Plant Resource Management

Keynote Speech

A Corrective Measure to Problematic Conventional Agricultural Approach

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Abstract
Some microbes and fauna (particularly insects) act as natural forest structuring (stratifying) and diversifying organisms or forest creating engineers. Removal of plants during the forest conversion to agriculture and subsequent practices such as tillage and the use of chemical inputs in crop cultivation create stress factors for all living organisms, thus reducing biodiversity of functional flora, fauna and microbes. Here, most of the disappeared biodiversity as a response to the stress factors enter into an inactive or dormant phase to bypass the unfavorable conditions, by forming 'seeds', which are stored in soil seed bank. It has been proven that surface-attached microbial communities known as biofilms secrete a wider range of environmentally important compounds than mono or mixed cultures of the same microbes. Some of those compounds break dormancy of the soil seed bank, thus re-establishing the lost biodiversity relatively short term for reinstating ecosystem sustainability. Biofilm based biofertilizers called biofilmed biofertilizers (BFBFs), which also can reinstate ecosystem sustainability, also render numerous biochemical and physiological benefits to plant growth, and improve soil quality, thus leading to a reduction of chemical fertilizer (CF) NPK use by 50% in various crops. This reduction has not been achieved by conventional biofertilizers so far. Thus, the concept of BFBFs is not only biofertilization, but also a holistic ecosystem approach. These formulations should therefore be considered as biofilmed microbial ameliorators (BMAs), rather than the BFBFs. If this agronomic practice could be adopted in the future, it would lead to a more eco-friendly agriculture with an array of benefits to health, economics and the environment.

Keywords: Agriculture, Biofertilizers, Biofilms, Chemical fertilizers, Microbial ameliorators

Creating plant diversity in natural forests

Some microbes and fauna (particularly insects) consume (feeding on) seedlings of the same species growing in high densities on the forest floor during forest succession. Thereby, they think the seedlings of the same species and open up gaps, thus allowing the other species too to emerge in the same manner, leading to remarkable diversity (Bagchi *et al.*, 2014). Thus, the microbes and insects act as forest structuring (stratifying) and diversifying organisms or forest creating engineers, which are extremely important. Their numbers are controlled by other organisms under high biodiversity status, thus not allowing them to become dominant and overgrazing.

Forest conversion to agriculture

Removal of plants during the forest conversion to agriculture and subsequent practices such as tillage and the use of chemical inputs in crop cultivation create stress factors for all living organisms, thus reducing biodiversity of functional flora, fauna and microbes. Here, most of the disappeared biodiversity as a response to the stress factors enter into an inactive or dormant phase to bypass the unfavorable conditions, by forming 'seeds', which are stored in soil seed bank. Then, their contribution to the ecosystem functioning (e.g. SOM and nutrient conservation etc.) in the agro ecosystems is lost. This leads to high fertilizer (e.g. nitrogen) losses, even up to 70% (Seneviratne and Kulasooriya 1994), resulting in huge economical and environmental costs, and also an enormous health cost consequently. Further, the remnant forest structuring and diversifying microbes and insects (the engineers) in the agro ecosystems derived from the forests start feeding on our crops in the absence of their conventional foods found in the forests. Then, we call them pathogens and pests attacking our crops. This is how pathogens and pests originate in the agro ecosystems. Thus, this clearly shows that we are the culprits for creating pathogens and pests in agriculture. Further, the reduced biodiversity in the agro ecosystems causes to reduce photosynthesis and soil carbon accumulation due to removal of flora, and depletion of soil organic matter with reduced fungal diversity and fauna. This leads to retarded nutrient cycling, soil moisture stress, pest and pathogen outbreaks, phytotoxin accumulation and yield decline etc, thus collapsing sustainability of the agro ecosystems.

The way we address the issues

We address above issues by killing pests and pathogens using agrochemicals, and also by further increasing chemical fertilizer use when yield declines etc., which consequently contribute to further depletion of the biodiversity and aggravate the issues. What we should have done, was to reinstate the lost biodiversity for re-establishing ecosystem functioning and sustainability. Thus, in this manner we have gone wrong in the conventional approach of agriculture.

