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Society for Fertilizers and Environment
Bidhan Chandra Krishi Viswavidyalaya
Mohanpur, Nadia,
West Bengal, India

From President's Desk

Soil health is the first requisite for agricultural and environmental sustainability: need for renewed thrust on organic composting

This is the third issue in a row on the role of soil biological health for sustainable productivity. In the earlier issues I have stressed mainly on the missing links in our research agenda, need for studies on microbial diversity, with support from molecular biology, in preference to soil physical and chemical properties owing to fast detectable changes of the first when compared with the latter two consequent to physical, chemical or climatic aberrations, and thereby urging to look for new indicators in the field of soil biology to index soil quality. To me 'soil health' *per se* is not a nomenclature in its simplistic term but a 'concept' to qualify agricultural and environmental sustainability urging for renewed efforts if necessary to have a relook into the entire domain and reinvent the methodologies and the parameters in tandem.

There is strong belief in many quarters in the recent times to concentrate on organic composting, using not only agricultural residues but also urban and industrial waste, avoiding environmental contamination of rivers, soil and atmosphere and minimizing the production of greenhouse gases, thereby attempting to give back to the soil over 90 % of the organic materials today being considered as trash. It will help reduce CO_2 emission by sequestering C and by modifying agronomic practices favouring such emissions, which are important steps to combat climate change phenomenon. The other decisive points include, besides contributing to plant nutritional aspects accentuated with favourable soil physical conditions, the development of processes and methodologies to study ecotoxicological aspects of all kinds of residues, independently of origin, creating an interface with human health. Compost may even suppress soil borne plant pathogens that causes significant damage on globally important food crops, although the results so far are inconsistent. Undoubtedly, we can claim that public health depends on healthy food, and this, in turn, is directly linked to the soil health, often termed as soil wealth.

As organic material composts, large complex molecules are broken down in a series of steps. The final products are simple, stable molecules which make up the humus-like matrix of nutrients and organic matter that we call compost. Microbial communities in the soil are enhanced and stimulated by the addition of organic waste, especially due to the presence of readily available nutrients and C compounds. A host of microbial activity and biochemical properties are important indicators of the impact of organic composting on soil. These are also qualitatively and quantitatively associated with the presence of extracellular hydrolytic enzymes which are important in the process of decomposition and mineralization of organic matter. The most important general indicators of soil microbial activity are microbial biomass C and soil respiration, while specific indicators are related to the activity of extracellular hydrolytic enzymes such as phosphatase and β-glucosidase, involved in nutrient cycling. The evaluation of biological and biochemical (say, β-glucosidase activity) soil properties have been suggested because of their relationship to the soil C cycle and the sensitivity of these indicators to detect changes resulting from agricultural management practices. The activity of phosphomonoesterase enzymes, such as acid and alkaline phosphatases, has been widely studied because of its importance in organic P mineralization, releasing orthophosphates that are readily assimilated by plants and soil microorganisms. The task is formidable to shift our attention to index soil health with stress on biological parameters for the compost-mediated soils to ensure agricultural and environmental sustainability.

HSSen
President

EXECUTIVE COMMITTEE MEETING

Date: March 08, 2017

Venue: KVK, RKMVU, Narendrapur

An Executive Committee (EC) meeting was held on 08 March, 2017 at 4=30 PM at KVK, R. K. Mission Vivekananda University, Narendrapur. The meeting was chaired by Dr. H.S. Sen, President of SFE.

Agenda-wise resolutions are presented hereunder:

1. Proceedings of the EC meeting held on 19 January, 2017 at ICAR-ATARI, Kolkata were accepted unanimously and confirmed in the meeting.
2. Prof. Mandal, Secretary, SFE, in details, briefed the house regarding the activities undertaken by the Society at different locations.
3. The EC also approved the guidelines for selection of Patrons and Fellows for presentation before the General Body.
4. The EC resolved that the theme for the next issue of SFE Newsletter will continue to be 'Soil Biological Health'. It was also resolved that one feasibility study on having one fixed format for Newsletter may be made by the editorial committee.
5. The scope for a two days National Seminar at Sabour was discussed. Professor B. Mandal and Dr. F. H. Rahman were given the responsibility to talk to the Vice-Chancellor of BAU for exploring the feasibility for such a seminar at Sabour.
6. A discussion was also held for organising a few additional programmes for farmers on maintenance of soil health with the help of ICAR-ATARI, Kolkata. Possibilities for organizing hands on training of state extension officials like KPSs were also discussed. Dr. D.Ghorai was requested to chalk out a blue print for the same. It was also suggested that awareness programmes for school students may also be organised in future.
7. The EC appreciated the facelift of the website of the Society

ANNUAL GENERAL MEETING

Date: March 08, 2017

Venue: KVK, RKMVU, Narendrapur

The AGM was chaired by Dr. H.S. Sen, President, SFE.Agenda-wise following resolutions were taken:

1. Minutes of the last AGM confirmed.
2. A detailed report on the various activities undertaken by the SFE was presented by the Secretary of the Society. It was informed that the Society presently has a strength of 145 members (include one annual member). Secretary also informed the house that three awareness programmes were conducted in Gosaba (South 24-Parganas), Burdwan and Potashpur (East Midnapore). He also informed the house that 2 Newsletter were also published during the reported period of the AGM. Secretary also presented the blue-prints for the future activities of the Society.
3. The statement of account of the Society, presented by the Treasurer, was approved by the house.
4. Nomination form for selection of patrons for the Society was presented in the house for discussion. It was decided that 3 patrons would be selected each year. Nomination form for such selection will be uploaded in the website of SFE.
5. Regarding selection of fellow, it was decided that in the next AGM, 2 Fellows of the Society will be selected on the recommendation of selection committee to be constituted by the EC for such purposes.
6. Under miscellaneous item, a number of queries were made by members present in the house. All their queries are addressed by the Secretary and President of the Society.

NEWS

National Seminar and Farmers' Interaction on "Maximizing fertilizer use efficiency and environmental health for posterity"

Date: March 08, 2017

Venue: IRDM, RKMVU, Narendrapur

The National Seminar was organized by the Society in collaboration with R. K. Mission Vivekananda University, Narendrapur at Narendrapuron the occasion of its 4th Annual Conventionon 08 March, 2017. More than 120 academicians, scientists, professionals, researchers, students and farmers participated in the seminar.

Inaugural session

The Seminar flagged off with Prof. Biswapati Mandal, Secretary, SFE welcoming the participants. Prof. Kunal Ghosh, immediate past President, SFE narrated briefly the origin of the Society for Fertilizers and Environment. The Guest of Honour Swami Shivapurananda, Asstt Administrative Head, IRDM F/C & Vice-Chairman SS KVK, RKMVU narrated the importance of natural resources in our life. The Special Guest Swami Sarvalokananda, Secretary, RKM Ashram, Narendrapur mentioned the role played by agrochemicals particularly fertilizers, pesticides, herbicides etc. in increasing the production of foodgrains to feed our growing population. He also highlighted the bad effects of those chemicals in our environment which are normally ignored by us. The Chief Guest Dr. D. D. Patra, Vice-Chancellor, BCKV, Mohanpur emphasised on location and crop specific technologies for increasing fertilizer use efficiency to overcome environmental hazards of fertilizer use. He was very optimistic that the next generation (farmers) would be very smart in using technologies to protect environment for their posterity. Dr. H.S. Sen, President, SFE narrated briefly the various activities of the Society during the last one year including publication of two issues of the Newsletter. He highlighted the uniqueness of the Society of Fertilizers and Environment and its activities in addressing the issues of both fertilizers and environment. The formal vote of thanks was given by Dr. N. C. Sahu, Organising Secretary of the Seminar.

Foundation Lecture of the Society for Fertilizers and Environment

The Foundation Lecture in the memory of Late Prof. N. P. Dutta was delivered by Dr. D. K. Das, Former President, Indian Society of Soil Science, New Delhi and Head, Div. of Agricultural Physics, IARI, New Delhi on *Emerging Techniques in Development and Use of Fertilizers*. In his lecture Dr Das highlighted the on the problem of over use of fertilizers like declining soil fertility, reduced fertilizer response etc. He suggested some management practices like use of nano fertilizer, soil test based fertilizer recommendation, smart fertilizers with high NUE and technologies like remote sensing, geographic information system and global positioning system, use of Hyper Spectral Remote Sensing (HRS)/Diffuse Reflectance Spectroscopy (DRS) to augment crop yield. According to him, efficient use of nutrients and water by using different controlled water supply system such as sprinkler, drip irrigation *etc* may be stressed upon.

