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COVID 19: Impact, Mitigation, Opportunities and Building Resilience

From Adversity to Serendipity

Perspectives of global relevance based on research, experience and successes in combating COVID-19 in Sri Lanka

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Post Covid-19 agriculture: The way forward

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ABSTRACT

The corona pandemic has had disastrous effects on global as well as local economies. Every country had to review and organize plans to recover from its ill effects on their economies. Currently the number one priority for Sri Lanka is the allocation of additional funds to contain and control the pandemic and provide relief to the people. Food production and food security are vital sectors that also need attention to prevent hunger and social unrest.

This paper will briefly cover the research and development efforts of the National Institute of Fundamental Studies (NIFS) that have produced two groups of low cost, eco-friendly biofertilizers which could significantly minimize the application of imported chemical fertilizers in agriculture without any reduction in crop yields. Widespread use of such fertilizers could make agriculture less dependent on imported fertilizers and make food production in Sri Lanka more self reliant and self sufficient. Unlike soluble chemical fertilizers which pollute the environment and contribute significantly to increase in environmental diseases, biofertilizers enhance organic matter development, improve beneficial soil microbial activity and make agriculture less polluting and more sustainable. Less soil and water pollution will decrease the incidence of kidney diseases, cancer and other environmentally related illnesses which are prevalent particularly among the farming communities of Sri Lanka, the backbone of agriculture. If biofertilizer use can be popularized, the Covid pandemic could be considered as a blessing in disguise which caused a revolutionary turning point in crop production in Sri Lanka to a truly benign activity.

Key words: Biofertilizers, Covid impact, Eco-friendly agriculture, Pollution reduction, Self reliant agriculture

1. INTRODUCTION

The Covid-19 pandemic has had a devastating impact on the global economy estimated to be in the region of 3.5 trillion US dollars. All countries big and small had to postpone their regular activities and divert their attention to meet the enormous challenges to control the virus and contain the rapid spread of the pandemic and minimize the death and devastation it was causing among their populations. Besides strengthening health services and providing immediate relief to the affected people, strengthening food production and establishing food security received high priority in Sri Lanka. Foremost among the government decisions was the reduction of all foreign imports in order to save foreign exchange and overcome the immediate necessity of minimizing the country's debt burden. A major imported component for agriculture in Sri Lanka is chemical fertilizers and any alternative that could reduce their application is an enormous relief to its economy. The conventional alternatives available are organic fertilizers such as composts, green

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manure, animal dung, crop residues etc. All these dead substrates provide nutrients to plants from their biomasses after further microbial decomposition into assimilable forms. Therefore they are required in large quantities to replace the nutrients provided by chemical fertilizers. Organic materials also take time to become available and are not quite suitable for short term crops like cereals, pulses and most vegetables. The best alternatives appear to be biofertilizers which are living entities that establish intimate associations with targeted host plants and continue to provide nutrients from external substrates. For example nitrogen fixing microorganisms like rhizobia form symbiotic root nodules with leguminous plants and fix nitrogen from air which is an external substrate. Similarly increased microbial biomass triggered by biofilm biofertilizers get intimately associated with the root systems and enhances nutrient use efficiency by the targeted host plants from inorganic and/or organic substrates. Because of these unique features, biofertilizers are not needed to be added in large quantities and they are suitable for short term crops. This paper will review the development of biofertilizers by the NIFS. The principal hypothesis was to examine to what extent these microbial fertilizers could replace the use of chemical fertilizers in agriculture. Even if a part reduction is achievable, it would be of immense economic and ecological benefit to the country and its people.

2. METHODOLOGY

One of the foremost areas of study undertaken by the NIFS was Biological Nitrogen Fixation (BNF) which is a key to sustainable crop production. Initial basic studies in this project were to isolate, characterize and identify (as far as possible) different nitrogen fixing microorganisms intimately associated with major crop plants of Sri Lanka, namely rice, maize, pulse legumes and short term vegetables.

