encompassing conceptual changes, scientific and technological advances. Recognition of fungal diversity and its significance for meaningful utilization for discovery of novel biomolecules including drugs and industrial enzymes has gained considerable momentum. In near future, mycologists have to play a pivotal role in identification of novel germplasm resource pools, understanding product manufacture in relation to mold morphogenesis and developing innovative techniques. At this point of time when the environmentalists are voicing out their concern at the dwindling biodiversity, this conference will provide a platform for the renowned and budding mycologists throughout the country. Increasing involvement of various mycologists as a experts in the multidisciplinary teams would be certainly worthwhile and such type of specialized conference will definitely boost the young scientists of India. For further details contact **Dr. P. W. Deotare** Organizing Secretary Deptt. of Botany, Shri Shivaji Science College Amravati – 444603 (M.S.) Email- prakash.deotare@gmail.com.

"Formulation Workshop" April 25th, 2011, Hyderabad - Technology Advancement Unit, ISCB in collaboration with ISCB project partners of Biopesticide project and Biofertilizer network in collaboration with Sathguru Management Consultants organized a one day Formulation Workshop for new and innovative microbial formulations. Dr Alok Adholaya, Director, Biotechnology and Management of Bioresources Division, TERI, Dr K.R. Viswanathan, Senior Advisor, SDC and Dr. S.R. Rao, Advisor, DBT were the chief moderators. Important issues discussed during the workshop were: (a) BFNet overview, shelf life and lyophilization method (b) Field efficacy and fluccolation method (c) Mass production and spray drying method (d) Bio-pesticide research at PCI with respect to mass production and formulation (e) Custom Nutrient management based on soil health assessment and (f) IP strategies and regulation.

17th International Congress on Nitrogen Fixation, 27 November – 1 December 2011 at Fremantle, Western Australia - The 17th International Congress on Nitrogen Fixation provides an opportunity to consider the questions– where are we now with nitrogen fixation and where are we going? On one hand we have very exciting opportunities being provided by molecular technologies, with advances in these areas coming at an ever-increasing rate. On the other hand, many of the challenges confronting successful application of nitrogen fixation technology in agriculture remain the same e.g. developing new legumes and rhizobia for agriculture; achieving successful inoculation through improved technologies; and understanding the conundrums surrounding the life of rhizobia in soil and rhizosphere such as ineffective populations and competition. The conference provides an opportunity to deal with all such problems in the presence of highly intellectual dedicated scientific community likely to gather at the occasion.

10th European Nitrogen Fixation Conference 2012 - The 10th European Nitrogen Fixation Congress (ENFC) will be held in Munich, Germany from the 2nd to the 5th of September 2012. This biennial congress series traditionally brings together

scientists from Europe and all over the world interested in biological nitrogen fixation and related fields. We cordially invite you to actively participate in the 10th European Nitrogen Fixation Congress, and the associated satellite events. The 10th ENFC will start with a satellite meeting on "Genomics of Nitrogen Fixing Bacteria". In addition, two satellite events will be organized for 6th/7th September: the "13th Symposium on Biological Nitrogen Fixation with Non-Legumes", focussing on the interaction of diazotrophic bacteria with practically most relevant Gramineae and the 1st "Molecular Mycorrhiza Meeting" (MMM). MMM will be the first event of a series initiated to satisfy the growing demand for a specialized scientific meeting covering the molecular genetic aspects of mycorrhiza. This combination of events will provide unique platforms to share and discuss latest scientific news on nitrogen fixation and the molecular interaction between plants and symbiotic microorganisms.

13th Symposium on Nitrogen Fixation with Non-Legumes – is scheduled for 6-7 September 2012 at Helmholtz Zentrum Munchen German Research Centre for Environmental Health, Ingolstaedter, Landstr, Neuherberg. Main topics of the symposium are: (a) Genomics and diversity of diazotrophs, (b) Genetics, biochemistry and physiology of diazotrophs, (c) Rhizosphere ecology, (d) Interaction with non-legume hosts, (e) Cyanobacteria and Frankia: Genomics, physiology, Ecology, (f) Application of nitrogen fixation with non-legumes and (g) Biological nitrogen fixation and energy balance in biofuel production.

