Compendium of Good Practices In Agriculture To Curb Agricultural Water Pollution

South Asia Environmental Capacity Building – Agricultural and Water Pollution Project

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in Agriculture to Curb Agricultural Water Pollution

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List of Acronyms

BCAs	Biological control agents
CKDu	Chronic Kidney Disease of Unknown etiology
DOA	Department of Agriculture
GAP	Good Agricultural Practice
IPM	Integrated Pest Management
NARC	National Agricultural Research Council
NCP	North Central Province
NRMC	Natural Resources Management Centre
PRA	Participatory rural appraisal
PGPR	Plant-growth-promoting rhizobacteria
SQCC	Seed Quality Control Centre
SSI	Sustainable Sugarcane Initiative

A view of agroforestry in Panchkhal valley, Nepal. Photo: LI-BIRD, Nepal

Executive Summary

This compendium includes important good agricultural practices tried and tested under the South Asia Environmental Capacity Building – Agricultural and Water Pollution Project (SAECB-AWP), October 2017-December 2020, implemented in Bangladesh, India, Nepal and Sri Lanka. The SAECB-AWP project is funded by the United States Department of State, Bureau of South and Central Asian Affairs (SCA). It is led by Caritas Switzerland in collaboration with country partners namely Arthacharya Foundation (Sri Lanka), Caritas Bangladesh (Bangladesh), DHAN Foundation (India), and LI-BIRD (Nepal). Key good agricultural practices are highlighted by country as follows:

BANGLADESH

Caritas Bangladesh (Bangladesh) has promoted biopesticides to help improve the yield and crop quality. Use of biopesticides can replace toxic chemical pesticides. Biopesticides allow the natural enemies of pest insects to play their complementary role in control strategies. Bio pesticides are not stand-alone products but work best as part of Integrated Pest Management (IPM). Evidence suggests that biopesticides can help increase crop production and produce toxic-free crop while reducing the costs of production.

Tricho-Compost: Commercialization of *Trichoderma* biofertilizer has raised hope among farmers. *Trichoderma* can be used in almost all type of crops. Using *Trichoderma* biofertilizer as an amendment with compost may give better results than any other fertilizer. It minimizes the use of traditional NPK fertilizer while improving the uptake of micronutrients such as Cu, Zn, Fe, Na etc. by plants. *Trichoderma* improves overall plant health, by creating a positive environment with symbiotic relationship with plants and releases various types of secondary metabolites including, growth hormones, endochitinase, proteolytic enzymes and benefits the plants through plant-microbe interactions.

INDIA

DHAN Foundation (India) has assisted farmers to adopt in situ sugarcane trash composting to maintain soil health and minimize pollution. Decline in sugarcane productivity has been witnessed in traditionally sugarcane grown regions for several reasons. Among the various reasons, burning trashes and less crop residue amendment to soil are key to soil health deterioration in sugarcane farming. Enriching soil health and minimizing soil and air pollution through in situ trash composting has been an effective approach to enriching soil fertility. Farmer's participatory research was conducted in 10 farmer's holdings with an area of 0.40 hectare each between 2013 to 2015 with an objective of improving soil fertility and cane productivity in Villupuram district, Tamil Nadu. The result revealed that shredding the trashes + TNAU bio-mineralizer @ 2 litres per ton of trash + Disc off bearer (T5) has significantly influenced soil organic carbon, available nitrogen, phosphorus and potassium. Shredding trashes coupled with TNAU bio-mineralizer @ 2 litres per ton of trash and disc off bearer exhibited a positive influence on soil, plant and environmental conservation.

Biochar is an ideal soil conditioner to sustain pulses productivity in rainfed ecosystem. Biochar application is one of the viable eco-friendly approaches to combat climate change and improve the soil health with sustainable crop production. Biochar is an anaerobic pyrolysis product derived from organic waste materials, resistant to further degradation and stored carbon in long-term in the terrestrial ecosystem. In order to understand the mechanism and harvest the benefits of biochar, DHAN Foundation conducted field experiments using acacia biochar with required NPK (Nitrogen, Phosphorous and Potassium) fertilizers and other crop management practices. Application of acacia biochar 5t ha-1 increased the available soil moisture 3.1 and 3.4 per cent at 15 and 30 cm soil depth than control. Acacia biochar application showed positive trend in organic carbon content build-up (1.0 g kg-1) N, P, K availability in soil and utility by crops over the control. Reduction of leaching loss of nutrient increases nutrient utility and hinders the eutrophication of water resources. Integrated application of biochar and phospho bacteria 2 kg ha-1 positively influenced the growth and yield attributes of black gram and boost the yield to the tune of 29 per cent over NPK alone applied plot under water deficit environment.