2.1. Development of Rhizobial biofertilizer

Isolation and characterization of rhizobia from root nodules of healthy, commonly cultivated legume crops of Sri Lanka essentially followed the procedures described by Somasegeran and Hoben (1991). Isolations commence with streaking inoculants of suspensions obtained either from surface sterilized, split (large nodules) or crushed root nodules (small nodules) on differential, selective media such as Congo Red Yeast Mannitol Agar (CRYMA). Growth on this medium enables the identification of contaminants which absorb the red dye as different from relatively less coloured gummy colonies of potential rhizobia. Purification of rhizobia from these mixed colonies was done by successive sub-culturing on the same medium until pure, white, gummy colonies of rhizobia were obtained. Such purified colonies were then transferred to standard Yeast Mannitol Agar. An isolated culture is subjected to characterization of colony morphology, cell morphology after Gram staining, and culturing on Bromo thymol blue Yeast Mannitol Agar (BRYMA) medium to see whether it is fast growing and acid producing or non-acid producing and slow growing. These isolates are further characterized for their ability to utilize different sources of carbon substrates and examined on their tolerance to temperature, pH and salinity. Finally the characterized rhizobial isolates are authenticated against their original host plants by testing whether they can nodulate the host under laboratory conditions. A few of the commonly field applied strains as biofertilizer inoculants have also been subjected to molecular analysis and identified based upon their 16S RNA sequences. In this manner a germplasm of rhizobial isolates from different food and forage legumes cultivated in Sri Lanka was built up.

2.2. Development of inoculants

The first step to prepare a rhizobial inoculant for a particular host plant is to screen a few of the characterized and authenticated isolates in pot experiments under greenhouse conditions for effective nodulation and efficient plant growth. The best strain is then cultured in 100 ml of Yeast Mannitol Broth (YMB) in 250 ml conical flasks under continuous, mild, rotary shaking. These cultures are used to inoculate 6 to 8 L of YMB with mild aeration as a semi-mass culture in a 10 L aspirator bottle. Strict sterile conditions are maintained to ensure that the culture remains uncontaminated (Figure 1). Once a sufficient cell density (10^8 – 10^{10} cells/ml) was obtained, 15 ml aliquots were removed under aseptic conditions, diluted 10 times to 150 ml and injected into 250 g of pre-prepared powdered coir dust enclosed in 200 µ gauge polypropylene bags and sterilized by autoclaving at 120°C and 1 kg/cm^2 pressure for 20 minutes. The inoculated bags were incubated at 28°C for 7 days to mature and covered in (250 µ gauge) black polythene covers and labelled with instructions for use. Finally the inoculant packet is enclosed in an attractive cover depicting the relevant crop legume and marketed (Figure 2 a & b).

(a)

(b)

Figure 2. (a) Inoculant packet preparation and (b) Marketed packet for vegetable bean

2.3. Field testing and field application

Prior to the release of an inoculant it is field tested preferably in more than one location where the crop is widely cultivated. It had been our practice to conduct field tests as much as possible in farmer's fields for two reasons. These fields mimic the actual conditions of the small holder farmers more closely than those in research stations which are well maintained. Moreover if the tests give positive results acceptance of the technology by the farmers is that much easier. The usual plot size adopted for field testing was 2m x 4m and the treatments were (i) Control with no inoculation and N-fertilizer addition (ii) Test plot with inoculation and without N-fertilizer addition and (ii) Standard plot with the recommended level of N-fertilizer applied without inoculation. These treatments were replicated three times and wherever possible arranged on a randomized complete block design. Depending on the site this design was sometimes changed. Two well designed field trials with replicates were conducted to obtain N-fertilizer yield response curves for soybean and vegetable bean. The effects of the corresponding rhizobial inoculants were read off from these curves. While the trial with soybean was conducted in 2008 in collaboration with Plenty Foods PLC in one of its outsource farmer's fields, the trial with vegetable beans was conducted in a farmer's field in Ankumbura (near Kandy) in 2018 with the facilitation of the Provincial Department of Agriculture, Central Province.