On the other hand, in natural forests with high biodiversity, there are no such issues in pests and pathogens due to delicate balance among organisms in the food-web. This balance is regulated by Edaphic ecosystem signal transduction (EST) among microbes in flora, fauna and in the soil (Seneviratne, 2015).

How to reinstate the lost biodiversity?

In the conventional approach, the lost microbial diversity is replenished by inoculating soil with mono or mixed cultures of microbial biofertilisers, biocontrol agents (e.g. nitrogen fixers, P solubilizers, Bacillus spp., Pseudomonas spp. etc.), organic fertilizers, crop rotation, agroforestry systems etc. These are relatively long term approaches for reinstating the lost biodiversity. As a recent trend, developed biofilms known as Biofilmed biofertilizers (BFBFs) are applied to the soil (Seneviratne *et al.*, 2008). They are surface-attached microbial communities, which secrete a wider range of environmentally important compounds than mono or mixed cultures of the same microbes. Some of the compounds break dormancy of the soil seed bank, thus re-establishing the lost biodiversity relatively short term for reinstating ecosystem sustainability (Seneviratne and Kulasooriya 2013).

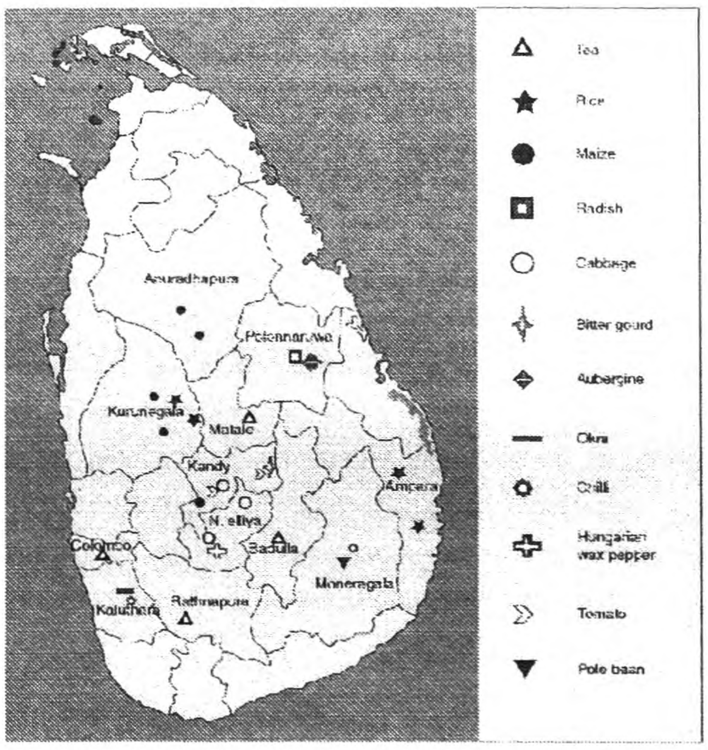

Figure 1: Locations and crops of field experiments conducted with biofilmed biofertlizers (BFBF) in different districts of Sri Lanka

Biofilmed biofertilizers

Different biofilms have been developed by using rhizosphere fungi and nitrogen-fixing bacteria from a wide range of genera, in order to be used as biofertilizers in agriculture and plantations (Jayasinghearachichi & Seneviratne 2004; Seneviratne *et al.*, 2011; Triveni *et al.*, 2013). Application of BFBFs was first tested for

Table 1: Mean crop yields following application of biofilmed biofertilizer (BFBF) combined with 50% of the recommended rate of chemical fertilizer (50% CF) compared with application of the recommended rate of chemical fertilizer (100% CF) in field experiments conducted in different agro ecological regions of Sri Lanka