NEPAL

Cultivation of Disease-and Insect-Pest-Resistant Crop Varieties: In Nepal, LI-BIRD promoted disease-and insect-pest-resistant crop variety of potato as a good agricultural practice for reducing agricultural water pollution. A large-scale cultivation of disease-and insect-pest-resistant crop varieties can significantly reduce the application of agrochemicals, thereby reducing land-based water pollution. For farmers, use of such varieties is the easiest and most cost-effective means to reduce application of agrochemicals in targeted crops while ensuring sustained yields. While a few disease-and pest-resistant crop varieties have been developed and are cultivated in Nepal, such varieties are not available for a myriad of crops that farmers grow. This good practice should be used in conjunction with judicious application of agrochemicals to control disease and pest outbreaks. In the future, crop improvement research must focus on developing more disease-and pest-resistant varieties across crop species.

Use of *Trichoderma* as a biological tool for crop disease management: *Trichoderma* spp. is one of the most commonly-used biocontrol agents for management of plant diseases. *Trichoderma* are soil-inhabiting fungi that can multiply rapidly. In Nepal, commercial use of *T. harzianum* and *T. viride* is most common, although other species are utilized as well. Because *Trichoderma* cannot fully control pathogens on their own, their use should be integrated with other measures, including chemical fungicides. *Trichoderma* can be applied for seed treatment, seedling treatment, foliar applications, soil applications, or as bio-fertilizer. They help establish an antagonistic microbial community in the rhizosphere that suppresses pathogens, promotes plant growth, increases nutrient availability and uptake, and enhances host resistance. While they can establish themselves in various environments, they are more effective under protected farming conditions (greenhouses) than under open field conditions, and are more effective against soil-borne pathogens than others.

SRI LANKA

Arthacharya Foundation has focused on providing surface water for drinking and avoiding indiscriminate use of agrochemicals in Sri Lanka. Several studies have indicated a causative role of agrochemicals in Chronic Kidney Disease (CKDu) in Sri Lanka. Findings suggest that agrochemicals especially phosphate fertilizers are a major source of inorganic arsenic in CKDu. The communities that source drinking water from shallow wells in close proximity to irrigation systems developed for agriculture with demonstrable seepage from irrigation system to the wells are more affected by CKDu compared to the communities without irrigation seepage into wells. In contrast, communities living in geographically close proximity to irrigation systems who obtain drinking water from wells sourced by natural springs appear to be less affected by CKDu. Fertilizer run-off from upstream agricultural activities in the hill country and consequent changes in the ionicity causing a Hofmeister-type protein denaturing nephropathy has been postulated to be linked with CKDu. Therefore, it is suggested that providing safe drinking water seems to be one solution for the problem with the development of surface water resources available in the area. Farmers have been encouraged to minimize the use of imported chemical fertilizer and use organic fertilizers in order to avoid further environmental damage and human health hazards.

Influence of GAP and Integrated Pest Management (IPM) on irrigated agriculture to mitigate water pollution: Excessive use of agrochemicals pollutes water resources and causes serious problems to the environment. Due to the existing water conveyance system from upcountry to reservoirs in North Central Province (NCP) through diversion of the river Mahaweli, it was also revealed that Cadmium, derived from contaminated phosphate fertilizer dissolved in irrigation water finds its way into reservoirs in the river and finally to the food, causing chronic renal failure among consumers. In the view of this problem, the Department of Agriculture (DOA) implemented several programs in collaboration with farming community in the affected areas to overcome the existing problems of pests and diseases. However, it has been observed that IPM also needs constant follow up and guidance to sufficiently train the farmers.

It has also been identified that the use of resistant varieties is the safest, cheapest, easiest and effective pest and disease management measure. Research activities are being conducted in farmers' fields for the introduction of crop rotation and conservation farming methodologies to eliminate the pest problems.

Introduction

This compendium provides a detailed understanding of good agricultural practices promoted in Bangladesh, India, Nepal and Sri Lanka in order to reduce water pollution from harmful agricultural practices. These practices were promoted as part of the South Asia Environmental Capacity Building-Agricultural and Water Pollution (SAECB-AWP) Project led by Caritas Switzerland in collaboration with country partners namely Arthacharya Foundation (Sri Lanka), Caritas Bangladesh (Bangladesh), DHAN Foundation (India), and LI-BIRD (Nepal).

Water pollution from agriculture has increasingly become a key issue in South Asia. Agricultural activities, mainly an excessive use of agro-chemicals, is a leading contributor to water pollution among the land-based sources. Through agricultural intensification, South Asian countries are determined to enhance agricultural production to promote economic growth, and ensure livelihoods and food security, paying little attention to water pollution caused by agricultural activities. It has posed threats to water quality at a regional scale. Because of increasing water pollution along with growing population and effects of climate change, the once abundant water resources of South Asia are getting scarce. Hence, water insecurity is rife in the region.