Figure 1. A sterile semi-mass culture of a selected purified Rhizobial strain

2.4. Large scale field applications and technology transfer

These activities were carried out in collaboration with the Department of Agriculture, Provincial Departments of Agriculture, Plenty Foods (Private) Limited and the Mahaweli Development Authority which facilitated the participation of farmers. Occasionally interested farmer groups often led by local Buddhist priests joined us to test this technology. It was an arduous task to wean the farmers away from the practice of applying chemical fertilizers to which they have been accustomed to, for six decades. Some of them did not believe that crop cultivation is possible without urea. Obtaining high yields with our inoculants in the trials conducted in farmers' own fields were helpful, but several farmers were hesitant to accept this novel technology. Field demonstrations of how to apply the inoculants (Figure 3a) and planting the treated seeds were conducted in several locations of crop cultivation (Figure 3b).

The different sites and locations where field studies were done with crop legumes are shown in Figure 4.

2.5. Inoculation of the forage legume clover (Trifoleum repens L.)

Application of rhizobial inoculant technology to the highly nutritive forage legume clover was not difficult because it was done in a well managed, organized livestock farm run by Ambewela Farms (Private) Limited. The results of field testing followed by large scale field trials were reported in Kulasooriya et al (2017). The results were so convincing that the management has stopped urea application to clover cultivations since 2017, minimizing N-pollution of this highland water catchment area located next to Horton Plains.

2.6. Studies with Biofilm Biofertilizers (BFBF)

The development of BFBF includes the isolation of fungi and bacteria from the rhizosphere of the targeted crop plant, screening for efficacy and pathogenicity,

Figure 3. Demonstrations of (a) seed inoculation and (b) inoculated seed planting

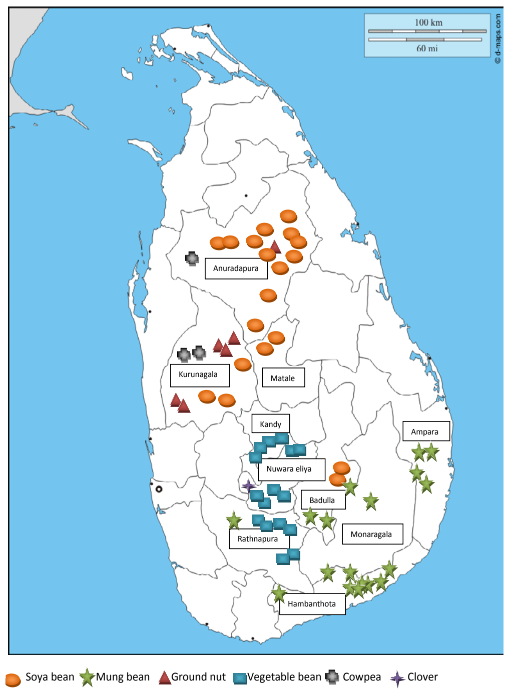


Figure 4. Sites where rhizobial inoculant trials were conducted

formulating biofilms and testing with the crop in greenhouse and field conditions. Small scale field testing as well as large scale field trials cwith Biofilm-Biofertilizers (BFBF) have been conducted in several locations covering all the agro-ecological regions of Sri Lanka. Commencing with tea (in collaboration with the Tea Research Institute), these experiments covered non-leguminous crops such as rice, maize, potato, carrot, leafy vegetables and even fruits like strawberry. A major brakthrough for BFBF came when large scale field trials conducted in collaboration with the Department of Agriculture (DoA) in several rice growing areas (Figure 5) gave really encouraging results.

Large scale (1 acre plot) rice field trials were conducted during Maha 2019/2020 and Yala 2020 seasons by the NIFS in collaboration with the DoA at 14 locations in 5 districts (Figure 5). The treatments included 90 kg NPK/ac only; 90 kg NPK/ac + BFBF (1 L/ac); 136 kg NPK/ac (DoA recommendation).