Technical session

There were two special lectures organized during the occasion which were delivered by two eminent scholars of the country in the field of natural resource management viz., Professor T. K. Adhya, KIIT University, Bhubaneswar and Professor D. K. Benbi, Punjab Agricultural University, Ludhiana. The session was chaired by Dr. H. S. Sen, President SFE.

The first lecture was on *"Fertilizer Use for Sustaining Soil Health"* delivered by Dr. D. K. Benbi, ICAR National Professor, PAU, Ludhiana. He listed the second generation problems of green revolution as soil degradation and micronutrient deficiency, stress on natural resources, decline in factor productivity, decline in water table, and growing incidence of disease-pests. He also observed that soil degradation was much higher in low-input than in high-input system of farming. He called for neutralizing acidity in soil created by use of urea fertiliser. Relating human health to the soil health, Dr Benbi pointed that micronutrient deficiency in human was strongly related to the micronutrients deficiency in the soil.

The second lecture on "Fertilizer Management for Climate Change Mitigation and Adaptation" was delivered by Dr. T. K. Adhya, Director of the South Asia Nitrogen Centre, New Delhi & Professor, KIIT University, Bhubaneswar. Dr. Adhya informed that consumption of fertilizer N was steadily increasing over the years with concomitant increase in the emission of NH_3 and NO_2 in the atmosphere. He said that of total fertilizer N used, 4% was accumulated in non-vegetarians body while 14% got accumulated in the vegetarians' body. He advocated different approaches and promising practices for enhancing nutrient use efficiency in crops. He advocated the '4R Concept' of fertilizer use to ensure sustainable crop production to feed the growing population while at the same time to reduce the negative impact of leakage of fertilizer N to the environment.

Few glimpses from the National Seminar.

ARTICLE

Micronutrients and plant disease suppression

Widespread micronutrient deficiency should be the key consideration of present day agriculture as it relates both crop and animal nutrition. Micronutrients are major limitation across the world and control crop productivity as well as quality of the produce. Wide spread deficiency of Zn (49%) followed by S (41%), B (32%), Fe (12%), Mn (4%) and Cu (3%) has been noticed in soils of India. Again hidden hunger of micronutrients is another noticeable phenomenon that may lead to even entire failure of crop and reduced level of micronutrients in plant parts (Singh, 2009). To feed the teeming population of the world with nourishing food, need based micronutrient management strategies is to be taken not only to alleviate the deficiency symptoms of plant but to fight against plant diseases and maximize crop productivity. Micronutrients can able to control pathogen damage in plants either directly by antagonising the pathogen or indirectly through enhancing plant defence mechanism by systemic acquired resistance and or stimulating antagonist population in rhizosphere. In the present article an attempt has been made to convey the importance of micronutrient with respect to plant health and disease management.

Soil is the major source of plant nutrients which are responsible for growth and development of plants as well as plant associated microorganisms. They are also important factors of plant disease control (Agrios, 2005). There is no general rule, as a particular nutrient can decrease the severity of a disease in a given environment and ecology but can also increase the severity or predispose the same plant(s) to infection in a different environment and ecology (Graham and Webb, 1991). Nutrient can affect disease resistance or tolerance of a given crop species in a given plant-pathogen system. Apart from genotypic and phenotypic control of resistance/tolerance, environmental condition especially toxic sufficiency and/or lethal deficiency of plant nutrients also govern the same of a given plant species and corresponding pathogen system. Interactions between plants, nutrients, and pathogenic diseases are very complex and not completely understood. Plant pathogen dynamics in response to nutrient availability are thought to be more complicated as nutrient deficiency/sufficiency in plant system modulate host physiological system and plant reacts differentially (susceptible or tolerance) against different pathogens. However, some nutrient elements have a direct and greater impact on plant diseases than others. Disease resistance in plants is primarily a function of genetics. However, the ability of a plant to express its genetic potential for disease resistance can be affected by mineral nutrition. Plant species or varieties that have a high genetic resistant to a disease are likely to be less affected by changes in nutrition than plants only tolerant of diseases. The physical resistance is the first line of defense in the plant system, generally governed by the strength and integrity of the cell walls and intercellular spaces. Nutrients play a major role in the plants ability to develop strong cell walls and other tissue. Moreover, the amount and composition of root exudates is affected by the nutrition of the plant. When plants have low levels of certain nutrients, these exudates will contain higher amounts of compounds such as sugars and amino acids that promote the establishment of the pathogen.

There are many factors that can affect the severity of plant disease such as date of sowing, crop rotation, mulching and mineral nutrients, organic amendments (manure and green manure), liming for pH adjustment, tillage, seedbed preparation and irrigation. Many of these practices affect the level of nutrients available for the plant and the pathogen which can affect the disease severity. In addition, nutrients can affect the development of a disease by affecting plant physiology or by affecting pathogen or both of them. The level of nutrients can influence the plant growth development and architecture which can affect the microclimate, therefore, influencing infection and sporulation of the pathogens. Balanced plant nutrients availability can affect the growth rate of the host which can enable host to escape or avoid infection when they are in most susceptible stage, while sufficiency and/or deficiency of plant nutrients may pre-disposed the normal plants to certain diseases.

Micronutrient and their role in plant growth and development

Micronutrients serve many roles in plant metabolism and growth. One of the frequent functions of micronutrients is to serve as catalysts or co-factors of various enzyme system involved in different metabolic reactions. Zinc is associated with the metalloenzymes like carbonic anhydrase, dehydrogenase, proteinase and peptidases, involved in synthesis of auxin and is capable of acting as a electron carrier for the oxidation reactions in plants. Iron, a part and parcel of enzyme systems like catalase and peroxidise plays a vital role in oxygen carrying system of plant and is essential for formation of chlorophyll. Manganese is an essential element of photosystem