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Advances in Biofertilizers Production Technology

Development of two culture media for mass cultivation of *Azospirillum* spp. and for production of inoculants to enhance plant growth - High yield culture medium is fundamental for production of inoculants for plant growth-promoting bacteria. Based on substitution of glucose in tryptone–yeast extract–glucose medium by Na-gluconate or glycerol, two new culture media were developed for mass cultivation of the commonly used plant growth-promoting bacterium *Azospirillum* sp. After 18 h of incubation, these modifications increased populations of different strains of *Azospirillum* (to $\sim 10^{11}$ cells ml^{-1} [single cell count] and $\sim 5 \times 10^9$ CFU ml^{-1} [plate count method]), significantly reduced generation time, and were also suitable for production of common synthetic inoculants. (Source – Bashan et al, 2011 Biol. Fertil Soil 47(8) : 963-969)

Standardization of liquid formulation of *Pseudomonas fluorescens* Pf1 for its efficacy against *Fusarium* wilt of tomato - *Pseudomonas fluorescens* strain Pf1 is studied as an effective biocontrol agent for the management of plant diseases and plant growth-promoting bacteria. Previous findings from our research group demonstrated that talc-based *P. fluorescens* Pf1 formulation effectively reduced several plant diseases in addition to promoting plant growth. The modernization of agro-techniques necessitates the development of a new formulation where liquid inoculants can play a significant role. Different chemicals such as trehalose, polyvinylpyrrolidone and glycerol were tested for the development of liquid formulation. Among these, glycerol amendment maintained the greater population level of *P. fluorescens* Pf1 up to 6 months of storage. Further, a study was conducted to standardize the dose of liquid-based formulation of Pf1 for seed treatment and seedling dip. An application of 10 ml kg^{-1} of seeds and 150 ml ha^{-1} of seedlings was found to be optimum for seed treatment and seedling root dip, respectively. The growth-promoting and antagonistic activities of Pf1 cultures of different ages were found to be greater up to 180 days of storage without much loss in viability of cells. The combination of seed treatment, seedling dip and soil drenching of liquid formulation recorded the minimum disease incidence of *Fusarium* wilt on tomato under glasshouse (17.33%) and field (4.81%) conditions. In addition, the liquid formulation increased the tomato fruit yield compared to untreated control under glasshouse and field conditions. Thus, this study offered successful technology for development of a liquid-based bioformulation *P. fluorescens* Pf1. **(**Source **-** Manikandan et al, 2010, Biological Control 54, (2) : 83–89)

Survival of Azospirillum brasilense in liquid formulation amended with different chemical additives - Liquid bioinoculant formulation has become the preferred technology to solve the problems associated with shorter shelf life, high contamination, poor quality, low field performance and processing solid carrier in carrier based bioinoculant formulation. In this experiment, we evaluated different concentrations of six different chemical amendments viz, polyvinyl pyrollidone (PVP), glycerol, gum arabica, trehalose, polyethylene glycol (PEG) and polyvinyl alcohol (PVA) for their ability to support growth and promote survival of Azospirillum brasilense in N2 free malic acid broth during the storage. Some concentrations of various additives to N2 free malic acid broth promoted higher Azospirillum population compared to Azospirillum cells in N2-free malic acid broth alone. Liquid Azospirillum bioinoculant formulated with trehalose (10mM) promoted long term survival of Azospirillum followed by glycerol (10 mM) gum arabica (0.3%) and PVP (2%) and they supported 10cells/ml up to 11 months of storage under ambient temperature (28℃ to 32℃), whereas PEG (1%), PVA (0.5%) and control (lignite carrier) recorded the same population upto 8

months, 6 months and 5 months respectively. The results of the present study clearly indicated that the liquid formulation of Azospirillum could be used more effectively than the carrier based formulation. Among the different chemical additives trehalose (10mM) performed well and sustained viable population $>10^7$ for 12 months. Trehalose is an enigmatic compound which act as a reserve carbohydrate that may be mobilized during stress. It is widely reported to enhance cell tolerance to desiccation, osmatic and temperature stress. It acts by stabilizing both enzymes and cell membranes. The possible effect of trehalose's protective action is that it may be incorporated into the cell (or) may induce the synthesis of metabolites that protect against stress which might be the reason for the higher population of Azospirillum cells in the trehalose treatments. Next to trehalose, 10 mM glycerol supported greater number of Azospirillum in liquid formulation. This may be due to high water binding capacity and may protect cells from the effect of desiccation by reducing the rate of drying (Source – Kumaresan and Reetha 2011, Journal of Phytology 3(10): 48-51).