Crop[a]	Mean ± SE crop yield (kg/ha)		Number of sites
	50% CF + BFBF	100% CF	
Tea	4300 ± 606	4100 ± 678	4
Rice	4420 ± 715	3580 ± 1295	5
Maize	2681 ± 322	2502 ± 338	3
Radish	1192 ± 251	992 ± 188	4
Cabbage	1302 ± 342	980 ± 249	4
Bitter gourd	1547 ± 445	1563 ± 440	4
Aubergine	748 ± 175	678 ± 260	4
Okra	3107 ± 1719	1739 ± 710	3
Chilli	3478 ± 1754	2350 ± 919	3
Hungarian wax pepper	238 ± 50	152 ± 39	3
Tomato	335 ± 86	397 ± 131	3
Pole bean	2762 ± 886	2396 ± 753	3

[a]Rice and maize field experiments were conducted during one or two seasons. Field experiments for vegetables were carried out during two consecutive dry and wet seasons. In the case of tea, the yields are annual averages over 4 years. In the same crop, mean yields of the two treatments were not significantly different at 5% probability level, according to Student's *t*-test.

soybean as a fungal-rhizobial biofilm, with increased N_2 fixation (by ca. 30%), shoot and root growth, nodulation and soil N accumulation over the application of the rhizobium alone (Jayasinghearachichi and Seneviratne 2004). Subsequently, developed biofilms were started to be tested extensively as biofertilizers for non-leguminous crops in several agroclimatic regions of Sri Lanka (Seneviratne *et al.*, 2009). Either soil or seed inoculation, or both at the same time, supplemented with 50% of the recommended CF (i.e. 50% CF + BFBF) was compared with the full dose (100%) of CF as the positive control. The 50% CF + BFBF was used here because it was confirmed from initial studies that 50% CF was the optimum level to be coupled with the BFBFs for maximizing yields in diverse soils (Seneviratne *et al.*, 2009). Generally, application of BFBFs alone is not recommended, since they are fungal-bacterial biofertilizers which may incorporate a considerable fraction of plant-available soil nutrients to the fungal biomass, thus reducing plant growth. So far, the BFBFs have been tested for 12 different crops in agricultural research centers as well as farmers' fields at 25 locations covering 12 districts in the country (Figure 1). Results revealed that crop yields with 50% CF + BFBF were not significantly different ($P > 0.05$) from, and hence comparable to, yields with 100% CF (Table 1). This clearly shows the potential of BFBFs in reducing CF use by 50% with numerous healths, economic and environmental benefits to agriculture and plantations. Widely varying soil and climatic conditions at the different locations tended to produce high variability in the yields of the same crop with the same treatment. It was reported recently that yields of crops treated with BFBFs were limited by low levels of P in the soil (Buddhika and Seneviratne 2014). BFBFs applied to rubber plants in the nursery also illustrated their potential in reducing CF use by 50% (Hettiarachchi *et al.*, 2012). In India, applications of cyanobacteria and plant growth-promoting rhizobacteria (PGPR)-based BFBFs were observed to increase plant growth and yields of mung bean and soybean (Prasanna *et al.*, 2014), and improve micronutrient biofortification in wheat (Rana *et al.*, 2012a, b).

Conclusion

The action of BFBFs differs from that of conventional biofertilizers which influence a limited set of functions such as BNF, mineral solubilization, plant growth hormone production etc. BFBFs show a wider range of more stable biochemical expressions and regulated metabolism for maximal effect, which are important in numerous functions of agro ecosystems. BFBFs reinstate sustainability of degraded agro ecosystems through breaking dormancy in the soil microbial seed bank, and in turn restoring microbial diversity and ecosystem functioning. Thus, the concept of BFBFs is a holistic ecosystem approach. BFBFs show not only enhanced biofertilization traits, but also biocontrol and other health and environment-related features. These formulations should therefore be considered as biofilmed microbial ameliorators (BMAs), rather than the BFBFs. Extensive studies conducted in various agro ecosystems in the country clearly show the potential of the BMAs in reducing CF use by 50% without lowering current yields of numerous agricultural and plantation crops. If this agronomic practice could be adopted in the future, it would lead to a more eco-friendly agriculture with an array of benefits to health, economics and the environment.

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