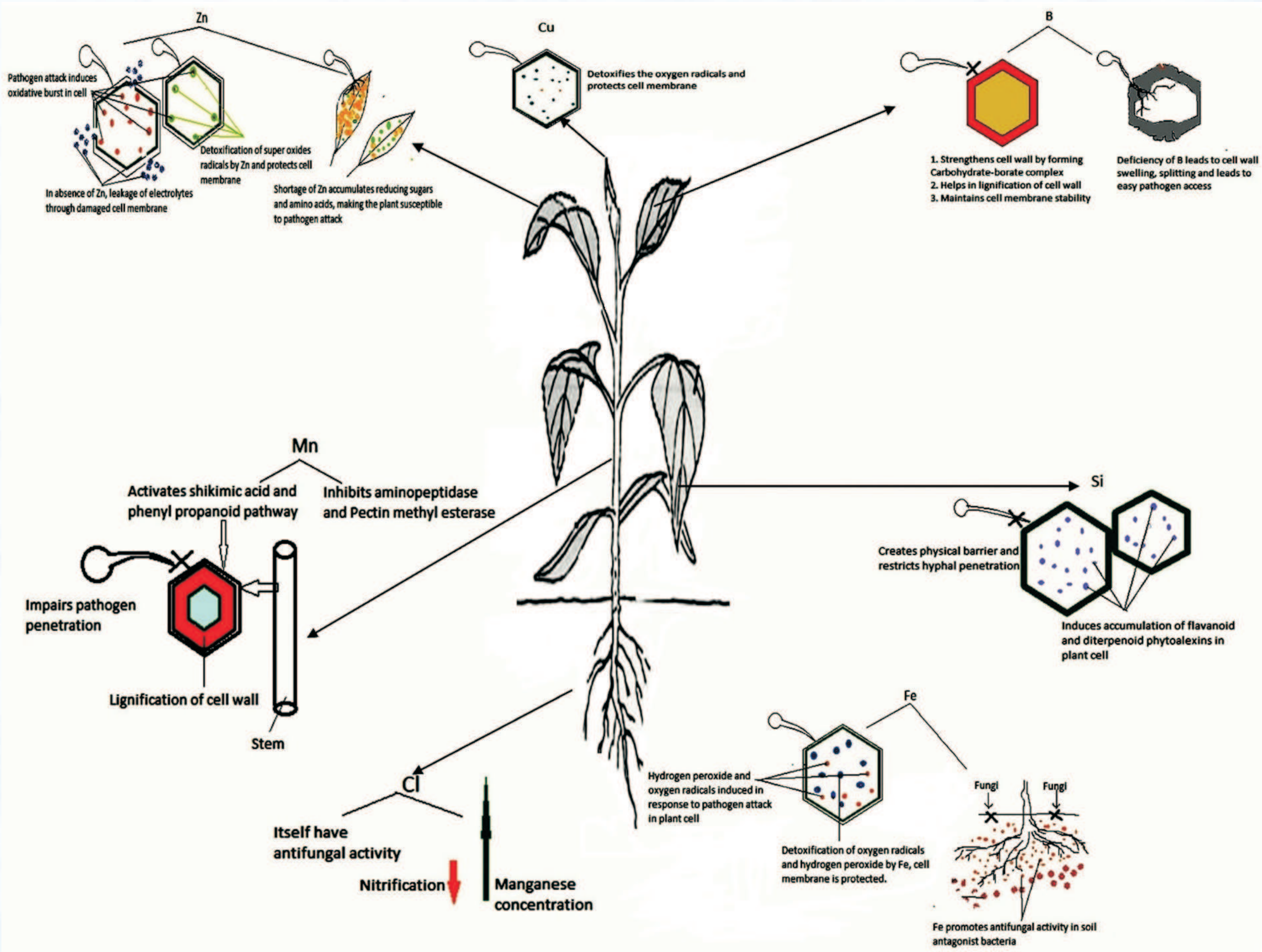

Fig 1. Schematic representation showing role of micro nutrient in plant disease suppression

II where it participates in photolysis. Copper which is very much essential in plants reproductive growth stage plays an important role in plant growth as an activator and part of enzymes like cytochrome oxidase, ascorbic acid oxidase and polyphenol oxidase. Zinc, copper and manganese also are involved in carbohydrate and protein metabolism of plant. Molybdenum is associated with nitrogenase, nitrate reductase enzymes and is essential for nitrogen fixing plants and organisms. Cobalt is essential for symbiotic nitrogen fixation and rhizobial growth and formation of enzyme cobalamin. Nickel is capable of existing in multiple oxidation states, and thereby function in redox reactions and is a part of enzyme urease. Boron is associated with rate of water absorption, translocation of sugars in plant and increased cellular activity that promote maturity with increased set of flowers, fruits, yield and quality. Boron also contributes to the integrity and functioning of the plasma membrane, probably by affecting physical properties of membrane proteins. Chloride is required for the water-splitting protein complex of photosystem II, it stimulates the activity of the vacuolar proton-pumping ATPase and it can function in osmoregulation, especially in stomatal guard cells.

Importance of micronutrients in reducing plant diseases

Micronutrients have diverse but essential role in plant functioning especially in photosynthesis, photolysis, protein, carbohydrate metabolism, phenyl propanoid pathway and also in plant metabolism by affecting the phenolics, lignin content and membrane stability. The role of micronutrients in management of diseases of several host-pathogen systems are mentioned here. Soil applications of manganese fertilizers are found to reduce common scab of potato (Keinath and Loria, 1996), *Fusarium* spp. infections in cotton and *Sclerotinia sclerotiorum* (Lib. de Bary) in squash (Graham and Webb, 1991; Agrios, 2005). Manganese has also been observed beneficial in the control of the diseases like - Potato Common scab (*Streptomyces scabies*), Rice Blast (*Pyricularia oryzae*), Rice Leaf spot (*Alternaria*), Wheat Mildew (*Blumeria grammis* var. *tritici*), Cotton Wilt (*Verticillium albo-atrum*), Avocado Root rot (*Pythium*), etc. (Simoglou and Dordas, 2006). Zinc nutrition is useful in the control of the diseases like - Root rot (*Phytophthora megasperma* / *Phytophthora dreschsleri*), Oranges Root rot (*Phytophthora nicotiana*), Citrus Mold (*Penicillium citrinum*), Various Leaf spot (*Cochliobolus miyabeanus/Cladosporium cladosporoides/Alternaria/Epicoccum*), Various Wilt (*Fusarium*), Various Stem/sheath blight (*Rhizoctonia solani*), Cotton Wilt (*Verticillium*), Tomato reniform Nematode (*Rotylenchulus reniformis*), Ginseng Bacterial leaf spot (*Pseudomonas cichorii*), Chickpea Root rot (*Fusarium*), groundnut Rot (*Rhizoctonia bataticola*), Rubber trees Powdery mildew (*Oidium heveae*), Wheat Take-all (*Gaeumannomyces graminis* var. *tritici*), Wheat Head scab (*Fusarium graminearum*), powdery scab/crook root (*Spongospora subterranean*), Soybean Foot rot (*Sclerotium rolfsii*), Pea Powdery mildew (*Erysiphe polygoni*), etc., Club root of Brassicas [*Plasmodiophora brassicae (*Woron.)] (Sen, 2005), Root rot of beans *[Fusarium solani* (Mart.)Sacc.] in bean, Wilt of tomato, cotton *[Verticillium albo-atrum* (Reinke & Berth)], tobacco mosaic virus in bean, tomato yellow leaf curl virus in tomato, Take-all [*G. graminis* (Sacc.)] (Graham and Webb, 1991) and powdery mildew [*Blumeria graminis* (D.C.) (Speer)] in wheat (Marschner, 1995), wart of potato (*Synchytrium endobioticum*), etc. Foliar application of Fe can increase resistance of apple and pear to *Sphaeropsis malorum* and cabbage to *Olpidium brassicae* (Graham, 1983). The elemental chlorine, when present as the chloride ion (Cl^-) is considered to be an essential micronutrient for nutritional purposes. Chlorine is required in very small amounts for plant growth and Cl deficiency has rarely been reported as a problem in agriculture. However, there are reports showing that Cl application can enhance host plants' resistance to disease in which fairly large amounts of Cl are required, which are much higher than those required to fulfil its role as a micronutrient but far less than those required to induce toxicity (Mann *et al.*, 2004). It has also been suggested that Cl might interact with other nutrients such as Mn. Chlorine has been shown to control a number of diseases such as stalk rot in corn, stripe rust in wheat, take-all in wheat, northern corn leaf blight and downy mildew of millet, and *Septoria* in wheat (Graham and Webb, 1991; Mann *et al.*, 2004). Copper also acts to detoxify oxygen radicals and hydrogen peroxide, thus limiting damage to plant cells. Cu has been beneficial in the control of the following diseases - Wheat Powdery Mildew (*Blumeria grammis* var. *tritici*), Sunflower Leaf/Stem spot (*Alternaria*), Ginseng Bacterial leaf spot (*Pseudomonas cichorii*), Wheat Leaf rust (*Puccinia triticina*), Rye Ergot (*Claviceps purpurea*), Barley Ergot (*Claviceps purpurea*), Rice Blast (*Pyricularia oryzae*), Wheat Leaf/Glume blotch (*Septoria*), Sugarbeet Cyst Nematode (*Heterodera*), Tomato Wilt (*Verticillium albo-atrum*), Cotton Wilt (*Verticillium dalhiae*), Potato Common scab (*Streptomyces scabies*), *Eucalyptus marginata* root rot (*Phytophthora cinnamomi*); Wheat Take-all (*Gaeumannomyces graminis* var. *tritici*), etc. Rice and sugarcane which accumulate high levels of Si in plant tissue are fertilized routinely with calcium silicate slag to produce higher yields and higher disease resistance. Si has been shown to control a number of diseases such as rice blast (*Magnaporthe grisea*), brown spot (*Cochliobolus miyabeanus* (Ito and Kuribayashi in Ito Drechs ex Dastur) in rice and sheath blight (*Thanatephorus cucumeris* (A.B. Frank) Donk.) in rice, and increase the tolerance of various turf grasses to *Rhizoctonia solani*, *Pythium* spp., *Pyricularia grisea* (Cooke sacc) and *Blumeria graminis* (DC) (Carver *et al.*, 1998; Alvarez and Datnoff, 2001; Seebold *et al.*, 2000; Zhang *et al.*, 2006). Silicon (Si) can decrease the intensity of blast as effectively as some fungicides, mainly because it has the potential to increase the partial resistance of cultivars to the same level observed in cultivars with complete resistance (Datnoff *et al.*, 1991). In this context, soil amendment with Si can be considered an effective strategy to decrease blast intensity, especially when rice is cultivated in Si-deficient soils.