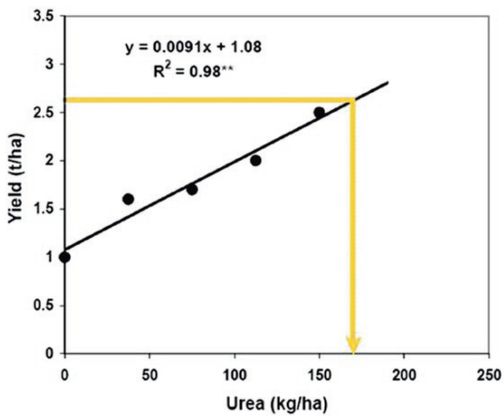
Figure 5. Districts where large scale BFBF field trials with rice were conducted

3. RESULTS

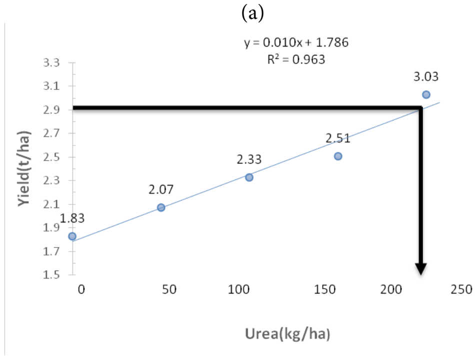
The isolated and characterized rhizobial culture collection at the NIFS today contains 204 rhizobial strains as stock cultures. The most commonly applied 5 strains used as field inoculants were subjected to molecular analysis and identified based upon their 16S RNA sequences.

The N-fertilizer response curves obtained for soybean and vegetable bean are given in (Figure 6 a & b). It is clear from both these curves that the yields obtained by the application of the inoculants were equivalent to those given under the highest level of recommended urea additions.

Reading from these curves it is seen that the yields obtained by inoculation coincide with the highest level of urea fertilizer application.



(a)



(b)

Figure 6. Yield response curves for urea applications to (a) soybean (*Glycine max* L) and (b) vegetable bean (*Phaseolus vulgaris* L)

All the field experiments conducted in farmers' fields with diiferent crop legumes where inoculation was compared with N-fertilizer additions, gave similar results (Figure 7 a, b, c, & d)

These results clearly show that the yields obtained by applying rhizobial inoculants were either equal or marginally above those obtained with the recommended levels of urea fertilizer.

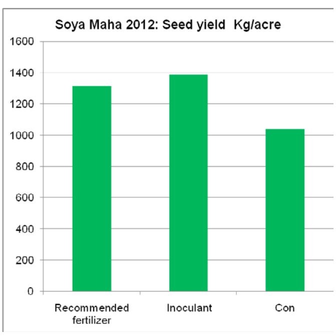
The nitrogen fixed by the endo-symbiotic rhizobia is supplied directly to the targeted host legume through its root nodules, whereas urea broadcast on to a field is freely available to all plants including weeds. Therefore a reduction in weed growth could be expected under inoculation. In a field trial conducted with vegetable beans weed biomasses under inoculation and urea application were recorded. The results showed a 70% reduction in weed growth under inoculation compared to N-fertilizer addition.

In all the experiments with BFBFs the results convincingly showed that they can replace all three major fertilizer additions of N, P & K by at least 50% without any reduction and sometimes with increases in yields. The Tea Research Institute even approved a recommendation for the application of BFBFs to nursery tea plants. With all other crops tested, similar results were observed.

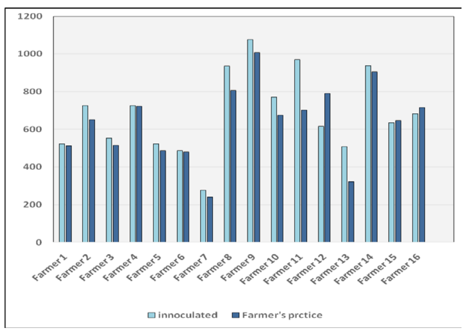
In 70% of the locations, grain yields of rice under BFBF treatments were significantly higher (by ca. 20%) than that of the 90 kg NPK/ac only and DoA treatments ($P < 0.05$). About 15,000 ac were cultivated with BFBF in Kurunegala & Ampara districts in Yala 2020. We have planned to increase the paddy land extent of the annual BFBF application to 150,000 ac this year.