Development and standardization of cyst based liquid formulation of Azospirillum bioinoculant - Azospirillum bioinoculant is well known for its high nitrogen fixing and plant growth promoting characters. The carrier based bioinoculants generally suffer from shorter shelf life, poor quality, high contamination and low field performance. Therefore, it is necessary to develop alternative new formulation of inoculants where cyst based inoculants can play significant role. The cyst based liquid formulation was developed by inoculating Azospirillum into the cyst inducing minimal salts medium (MSM). One hundred per cent conversion of vegetative cells into cyst cells was noticed in 96 h. The survival of cyst cells in the MSM was observed up to one year and two months and interestingly, the population level of 10^8 was maintained till the final observation. The cyst cells of Azospirillum accumulated poly- β - hydroxybutyrate (PHB) granules and exhibited desiccation tolerance up to 20 days and temperature tolerance up to 40 ℃. Thus the cyst based liquid formulation has twin advantage of longer shelf life and tolerance to harmful environmental conditions. Regeneration of cyst cells into vegetative cells in different media viz., tap water, sterile water, rice gruel and nutrient broth was studied. The changes started within 3 h and complete return of vegetative cells was observed at 24 h. Although all the media tested favoured regeneration, comparatively quicker regeneration was observed in nutrient broth and followed by rice gruel. Thus, cyst based liquid formulation of Azospirillum has all the survival advantages and can be used as a potential bioinoculant. (Source – Vendan and Thangraju 2007, Acta Microbiologica et Immunologica Hungarica 54(2): 167-177)

Survival and Phosphate Solubilizing Ability of Bacillus megaterium in Liquid Inoculants under High Temperature and Desiccation Stress - Inoculation of phosphate-solubilizing microorganisms along with rock phosphate is known to enhance the available P from soil. The success of such solubilization is largely dependent on the ability of the inoculant strain to survive under adverse environmental conditions. In this context, liquid inoculants are gaining importance and are becoming popular with longer shelf-life. In the present investigation, a preliminary study was conducted to determine the survival of Bacillus megaterium in liquid formulations supplemented with osmo/cell protectants under the influence of high temperature, desiccation stress and their subsequent influence on P-uptake by cowpea plants. Liquid inoculant-2 containing osmoprotectants viz., polyvinyl pyrrolidone (PVP), high quantity of glycerol (12 ml L^{-1}) and glucose supported higher viable population up to a storage period of four weeks at 48ºC (log10 10.62 CFU ml^{-1}) and desiccation stress (log10 10.04 CFU ml^{-1}) as compared to liquid $inoculant^{-1}$ containing osmoprotectants viz., PVP, low quantity of glycerol (1 ml L^{-1}), trehalose, arabinose and FeEDTA; and nutrient glucose broth without any osmoprotectants. Liquid inoculant-2 also enhanced the P-uptake of cowpea plants significantly. (Source Velineni and Brahmprakash J. Agr. Sci. Tech. (2011) Vol. 13: 795-802)

Book Reviews

Associative and Endophytic Nitrogen-fixing Bacteria and Cyanobacterial Associations Nitrogen Fixation: Origins, Applications, and Research Progress, Vol. 5Elmerich, Claudine; Newton, William E. (Eds.) 2007, XXI, 321 p. - This book is the self-contained fifth volume of a comprehensive seven-volume series covering both fundamental and applied aspects of nitrogen-fixation research since the 19th century. It addresses the issues arising from bacterial colonization of either the plant-root surface or other tissues as well as their modes of doing so. These associations are less formalized than the rhizobia-legume symbiosis but, as more and more of them are discovered, their myriad of effects on their plant hosts is becoming understood. Among the effects, in addition to often providing fixed nitrogen, plant growth can be promoted and plant diseases controlled. An understanding at the molecular level of the mechanisms by which these bacteria benefit crop productivity is an important issue in agriculture. This book describes the milestones in the discovery of the associative and endophytic nitrogen-fixing bacteria (*Azoarcus, Azospirillum, Gluconacetobacter, Herbaspirillum*, and others) found intimately involved with cereal crops, forage grasses, and sugar cane. It provides a comprehensive overview of their phylogeny, physiology, and genetics as well as of the biology of their association with their host plants, including tools for in situ localization and population-dynamics analysis. There are also chapters describing the bacterial functions required for a bacterium to be competent and competitive in the rhizosphere; these include chemotactic response, adhesion and motility, enzymes and secondary-metabolite production, and synthesis of phytohormones, which play an important role in the association with the host plants. In addition, the plant's response to inoculation is reviewed. The book also provides an up-to-date analysis of the different associations of cyanobacteria with fungi, diatoms, bryophytes, cycads, *Azolla*, and *Gunnera*, including the complex regulatory network that controls the differentiation of vegetative cells into nitrogen fixing heterocysts. No other available work provides the up-to-date and in-depth coverage of this volume, which is intended to serve as an indispensable reference work for academic, government, and industrial scientists working in the areas of plant microbiology, ecology, and genetics, including those studying plant growth and biocontrol; to assist students to enter this challenging area of research; and to provide science administrators with ready access to vital relevant information.