Micronutrient mediated plant disease resistance and mechanisms

The effect of micronutrients on reducing the severity of diseases can be attributed to the involvement in physiology and biochemistry of the plant, as many of the essential micronutrients are involved in many processes that can affect the response of plants to pathogens (Marschner, 1995). Application of nutrients such as Mn, Cu and B can release Ca^{2+} from cell walls through cation exchange, which interact with salicylic acid and activate systemic acquired resistance mechanisms (Reuveni *et al.*, 1997; Reuveni and Reuveni, 1998). Micronutrients play an important role in plant metabolism by affecting the phenolics and lignin content and also membrane stability (Graham and Webb, 1991). Fig. 1 clearly indicated the role of micronutrient in plant functioning especially in protein, carbohydrate metabolism, phenyl propanoid pathway and also in plant metabolism by affecting the phenolics and lignin content, membrane stability, enhancement of phytoalexins synthesis and triggering of genes related to systemic acquired resistance.

Mn inhibits the induction of aminopeptidase, an enzyme which supplies essential amino acids for fungal growth and pectin methylesterase, a fungal enzyme that degrades host cell walls. Mn controls lignin and suberin biosynthesis (Vidhyasekaran, 1997) through activation of several enzymes of the shikimic acid and phenylpropanoid pathways (Marschner, 1995). Both lignin and suberin are important biochemical barriers to fungal pathogen invasion (Vidhyasekaran, 1997, 2004), since they are phenolic polymers resistant to enzymatic degradation (Agrios, 2005). *Trichoderma* species are used in plant disease control due to secretion of some chitinase enzymes as a strong factor involves in biological control. Application of microelements fertilizers can have impact on biological control efficacy of microorganisms. In a study, Morid and Zafari (2013) showed that manganese influences the chitinase production of *Trichoderma*, significantly positively while copper and iron showed a negative effect on the activity of the enzyme and thereby indirectly influences the activity of soil borne plant pathogenic microorganisms. Zn has been reported to reduce disease severity, which could be due to the toxic effect of Zn on the pathogen directly and not through the plant's metabolism (Graham and Webb, 1991). As an activator of Cu/Zn- Super oxide dismutase (SOD), Zn is involved in membrane protection against oxidative damage through the detoxification of superoxide radicals (Cakmak, 2000). Zinc was found to have a number of different effects as in some cases it decreased, in others increased, and in others had no effect on plant susceptibility to disease (Graham and Webb, 1991). Zinc plays an important role in protein and starch synthesis, and therefore a low zinc concentration induces accumulation of amino acids and reducing sugars in plant tissue (Marschner, 1995) stimulate the growth and sporularion of fungi. It is known that Zn shortages contribute to the accumulation of unused sugars within the plant. In this respect Zn deficiency predispose the plant to the successful invasion of fungus and bacteria. Feeding intensity and reproduction by sucking insects, as a vector of viruses point of view, tend to be higher on plants with a higher amino acid content. This condition is typical of plants with a Zn deficiency. In summary, it can safely be concluded that improving the Zn nutrition of crops will be helpful against many, but not all diseases. Boron nutrition mediated physiological and metabolic activities reducing disease susceptibility in plant system attributed to (1) strengthening cell wall structure through the formation of carbohydrate-borate complexes, which control carbohydrate transport and cell wall protein metabolism, (2) controlling cell membrane permeability, stability or function, or (3) its role in metabolism of phenolics or lignin (Brown *et al.*, 2002; Blevins and Lukaszewski, 1998). In B deficient condition, plant cell walls tend to swell and split, and to result in weakened intercellular space. This results in a weakened physical barrier to initial infection and expansion of the infection. Sanjeev and Eswaran (2008) observed that boron nutrition (borax @ 500 and 750 ppm) contributed to the maximum inhibition of mycelial growth of *F. oxysporum* f. sp. *cubense* and boron can be used as prokaryotic inhibitor at a certain concentration. Sanjeev and Eswaran (2008) also showed that the sporulation capacity of the *biocontrol agent T.viride* was found to be maximised by the addition of borax (500 ppm). Therefore, response of soil born phytopathogenic prokaryotes such as Ralstonia, Pectobacterium, Pantoea, etc. to boron can be assessed and if found that the concentration is not toxic to other beneficial plant associated microorganisms, then altered B nutrition can be used as effective means of management of the diseases due to these soil borne plant pathogens. In rice, Si application has been associated with an increase in the density of silicified buliform cells in the leaf epidermis that helped to increase resistance against blast (Kim *et al.*, 2002). According to Rodrigues *et al.* (2003), Si-mediated resistance to *Pyricularia grisea* in rice was related to the great accumulation of phenolic compounds.

Conclusion:

Micronutrients play key role not only in managing soil health but have essential role in plant functioning, thereby correcting deficiency symptoms of plant, fight against plant diseases, providing healthy environment for the growth and development of the beneficial microbial consortium surrounding root rhizosphere and maximize crop productivity. In summary, it can safely be concluded that improving the micronutrient nutrition of crops will be helpful against many, but not all diseases. Altered micronutrient nutrition can be used as effective means of management against the soil borne diseases by antagonizing the pathogen, and stimulating the growth of the antagonists.

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Soil Microbes in Sustaining Agro-ecosystem Productivity

"Deciphering the quaint, fantastic and multitudinous association of microorganisms that constitute the complexity of the rhizosphere region, the author is tempted to hazard the opinion that the tenancy provided by plant roots to alien microorganisms is amazing and astounding ……"

Kakkar (1970)

Healthy soils contain enormous numbers of diverse living organisms, and assembled in complex and varied communities. They range from the myriad of invisible microbes, bacteria and fungi to the more familiar macro-fauna such as earthworms and termites (FAO, 2002). Plant roots can also be considered as soil organisms in view of their symbiotic relationships and interactions with other soil components. These diverse organisms interact with one another and with the various plants and animals in the ecosystem, forming a complex web of biological activity. Environmental factors, such as temperature, moisture and acidity, as well as anthropogenic actions, in particular, agricultural and forestry management practices, affect to different extents soil biological communities and their functions. From seed germination until the plant reaches maturity, microorganisms grow associatively unless measures are taken in laboratory experiments to deliberately exclude them. This situation, which is now termed "rhizocoenosis", is commonly ignored by to-days agro-technologies meant for intensive agriculture. Beneficial bacteria usually colonize on surface and within tissues of different parts of the host plant, where they live commensally or execute beneficial functions for the host. Depending upon the site of colonization, these beneficial bacteria are broadly categorized into two groups namely endophyte (within plant tissues like root, leaf, stem, seeds, etc.) and rhizobacteria (tightly- and loosely-adhered rhizobacteria) (Lynch 1990; Thokchom *et al.*, 2014). Plant seeds usually fall on the soil, a complex microbial habitat, and lay dormant waiting for environmental signals to germinate. As seeds begin to germinate, seed endophytes are important founders of the seedling bacterial community. With the establishment of seed bacterial community, plants also start exerting modifying effects in the rhizosphere through secretion of root exudates for selective recruitment of certain members of the native soil bacteria, which is termed "rhizobacteria" (Hardoim *et al.*, 2012).

Beneficial microbes in agriculture

Beijerinck in the Netherlands was the first to isolate and cultivate a microorganism from the nodules of legumes in 1888. He named it *Bacillus radicicola*, which is now placed in *Bergey's Manual of Determinative Bacteriology* under the genus *Rhizobium.* In the early 20th century, a product containing *Rhizobium* sp. was patented (Nobbe and Hiltner, 1896), which marked the beginning of inoculating beneficial microbes in plants. Although it was not known that bacteria exist until Anton von Leeuwenhoek (1683) discovered, their potential to stimulate plant growth and help in crop production has been exploited since ancient times. By the end of the 19th century, the practice of mixing "naturally inoculated" soil with legume seeds was a recommended method of legume inoculation in USA (Bashan, 1998). Another humble organism, blue green algae was first evidenced and recorded their role in N fixation in rice culture by P. K. De (Dey, 1939). Theophrastus (372–287 BC) suggested the mixing of different soil samples for remedying defects and adding heart to soil (Tisdale and Nelson, 1975). Kloepper and Schroth (1978) coined the term 'rhizobacteria' to the soil bacterial community under the influence of plant roots and named as 'plant growth-promoting rhizobacteria (PGPR)' and in subsequent time PGPR group suggested within the broad group of beneficial bacteria, which now terms “plant growth promoting bacteria (PGPB)' as proposed by Bashan and Holguin (1997). Then after, it has been considered as the crucial component in the agricultural food production and management systems. Researchers have worked on PGPB numerous occasions in different parts of the globe and frequently reported the plant growth promoting attributes of these PGPBs.