4. DISCUSSION

It is evident from all these results that rhizobial inoculation has the potential to completely replace the application of urea to soybean, green gram, vegetable bean and groundnut without any reduction in yields. Presently these inoculants are marketed to farmers at very reasonable prices. For example, a 250 g packet of inoculants sufficient for seed



(a)



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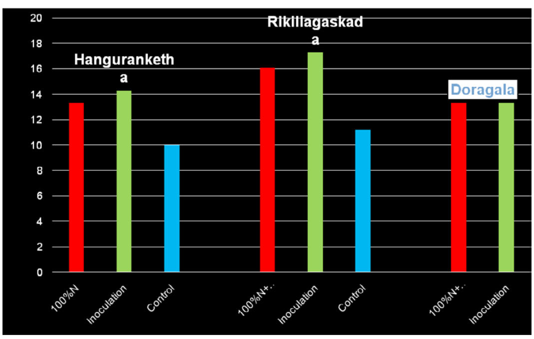
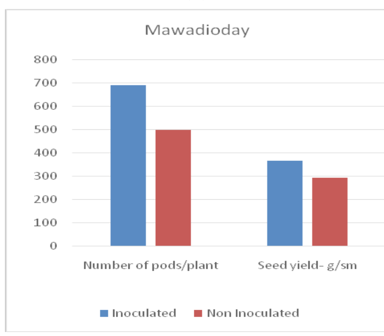


(c)



(d)

Figure 7. Yields obtained by rhizobial inoculation on (a) soybean (*Glycine max* L), (b) mung bean (*Vigna radiata* L), (c) vegetable bean (*Phaseolus vulgaris* L) and (d) groundnut (*Arachis hypogea* L) in comparison to urea application.

dressing and cultivation of one acre of soybean, green gram or groundnut is priced at only Rs.400/-. The equivalent of urea will cost the farmer more than Rs.1500/-. For vegetable beans a 100 g packet that can inoculate 1 kg of bean seeds is priced at Rs. 120/-. The recommended urea application for a hectare of bean cultivation is 220 kg.

Moreover rhizobial inoculants are applied as seed dressings as grams per hectare while urea has to be added in kilograms (150 kg/ha for soybean, 220 kg/ha for vegetable bean). Therefore farmers have to incur additional costs to transport, store and apply chemical fertilizers. These differences in weights become specially critical to vegetable bean farmers of the central mountain regions where this crop is widely cultivated in undulating terrains (Figure 8).

Since weed growth is much less under inoculation in comparison to urea application, farmers can also save on the cost of weedicide applications. All this goes to show that inoculation technology could significantly reduce the cost of production of legume crops.

All these legumes are highly nutritious pulse crops commonly consumed by the people of Sri Lanka, sometimes referred to as the 'poor man's protein diet'. Unfortunately Sri Lanka does not produce enough of these commodities and it is reported that we import 70% of our soybean and 40% of our green gram requirments. Even the Budget speech of 2020 mentioned that we are unable to produce the required amount of '*Thriposha*' (a highly nutritive preparation given to lactating mothers and infants) due to the shortage of soybean and maize. One of the remedies that can be implemented is to expand the cultivation areas of legume crops in Sri Lanka and offer attractive prices to the farmers for their produce. With rhizobial inoculantion the cost of production can be reduced significantly and if such a strategy is followed with enthusiasm the country could be self sufficient in these commodities within a short period. As these inoculants are locally produced this is self reliant self sufficiency.

Figure 8. Terrace cultivation of beans in Central mountains

If BFBF could be adopted in rice across the country we could save over Rs. 6 billion per annum in foreign exchange for the country and replace over 100,000 tonnes of Chemical Fertilizer being imported annually.The overall benefit of the BFBF use, including the saving on human health and the environment would be over a hundred billion rupees.

ConclusionAs such, it is proposed to take steps to promote the application of biofertilizers and bring about a revolution in agriculture from a costly, environmentally detrimental activity to a low cost, eco-friendly, sustainable system that could improve the health of the nation particularly of our farming communities which provide the invaluable service of food production.

5. ACKNOWLEDGEMENT

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