Microbes and Microbial Technology: Agricultural and Environmental Applications - By Iqbal Ahmad, Farah Ahmad, John Pichtel 2011 Publ Springer, ISBN1441979301, 9781441979308, 516 pages - This book focuses on successful application of microbial biotechnology in areas such as medicine, agriculture, environment and human health.

PGPR: biocontrol and biofertilization, Zaki A. Siddiqui, Springer, 2006 - Science - 318 pages - PGPR have gained worldwide importance and acceptance for agricultural benefits. These microorganisms are the potential tools for sustainable agriculture and the trend for the future. Scientific researches involve multidisciplinary approaches to understand adaptation of PGPR to the rhizosphere, mechanisms of root colonization, effects on plant physiology and growth, biofertilization, induced systemic resistance, biocontrol of plant pathogens, production of determinants etc. Biodiversity of PGPR and mechanisms of action for the different groups: diazotrophs, bacilli, pseudomonads, and rhizobia are shown. Effects of physical, chemical and biological factors on root colonization and the proteomics perspective on biocontrol and plant defence mechanism is discussed. Visualization of interactions of pathogens and biocontrol agents on plant roots using autofluorescent protein markers has provided more understanding of

biocontrol process. Commercial formulations and field applications of PGPR are detailed.

Potential Microorganisms For Sustainable Agriculture: A Techno-Commercial Perspective by D. K. Maheshwari and R.C. Dubey, I. K. International Pvt Ltd, 2008 - Technology & Engineering - 498 pages - The number of potential microbes exploited commercially is scanty irrespective of their high number present in the diverse habitats. In recent years, they have shown successfulness in multifarious areas such as production of industrially viable products, organic chemicals, pharmaceuticals, recovery of metals, improvement and maintenance of environmental quality, and insect and pest control. The Twenty-three articles included here fall under three broad categories, namely, agricultural microbiology, industrial microbiology and bioremediation. The psychrophiles hold many biological secrets such as biochemical limits to macromolecular stability and the blueprints for constructing the stable macromolecules. Lactic acid bacteria are known for their role in the preparation of fermented dairy products. Potential strains for production of lactic acid with emphasis on its fermentation, economics and systematics have been dealt with in greater detail. Biotechnological applications of pectinases in general and alkaline pectinases in particular play an important role in industry. Production, characteristics and applications of microbial alkaline pectinolytic enzymes have been elaborated. Production of ergot alkaloids thrives a novel knowledge. Now-a-days, semi-synthetic ergot alkaloids are widely used as a potential therapeutic agent. Microbial production of glucans, functional organization and their industrial significance have been systematically reviewed. Bioactive exopolysaccharides from mushrooms have gained importance in recent years. Production and characterization of exopolysaccharides and conversion of unsaturated fatty acids into value-added hydroxyl fatty acids by using microorganisms are used in a wide range of industrial products. Enhancing the microbial production of 1,3-propanidial and its application highlights the commercial exploitation of potential microorganisms. Aldehyde and organic acid production by using oxydases and their derivatives advantageous role in industry. Some chapters are devoted to the potential entomopathogenic fungi for management of insect pests, biotechnological applications of fusaria, microbial metabolite-mediated biocontrol of soil-borne plant pathogens, bioremediation of heavy metals, organochlorine and organophosphate pesticides. Bioinoculants apart from being eco-friendly are being used, but reviewers have emphasized the constraints in commercial bioinoculant production and their quality assurance. All the articles of this volume depict the role of microorganisms in agricultural industries. The exploitation of such beneficial microorganisms may improve agricultural systems with economically sound production of human food and animal feed.