Soil microbes as regulator of ecosystem processes

Soil biota community perhaps the most diverse community and spatially distributed within maze of highly heterogeneous habitat, the soil. In recent years, the information on mechanisms of how soil biota especially these microbes affect the ecosystem and ecology are started accumulating, but still not fully understood, despite of their large numbers. Soil microbes take important role in regulating plant productivity and are found beneficial especially in areas of poor nutrient ecosystem (Zelicourt *et al.,* 2013). One of the most crucial processes in plant nutrition i.e. biological nitrogen fixation is carried out by nitrogen-fixing bacteria, contributing for about 5–20% in grassland and savannah to 80% in temperate and boreal forests of all nitrogen. Free-living microbes also strongly regulate plant productivity, through the mineralization of, and competition for, nutrients that sustain plant productivity. Moreover, soil microbes also regulate the dynamics of plant community and plant diversity, which is an indicator for plant abundance (Bardgett, 2005). Conservative estimates suggest that 20,000 plant species are completely dependent on microbial symbionts for growth and survival pointing to the importance of soil microbes as regulators of plant species richness on Earth. Overall, soil microbes must be considered as important drivers of plant diversity and productivity in terrestrial ecosystems. Microorganisms may comprise of mixed populations of naturally occurring microbes that can be applied as inoculants to enhance functional microbial diversity and their activities. Past reports have indicated that the inoculation of efficient microbial community to the soil ecosystem improves growth, yield and quality of crops, and soil quality. These microbial populations usually encompass selected functional groups including plant growth promoting bacteria, N_2-fixers, plant disease suppressive bacteria and fungi, soil toxicant degrading microbes, actinomycetes and other useful members of soil microbial community. It is an added dimension for optimizing our soil and crop management practices such as crop rotation, organic amendments, conservation tillage, crop residue recycling, soil fertility restoration, maintenance of soil quality and the bio-control of plant diseases. If used adequately, microbial communities can significantly benefit the agriculture practices and able to restore ecosystem processes of degraded ecosystems.

Fertilizers inputs and soil microbiota

Application of nutrient inputs to the soil affects below ground communities. In a review, Allison and Martiny (2008) reported that 84% of 38 studies indicated the sensitivity of microbial communities to nitrogen (N), phosphorus (P) and potassium (K) fertilization. Bardgett (2005) reported that the relative dominance of the bacterial based energy channel and fungal based energy channel in terrestrial ecosystems is linked to the resource quality dependent on the above ground biota community. On the other hand, the net primary production in terrestrial ecosystems is generally N limited and soil microorganisms may be carbon and nitrogen limited. These ecological theories clearly indicated that the C and N inputs in terms of quality and quantity in soils directly linked to the response of the soil biota community. The data from unmanaged ecosystems suggest that increasing N inputs suppress soil microorganisms (Lu *et al.*, 2011). High application rates of inorganic fertilizer inputs lead to temporarily very high osmotic potentials and potentially toxic concentrations of the N forms added. At higher application rates, short- and long-term effects on soil pH may also be more pronounced in agroecosystems.

Recently, Geisseler and Scow (2014) performed a meta-analysis based on 107 datasets from 64 long-term trails around the world to have a better understanding on the long-term effects of mineral fertilizers on soil microorganisms. Findings revealed that mineral fertilizer application led to a 15.1% increase in the microbial biomass (C_{mic}) above the levels in unfertilized control treatments. However, the magnitude of the effect of fertilization on C_{mic} was pH dependent i.e. fertilization reduces C_{mic} in soils with a pH below 5.0 in fertilized plots; whereas, C_{mic} increase significantly in fertilized plots at higher soil pH values. The application of urea and ammonia fertilizers can temporarily increase pH, osmotic potential and ammonia concentrations to levels inhibitory to microbial communities. Application of fertilizers may strongly affect soil microbial biomass and community composition in the short term. Long-term repeated mineral N applications may alter microbial community composition even when pH changes are small. It was further concluded that the specific microbial groups respond to repeated applications of mineral fertilizers, however, varies considerably and seems to depend on environmental and crop management related factors.

Biomass burning and N cycling genes in Jhum soils

Biomass accumulation and heterotrophic decomposition are two important processes of C and N cycles within an ecosystem. Any anthropogenic disturbances on these two processes may upset the ecosystem functioning. In a recent study, Thakuria *et al.* (unpublished data) investigated the influence of burning and the length of fallow phase (burnt and unburnt soils from 5, 10, 15, 20 yrs Jhum cycles) on the abundance of N-fixing (*nif*H) and archaeal ammonia oxidizing (*amo*A) genes. Besides, the abundance was also compared in the rhizosphere of 3 important Jhum crops *viz*. rice, maize and colocasia fallow length wise. Results indicated that

Archaeal *amo*A gene copy number was below detection limit in unburnt soils, whereas the abundance of gene copy number ranged from 3.75E+04 to 2.40E+05 in burnt soils and showed the abundance trend in order of 10 years > 5 years > 20 years fallow length. The abundance of *nif*H gene copy number in unburnt soils of 5 yrs fallow length was significantly lesser than in burnt counterpart. Whereas, in longer fallow periods (10 and 20 yrs) the copy number of *nif*H gene in burnt soils were significantly lesser compared to unburnt soils of the respective fallow length. Findings suggest that the archaeal community is supportive of ammonia oxidization process in burnt soils, which is not true for unburnt soils. Burning positively impacted *nif*H gene copy number in shorter fallow phase (5 yrs), whereas reverse is true in longer fallow phase (10- and 20-yrs). The maximum *nif*H gene copy number was detected in soils of 10 yrs fallow phase. The abundance of *nif*H gene gradually reduced with the increasing length of the fallow phase. Besides, colocasia rhizosphere supported more *nif*H abundance than cereal crop rhizosphere in *Jhum* fields. These findings clearly indicated the influence of anthropogenic disturbances on the above-ground and below-ground biota community linkages.

Microbial bioinoculants as component of nutrient management practices

The interactions between a plant and inoculants can be of different kind: neutral, beneficial or antagonistic. Therefore, in developing a microbial consortium, it is of prime importance to screen out plant growth promoting microbes from soil that are compatible to each other. Synthetic biology has developed the concept of microbial consortium and showed how creatively the microbes are engineered in laboratory to burgeon their importance in plant growth promotion. Microbial consortium is a product carrying more than one live beneficial microbes showing synergistic or syntrophic interaction to each other; the inoculation on consortium mode enhances fitness benefits of the host plant by maintaining a better state of nutrient cycling in soil, executing more complicated processes and encountering more changeable environments than monocultures (Brenner *et al.,* 2008). The plant growth promoting mechanisms associated with microbial consortium are nitrogen fixation, dissolution of insoluble phosphates, potassium, and zinc, excretion of beneficial enzymes like ACC-deaminase enzyme that cleaves ACC, the immediate precursor of ethylene, and cellulase enzymes that decompose cellulose containing compounds, production of phytohormones like IAA, siderophore compounds, exopolysaccharide secretion for improvement of soil structure, and serving as a biocontrol agent. The introduction of inoculants technology in agriculture as a holistic approach is found to be quite convincing in reducing the levels of chemical use (Trabelsi and Mhamdi, 2013).

The 21st century agriculture possess many challenges including meeting the food demands for the growing population, expected to be 9.15 billion by the year 2050 (FAO, 2012). Modern agriculture is heavily dependent on regular fertilizer inputs which in-turn effects the below ground communities. In addition to it, another main driver that provoked attention is the environmental problems due to heavy utilization of chemicals degrading the soil quality as well as threatening the food security (Günes *et al.*, 2014), which led the scientists, workers and policy makers to reassess the conventional agricultural practices and to rely more on biological inputs (Glick, 2014). The extent of soil acidification limits food production of about 30-40% of the world's arable soils, up to 70% of potentially arable land (Hede et al, 2001) and 26.22 Mha of North East India (Sharma *et al.* 2006), carrying multiple problems like mineral toxicities, deficiencies, and restricted root growth. Addition of organic amendments may offer an option to supplement/augment inorganic fertilizers and support sustainable, biologically regulated nutrient supply systems. In integrated nutrient management (INM) approach, the total nutrient requirement is met jointly by fertilizers, organics and bio-fertilizers in a balanced way. Though balanced nutrition through inorganic fertilizers alone may enhance crop productivity by improving chemical stability, it does not make the system sustainable because of less than optimum soil organic matter content, soil physical environment and (resultant) soil biological condition. Maize-wheat or rice-wheat systems were found to be sustainable only when fertilizers were supplemented with organic manures. Significant improvement in organic carbon, total-N, mycorhizal infection, activity of soil enzymes, microbial biomass, soil respiration and potentially mineralizable-N was reported in 50% NPK plus FYM (6 t ha^{-1}) compared to 100%NPK in maize-wheat or rice-wheat system (Kang *et al.,* 2005). The successes of a few prominent bioinoculant mediated nutrient management practices in acid soils of North East India are discussed hereunder.

