Biofilm biofertilizers for incorporating biodiversity benefits and reducing environmentally harmful subsidies in agriculture

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BIOFILM BIOFERTILIZERS FOR INCORPORATING BIODIVERSITY BENEFITS AND REDUCING ENVIRONMENTALLY HARMFUL SUBSIDIES IN AGRICULTURE

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Summary

Any natural ecosystem (e.g. a forest) is composed of a food web-based network of interactions of organisms. Nutrients are conserved in the ecosystems by cycling them in producers-consumers-decomposers loops. Thus, food web-based network of interactions of microbes, flora and fauna is the key for the ecosystem sustainability. As long as all the interactions are intact, the ecosystem is equilibrated and sustainable. There are some microbes and insect fauna, which contribute to structure or stratify plants of a forest ecosystem, by consuming seedlings of the same species growing at high densities on the forest floor and thereby thinning them, thus allowing the other species too to emerge in the same manner, leading to remarkable diversity. In forest conversion to conventional agriculture, stress factors like forest clearing, tillage and chemical inputs reduce biodiversity of functional flora, fauna and microbes. Most of the disappeared biodiversity enter into an inactive or dormant phase to bypass the stress factors, by forming 'seeds', which are stored in soil seed bank. Then, the natural food web collapses in agroecosystems. In the absence of other plants in conventional croplands, those forest structuring and diversifying remnant microbes and insects start feeding on our crops. This is how pathogens and pests originate in agroecosystems. Eventually, all the above anthropogenic activities lead to collapse the sustainability of the agroecosystems. To address this, beneficial biofilms have been formulated to be used in agriculture as biofertilizers called biofilm biofertilizers (BFBFs). The BFBFs render numerous biochemical and physiological benefits to plant growth, and improve soil quality, thus leading to a reduction of environmentally harmful, subsidized chemical fertilizer (CF) NPK use by 50% in various crops. The role of BFBFs is to reinstate sustainability of degraded agroecosystems through breaking dormancy of the soil microbial seed bank, and in turn restoring microbial diversity and ecosystem functioning. As such, this contributes to a more eco-friendly agriculture with an array

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INTRODUCTION

Nutrients are conserved in natural, undisturbed ecosystems, leading to sustainability, particular due to their cycling in the producers-consumers – decomposers loops of the food web. Functional microbes, flora and fauna in ecosystems interact synergistically (positively) or antagonistically (negatively). As long as all the interactions are intact, the ecosystem equilibrated and sustainable. Microbes and insects play an extremely important role in forest structuring and diversifying. In forest conversion to conventional agriculture, stress factors like forest clearing, tillage and chemical inputs reduce biodiversity of functional flora, fauna and microbes. Further, the reduced biodiversity imposed by the stress factors in agroecosystems leads to reduced photosynthesis and carbon accumulation due to removal of flora, and depletion of soil organic matter due to reduced fungal diversity and fauna. This leads to retarded nutrient cycling, soil moisture stress, pest and pathogen outbreaks, yield decline etc., thus collapsing sustainability of the agroecosystems. In conventional agriculture, we address above issues by killing pests and pathogens, by increasing chemical fertilizer use with yield decline etc., which contribute to further depletion of biodiversity. Therefore, we have to look for alternative methods which reinstate the degraded ecosystems.

Use of microbial ameliorators is a promising alternative as microbial communities have a great impact on biosynthesis and biodegradation in the nature. Considerable attention has been focused recently on microbial biofilms and their potential on bioremediation in contaminated environments, because they result in more effective bioremediation than conventional methods. With this understanding, we developed biofilm biofertilisers (BFBFs) for reinstating biodiversity of degraded agroecosystems. Their major role after field application is to increase soil biodiversity through breaking dormancy of the soil seed bank that was developed under the stress conditions. This increase of the biodiversity leads to improve ecosystem functioning, which in turn reinstates sustainability of degraded agroecosystems.

METHODOLOGY

Developed biofilms were tested for non – leguminous crops in several agroclimatic regions of Sri Lanka. Twelve different crops have been tested in agricultural research centres as well as farmers' fields at 25 locations covering 12 districts in the country. Either soil or seed inoculation, or both at the same time, supplemented with 50% of the recommended chemical fertilizer (CF) (i.e. 50% CF + BFBF) was compared with the full dose (100%) of CF as the positive control. There were three replicates for each treatment. 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, trials were conducted over 4 years. Yield data were recorded at the time of harvesting. Finally data were analyzed by ANOVA and mean were separated by Student's t- test.

RESULTS AND DISCUSSION

Results explained 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% which contributes to address the environmental issues caused by high CF usage. To our knowledge, conventional biofertilizers have not been able to achieve this CF reduction so far. Application of BFBFs was first tested for 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). The increased N supply in the rhizosphere with the BFBF application was reflected by increased soil NH_4^+ availability (Buddhika et al., 2012). The BFBF application also reduced NO_3^- availability (Seneviratne et al., 2011), thus increasing N use efficiency, and reducing adverse effects of N on health and the environment.

Not only that, application of BFBFs was reported to restore agroecosystems that were depleted due to agronomic practices (e.g. tea cultivation; Seneviratne et al., 2011). This was evident from increased soil microbial biomass carbon (MBC), organic carbon, moisture retention and hence drought tolerance, and root-associated nitrogenase activity in the study. Biofilms have a wider array of biochemical expressions of exudates compared with the monoculture counterparts of the biofilm which support the fertilizing potential (Bandara et al., 2006; Herath et al., 2013). Further, the emergence of diverse microbes with BFBF application is caused by breaking dormancy of dormant microbial forms in the soil seed bank as a response to this biochemicals secreted by the biofilms (Seneviratne and Kulasooriya, 2013). The increased microbial diversity is considered to be one of the most important indicators of soil quality (Bastidia et al., 2008; Sharma et al., 2011), and is also an important determinant of soil health for increased productive capacity (Fernandes et al., 1997).

CONCLUSION

Extensive studies conducted in various agroecosystems in the country clearly show the potential of the BFBFs in reducing CF use by 50% without lowering current yields of numerous agricultural and plantation crops. It is expected that BFBFs would increase demand for biofertilizers in the future, because they replenish the largely depleted microbiome in conventional agriculture, leading to sustainability of the agroecosystems. They also help to reduce considerably, environmentally harmful subsidies like costly chemical fertilizers, contributing to a cost effective agricultural production.

Table 1. Mean crop yields following application of biofilm 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 agroecological regions of Sri Lanka.

Crop	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

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