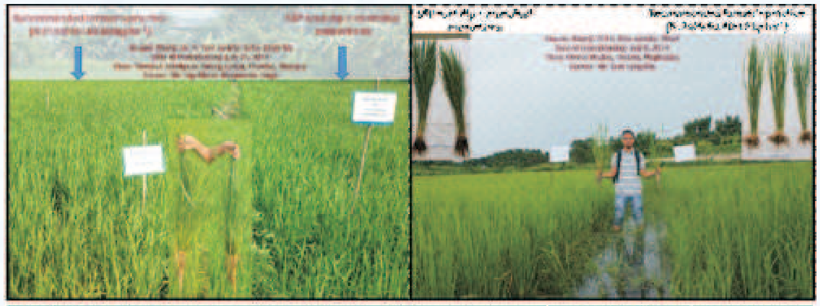
Bacterial inoculants based INM for rice-legume-rice rotation

The role of bioinoculant-based integrated nutrient management (INM) practice was evaluated on rice-legume–rice (RLR) in a rainfed production system in Assam, India (Thakuria *et al.*, 2009). Bioinoculation was done with *Azospirillum*, *Rhizobium* and phosphate-solubilizing bacteria and fertilization with rock phosphate, compost, and muriate of potash. After harvest of 9 consecutive crops in 3 years (Fig. 1), cumulative grain yields, removal of N, P and Zn by rice, soil N balance was significantly higher in bioinoculant based INM than in farmers' practice, compost alone or fertilizer alone treatments. Improvement in soil biology was evident from increase in proportion of soil aggregates in micro- (53–250 μm) and macro- (250–2,000 μm) aggregates. Besides, fungal/bacterial biomass C:N ratio indicated a better state of C and N mineralization under bacterial bioinoculant based INM plots. Authors argued that fungal/bacterial biomass C:N ratio seems to be a more reliable indicator of C and N dynamics in acidic soils than total microbial biomass C. Compost alone or bioinoculant-INM plots showed higher numbers of earthworms' casts compared to chemical alone and bioinoculants based INM plots. PCR-DGGE profiles revealed changes in bacterial community composition in soils due to differences in nutrient management which were according to the states of C and N dynamics in acidic soil under RLR rotation.

In North-East India, a recent study examined the role of inoculation of microbial consortium (root endophyte and rhizosphere bacteria of wild rice) on adaptation of cultivated rice variety (CAUR3) to a toxic Al concentration gradient in acid Inceptisols (Das *et al.*, 2015). Successful colonization of rice plant by microbial consortium conferred better habitat-fitness benefit resulting in higher root surface area, volume and length, root and shoot biomass and lower root diameter, and lower H_2O_2 activity in fully expanded leaves than that of uninoculated plants. The interaction effects between endophyte inoculation and Al levels was significant ($P<0.001$) in terms of the contents of malondialdehyde, carotenoids and cell membrane stability. The toxic effect of an approximate 100ppm Al could be compensated due to endophyte inoculation.

Seedling root-dip method of phosphorus management in acid soils

The use efficiency of water soluble inorganic P fertilizer *viz*. single super phosphate exhibits hardly 15-20% of the applied quantity in a crop season in strongly acid soils of NE India. Application of higher quantity of inorganic P fertilizer is mere a wastage of poor farmers' money and can also pose a serious environmental pollution. As an alternative to conventional way of P management in acid soil, t*he rhizosphere-based P management approach seems to be pertinent in acid soils for enhancing P-use efficiency and yield of crops because: (a) There are no substitutes for P in agriculture* and (b) a *potential Global P crisis in near future.* Recently, the usefulness of the root-dipping in SSP-MC slurry method of P management has been demonstrated in an acid Inceptisol (Kalidas-Singh, 2014). Prior to transplantation of the SSP-MC (microbial consortium) treated rice seedlings, rock phosphate (RP) needs to be broadcasted on the main field @125 kg ha^{-1} along with 50% of the recommended dose of Urea (133 kg ha^{-1}) and MOP (66 kg ha^{-1}). The comparative performance of the rhizosphere based P management method and the recommended inorganic fertilizers practice was evaluated on transplanted *Kharif* rice in the farmers' fields of Manipur and Meghalaya. Results from the field trials indicated that the root-dipping in SSP-MC Slurry method of P management produced comparable yield of rice with that of recommended inorganic fertilizers (NPK) and the input cost of the rhizosphere based P management method was approximate half of the price involved in the later method (Fig. 2).



Nutrient management	Yield of rice (t ha^{-1})	Input cost (Rs. ha^{-1})
Farmers' practice (133 kg Urea + SSP 250 kg + MOP 66 kg) per ha	5.18a	4490.00
Root dip practice (SSP 7.0 kg + biofertilizer 4.0 kg) + (Urea 66 kg + MOP 33 kg + RP 90 kg) per ha	5.20a	2460.00
Results were obtained from field trials conducted at Thoubal (Manipur) and Umroi Madan (Meghalaya)		
Advantage of root-dip SSP-MC slurry method: Comparable yield with the investment of 50% less costs on fertilizer inputs.		

Fig. 1. Comparative performance of bioinoculant based INM practices and conventional farmers' practice (N:P:K@40:20:20 kg ha^{-1}) in terms of yield of rice-legume-rice rotation in light textured alluvial soils of Brahmaputra valley of Assam.

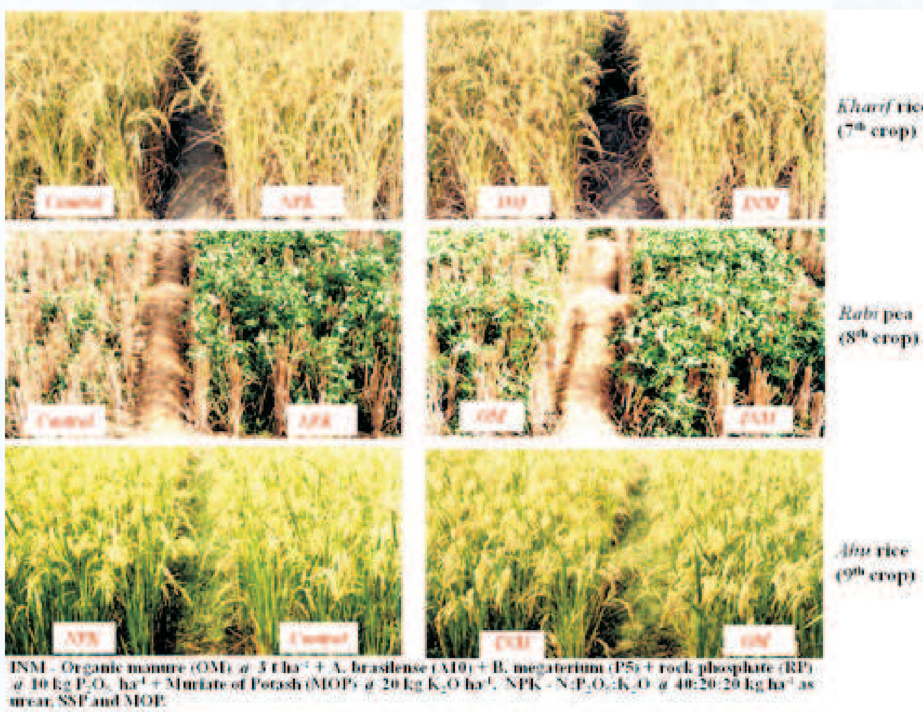


Fig. 2. The comparative benefit of the root-dipping in SSP-MC slurry method over the recommended farmers' practice on growth and yield of *Kharif* rice during 2014.

Conclusion

The ecosystem processes of decomposition and nutrient mineralization/transformation determine the availability of nutrients for plant uptake and in these processes microbes play key roles. Microbes are also important components of soil food web, where intense interactions with other soil organisms are very likely. Therefore, it is imperative to understand the role of soil biota and interactions among them within soil food web on ecosystem processes. The abundance and activities of microbes can greatly be influenced by the feeding activities of microvore fauna and ultimately affecting the nutrient flux. Further the higher-level consumers can have cascading effects on soil food webs that ultimately affect microbes and the processes that they drive. Soil fauna also modify greatly the physical structure of soil, thereby affecting the habitat and activities of other fauna and microbes, and also influencing the physical movement of water and solutes through soil. Such interacting factors cause variations in soil food web diversity. On the other hand, external inputs like inorganic fertilizers, pesticides and herbicides, etc. applied to agro-ecosystems have tremendous influence on the diversity and activities of soil food web. However, such modifying effects of external inputs on soil food web diversity and functions are thought to be highly redundant because of higher degree of redundancy in soil food web diversity. There is emerging evidence, however, that biodiversity effects on soil processes can be predicted by the degree of functional differences among species. Much is still to be learnt about the functional role of soil food web interactions, especially of microbes, and also the relative importance of these biotic forces to abiotic ones as drivers of ecosystem function.

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Impact of inorganic fertilizers on soil biological health

Soil performs ecological services for the survival and nourishment of life in the planet. So, maintaining and upkeeping soil health has paramount importance for sustainability of ecosystem. Soil health is assessed by measuring a wide variety of physical, chemical, and biological properties, processes, or characteristics. Biological properties are more sensitive to changes than chemical and physical ones and could describe soil health innately. Soil microbial biomass C and N, mineralizable C and N, soil extracellular enzymes and soil microorganism are the properties which describe biological soil health. Wide disparities in NPK ratio along with inability of integrated use of all sources of plant nutrients deteriorate soil health and thus nutrition of plants in India. However, farming has become more profitable with higher crop yield through use of those inorganic NPK fertilizers. The effect of long-term application of inorganic fertilizers on soil biological properties is thus of topical importance for upkeeping soil health.

Soil microorganisms are living, active and first response part of soil. Application of fertilizers thus may have a preliminary influence onto the soil biological activities and recycling of nutrients. Moreover, soil contains microorganism which are very versatile in species, quantity, and also vary from soil to soil and season to season. Use of inorganic fertilizers and changes of cropping systems play a significant role on such biological attributes and activities mostly unknown to us.

Microbial, biochemical and metabolic activities of soil have been suggested as early and sensitive indicators of changes in soil health as they manifest themselves over shorter timescales and are central to the ecological function of a soil. Biological indicators are more sensitive to changes than chemical and physical ones and could describe the soil health in a broader picture. Now-a-days attention is on particularly to study soil biological properties as these are early indicators for identification of stress or sudden changes in ecosystem. The measurement of the biological component of soils in the first instance will thus be more suitable to assess soil health. Whenever there is any aberration in the soil system *viz*., heat or cool, freeze or thaw, drought or flood, acidity or salinity, loss of organic matter, contamination by toxic metal-metalloid, inorganic/ organic/exotic biotic pollutant soil organisms are the first to feel the stresses. These organisms confer initial resistance or resilience capacity of soil to overcome those stresses but with limited capacity or potentiality. Use of high dose of chemical fertilizers, restricts the activities of nitrogen fixing and nitrogen transforming microbes, phosphate solubilising organisms *etc*. Nitrogen supplying fertilizers upon hydrolysis also produce ammonium, decrease soil pH and affecting activities of those microbes. However, inorganic fertilizers also facilitate high root biomass and easily decomposable rhizodeposition that support population of fungi, actinomycetes, and *r*- strategists population; oppositely with low biomass, minimal substrate flux of complex and insoluble organic substances facilitates slow growth of the *K*-strategists population of microbes (Cycon´ *et al*., 2013). Considering all these, monitoring of soil biological health may be done using soil microbial biomass C and N, respiration, mineralization rate of C and N and activity of some soil extracellular enzymes activities like dehydrogenase, fluorescein diacetate hydrolysing *etc*., microbial diversity and phospholipid fatty-acid analysis.

Microbial biomass C *and N*

The microbial biomass denotes the living component of soil organic matter but excludes micro-fauna and plant roots. It constitutes a small but active fraction of soil organic matter and is important for changes in soil fertility because of its susceptibility to management practices. Microbial biomass C (C_{mic}) and N (N_{mic}) comprise about 1 to 5% and 1 to 6% of total organic C and total organic N content (w/w) of soils. Soil microbial biomass acts as a reservoir of plant nutrients and is a major determinant for governing the nutrient *viz*., N, P, and S availability in soils. Use of inorganic fertilisers can increase the plant biomass production which in turn increase the amount of residue return to the soil and thus improve biological activity of soils. In addition, several workers reported that soil microbial biomass increased with root growth and rooting density of crop which is typical responses of plants to recommend fertilization rates. The most straightforward index used in the literature for it is the metabolic quotient (qCO_2) [per cent C_{mic}/TOC (total organic C)] for evaluating ecosystem development, disturbance or system maturity. Another important parameter used for assessing soil biological health is the microbial quotient [C_{mic} /SOC (oxidizable organic C)], an indicator of changing soil process under different cropping sequence and management practices. These parameters are more useful measure than either C_{mic} or SOC individually because they are a ratio and avoid the problems of working with absolute values and help in comparing across soils with different organic matter content. The proportion of N_{mic} as per cent of SON (soil organic N) is a measure for the amount of N incorporated in microbial biomass and is subsequently used as an indicator for mineralization potential of organic N and thus, the whole organic matter. Inorganic fertilization (NPK) maintained 52.8 and 21.1% higher microbial biomass C compared to control in rice-wheat and rice-mustard-sesame cropping systems (Table 1). However, the same treatment maintained only 5.0 and 17.4% greater microbial biomass N in the respective cropping systems. For all the cropping systems, the value of microbial quotient was greater in the NPK compared to other treatments without fertilizers.

Table 1. Variation in the magnitude of microbial biomass C and N in soils with different cropping systems and treatments (Basak *et al*., 2016; Basak, 2011)

Soil parameters	Rice-wheat		Rice-mustard-sesame	
	Control	NPK	Control	NPK
Microbial biomass C (µg C g^{-1})	417.3	637.4	395.2	478.5
Microbial quotient (µg C_{mic} g^{-1} TOC ×100)	5.1	6.9	6.1	6.8
Microbial biomass N (µg NH_4N g^{-1})	55.7	58.5	44.2	51.9
% N_{mic} over TON (µg N_{mic} g^{-1} TON × 100)	5.9	6.1	7.3	7.6
Potentially mineralizable N (µg NH_4N g^{-1} in 23 days)	31.6	44.2	42.1	60.1

Mineralizable C and N

Carbon mineralisation is an index of total soil biological activity including soil microorganisms, macro-fauna and plant roots. It reflects the overall activity or energy spent by the indigenous soil microbial pool. This is one of the most important parameter to monitor the microbial mediated processes like decomposition of organic matter in soil. Rate of C mineralisation depends on the substrate availability, moisture and temperature of the soil. The amount of mineralizable C (C_{min}) was greater on 3rd, 6th, 13th and 23rd days of incubation for NPK compared to control treatment (Fig. 1). The microbial mineralization of nitrogen (N_{min}) is a useful biological attribute for monitoring biological health of soil because both the accumulation and mineralization of N in soil are predominantly a biological process. The possible use of soil N mineralization as an index of soil health is relevant because of the relation of this process with the capacity of the soil to supply N for crop growth and also because of the risk of water and atmospheric pollution with the NO_3-N in soils. The soil N-mineralization rate under rice-wheat and rice-mustard-sesame was enhanced due to the addition of NPK fertilization by 39.8 and 42.8%, respectively, compared to treatment without fertilizers (Table 1).

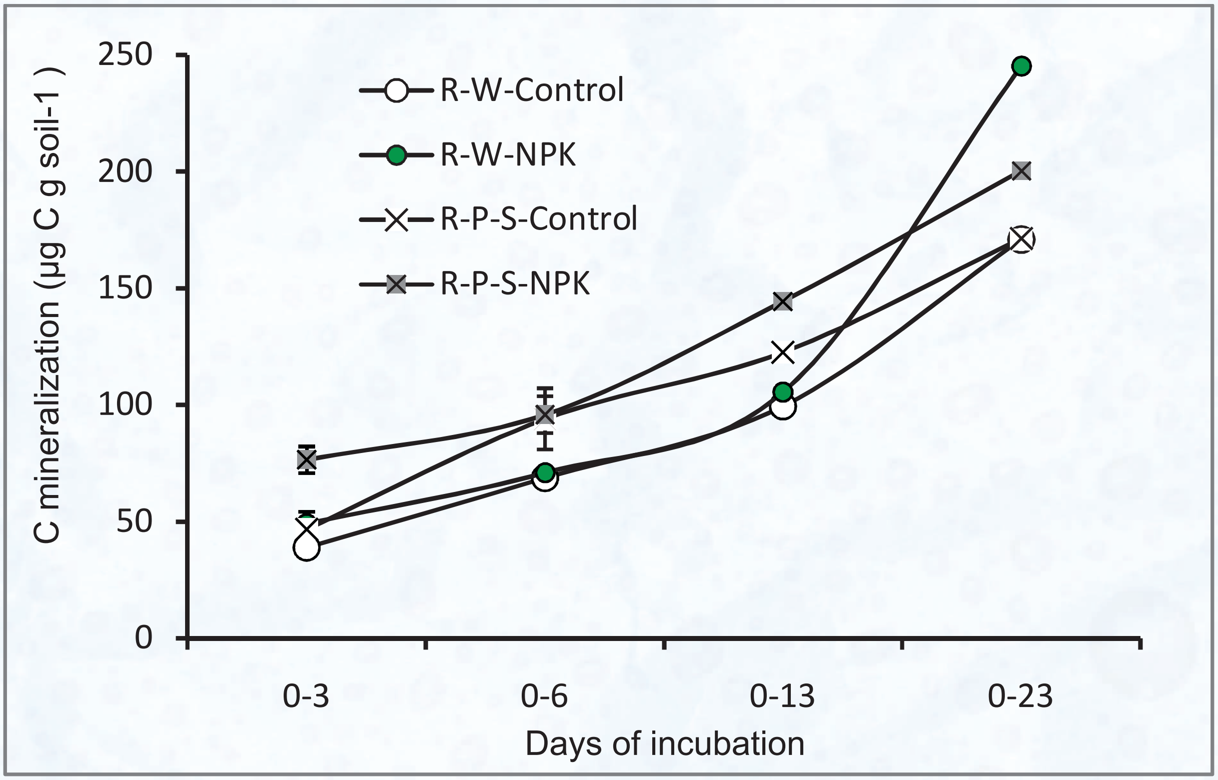

Fig.1. Carbon mineralization (µg C g^{-1}) at different days of incubation with different treatments and cropping systems (R-W and R-P-S = rice-wheat and rice-potato-sesame, respectively) (Basak *et al*., 2016; Basak, 2011)

Soil extracellular enzymes

A high level of enzyme activity is essential for maintaining soil health. Enzyme activities are an important index of the biological activity of a soil because they are involved in the dynamics of soil nutrient cycling and energy transfer. Enzymatic processes are closely associated with soil fertility as they mediate the conversion of unavailable forms of nutrients to forms that are readily assailable by plants and microbes. Enzymes accumulated in soil are free enzymes such as exo-enzymes released from living cells, endo-enzymes released from disintegrated cells and enzymes bound to cell constituents. Of these, dehydrogenase is one of the most important soil biological indicators because it exists only in viable cells and plays an essential role in initial stages of oxidation of soil organic matter by transferring electrons or hydrogen from substrate to acceptors. Hydrolysis of fluorescein esters has also been used to measure microbial activity in environmental samples because it reflects protease, lipase, and esterase activities. Likewise, *β*-glucosidase (conversion of disaccharides into glucose) is also an important enzyme in terrestrial C cycle, which constituted an important energy source for microbial biomass. Acid and alkaline phosphatases catalyze the hydrolysis of P-ester bonds binding P to C (C-O-P ester bonds) in organic matter and release inorganic P from organically bound P (leaf litter, dead root systems and other organic debris) without concomitant release of C. Among the two phosphatases, acid phosphatase is mainly produced by plants and soil microorganisms. On the other hand, aryl sulphatase activity (ArS) is associated with fungal and bacterial hydrolysis of ester sulphate to inorganic SO_4. Cultivation with inorganic fertilizers NPK caused an increase in activities of all the soil enzymes but at different rates (Table 2). Dehydrogenase, acid phosphatase and aryl sulphatase activity were enhanced at higher rate for R-M-S (24.7, 35.1 and 7.6%) compared to R-W (1.3, 17.1 and 6.5%) cropping system. Whereas, fluorescein diacetate hydrolyzing activity, urease, *β*-glucosidase and alkaline phosphatase activities were increased at higher rate in R-W (14.3, 14.2, 11.5 and 9.8%) compared to R-P-S (9.5, 10.5, 3.3 and 2.8%) system.

Table 2. Activities of soil extracellular enzymes under different treatments and cropping systems (Basak *et al*., 2016; Basak, 2011)

Soil parameters	Rice-wheat		Rice-mustard-sesame	
	Control	NPK	Control	NPK
Dehydrogenase (µg TPF g^{-1}soil $24h^{-1}$)	57.9	58.7	64.5	80.4
Fluorescein diacetate (µg fluorescein g^{-1}soil h^{-1})	71.5	81.7	44.4	48.6
Urease (µg NH_4N g^{-1}soil 2 h^{-1})	54.8	62.6	56.8	62.8
β-glucosidase (µg *p*-nitrophenol g^{-1}soil h^{-1})	72.1	80.4	59.8	61.8
Acid phosphatise (µg *p*-nitrophenol g^{-1}soil h^{-1})	133.2	156.0	70.4	95.1
Alkaline phosphatise (µg *p*-nitrophenol g^{-1}soil h^{-1})	252.1	276.9	244.4	251.2
Aryl sulphatase (µg *p*-nitrophenol g^{-1}soil h^{-1})	113.8	121.2	14.4	25.4

Microbial population

Microorganisms are indispensable for key soil functions like decomposition of soil organic matter, degradation of xenobiotics, and formation of soil aggregates. They can also act as a source and sink for plant nutrients. Contradictory results, however, reported on the effect of fertilization on biomass and activity of soil microflora. Such variations were possibly associated with various environmental variables like soil texture and carbon content, plant cover and the period of fertilization. The two major important microorganisms involved in soil biological health are N-fixing and phosphate solubilising bacteria. The size and composition of microorganisms can be useful indicator of soil health. Many soil organisms are beneficial but some others are devastating to crops, humans and animals. Beneficial organisms take part in many physical and chemical reactions that improve soil structure, break down organic matter and recycle nutrients. Soil should thus contain more population of beneficial microorganisms for it to be in good health. On average, population of both the nitrogen fixing bacteria (N-fix) and phosphate solubilizing bacteria (PSB) increased with inorganic fertilization compared to the control (Table 3). However, a greater increment in population of PSB was observed compared to N-fixing bacteria.

Table 3. Variations in microbial population under control and NPK treatment for different cropping system (Basak *et al*., 2016; Basak, 2011)

Soil parameters	Rice-wheat		Rice-mustard-sesame	
	Control	NPK	Control	NPK
Nitrogen fixing bacteria (c.f.u × 10^4 g^{-1} soil)	26.7	34.2	18.7	34.2
Phosphate solubilizing bacteria (c.f.u × 10^5 g^{-1} soil)	46.9	55.1	27.4	42.9

Conclusion

Assessment of soil biological parameters is important for curbing soil degradation. Greater in values of those useful parameters will help to ensure low soil degradation and sustained soil resources. A balanced use of fertilizers in agriculture can improve soil biological properties and enrich the nutritional status of different crops grown as food. Forms of fertilizers *viz*., ammonium or nitrate or SSP or DAP *etc*. may also influence but hardly any efforts were made to evaluate their effects. Similarly, use of STCRC (soil test based fertilizer recommendation for targeted yield) technology for balanced fertilizer management may ensure a better biological health in soils.

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Upcoming events of the Society:

1. Outreach programme on "Soil health management issues" will be organized at Sargachi R K Mission, Murshidabad on Sept 8-9, 2017 in collaboration with Murshidabad KVK, Bhagabangola, Murshidabad. The following persons will act as resource persons for the meet: Dr. H.S. Sen, Prof. B. Mandal, Dr. D.C. Nayak, Dr. F.H. Rahman, Dr. D. Sarkar and 2/3 Professors from BCKV.

2. Workshop on "Judicious utilization of soil, water and fertilizers under changing climate and crop productivity strategies" will be organized at FACC (Lake Hall), BCKV, Kalyani, on Sept 22-23, 2017 in collaboration with Krishi Vigyan Kendras of BCKV. A team of scientists from SFE and BCKV along with relevant resource persons from ICAR Institutes, KVKs and line departments

Editors: H. S. Sen, Biswapati Mandal, Dipankar Ghorai, F. H. Rahman and Dibyandu Sarkar

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