Among the three-major global water consuming sectors – agriculture (irrigation, livestock watering, aquaculture), municipalities (domestic, municipal) and industry – the agriculture sector consumes the most[1]. Agriculture in South Asia withdraws 91% of water-well over the global average and much higher compared to other sectors. Further, agriculture deteriorates water quality through various pollutants, namely nutrients such as nitrate, ammonia or phosphate; pesticides; salts; sediments; organic matter; pathogens; metals; drug residue; hormones and feed additives. Contributing to water-borne diseases, poisoning fish and birds, eutrophication, and loss of biodiversity, water pollution is not only reducing the quantity of safe water but also posing significant threats to human health and ecosystems This also produces serious negative impacts on livelihoods, the environment, ecosystem, health and well-being. This problem has been recognized in the 2030 Agenda for Sustainable Development, which includes a specific target for improving water quality in Sustainable Development Goal 6.

In this background, the SAECB-AWP project was designed to address agricultural water pollution through exploring good agricultural practices and intra-country and regional cooperation. The project was implemented in the four South Asian countries Bangladesh, India, Nepal and Sri Lanka from October 2017-September 2020. The principal objectives of the project were as follows:

- Take stock of national policies and strategies on agriculture, livestock and other land-based sources of water pollution
- Strengthen country and regional capacity to address challenges pertaining to land-based water pollution and its consequences on ecosystem, biodiversity, human health and livelihoods
- Pilot, test and exchange high-impact water pollution mitigation technologies and practices, and improve agricultural productivity and human health through action research
- Establish a regional level multi-stakeholder and multi-disciplinary mechanism to promote regional connectivity for reducing land-based pollution.

[1] FAO and IWMI 2018. More people, more food, worse water? A global review of water pollution from agriculture. Rome: Food and Agriculture Organization of the United Nations (FAO).

BANGLADESH

Promoting Biopesticides

Md. Zahurul Islam (PhD Fellow), Germplasm Officer, Horticulture Centre, Chapai Nawabgonj, Bangladesh

Md. Bozlur Rahman in process of preparing neem solution as bio-pesticide. Photo: Caritas Bangladesh

ABSTRACT

Biopesticides provide natural protection for crops. They help to improve the yield and crop quality. Use of biopesticides can replace toxic chemical pesticides. Biopesticides allow the natural enemies of pest insects to play their complementary role in control strategies. It is not environmental friendly to apply chemical insecticides and pesticides to control insects and pests in paddy, potato, and wheat fields. Bio pesticides are not stand-alone products but work best as part of Integrated Pest Management (IPM). Biopesticides can help increase crop production and produce toxic-free crop while reducing the costs of production.

HIGHLIGHTS

» Increase crop production

» No adverse effects on the environment and human health

» Reduce costs of production

» Toxic free crop production

Keywords: Pest, Disease, Pesticides, Agrochemicals, Organic Pesticide

Md. Anamul Islam applying neem leaf solution in his rice plot. Photo: Caritas Bangladesh

CONTEXT

Agricultural crops in Bangladesh are adversely affected by various pests and diseases. Farmers are using chemical pesticides to control pests and diseases. But these agrochemicals have caused negative effects on human health and the environment. Use of bio fertilizers and bio pesticides can play a vital role to reduce the use of hazardous pesticides.

METHODOLOGY

As the first step, participatory rural appraisal (PRA) workshops were conducted to understand, among others, the local challenges of farmers. In addition, screenings of key innovations and best practices were undertaken. In Bangladesh, the PRAs took place in 2017 in 10 villages of Paba sub-district under Rajshahi district. Excessive use of chemical pesticides was raised by farmers as a serious problem. During screening exercises for best practices and key innovations, bio pesticides were regarded as a suitable practice to be introduced through the SAECB-AWP project.

Technical practice description

Neem (*Azadirachta indica*) Leaf Solution

Neem Leaves solution have been used to control a wide range of pest and diseases in paddy.

Ingredients

1. 1 Earthen pot
2. 1 Kilogram Neem (*Azadirachta indica*) Leaves
3. 40 gram detergent power
4. 5 Litre fresh water

Group of farmers showing variety of bio-pesticides. Photo: Caritas Bangladesh

Preparation

1 kg Neem Leaves, 40 gram detergent powder mixed in 5 litre of water and boiled for 15-20 minutes. Then the extracts need to be cooling for spray on plants. Solutions need to be dissolved in 10-15 litres of fresh water again.

Spraying dose

10 litre/0.02 ha Neem solution, applied 4 times

1st spraying: 15 DAT

2nd spraying: 25 DAT

3rd spraying: 40 DAT

4th spraying: 50 DAT

Twigs of neem plants are kept over the stored rice to control rice weevil.

Neem Leaves solution have been also used to control white fly and aphid of potato

Ingredients

1. 1 Earthen pot
2. 1 Kilogram Neem Leaves
3. 40 gram detergent power
4. 5 Litre fresh water

Preparation

1 kg Neem (*Azadirachta indica*) Leaves, 40 gram detergent powder mixed in 5 litre of water and boiled for 15-20 minutes. Then the extracts need to be cooling for spray on plants. Solutions need to be dissolved in 10-15 litres of fresh water again.

Md. Soroadi at his rice field between research and control plot. Photo: Caritas Bangladesh

Dry Neem (*Azadirachta indica*) Leaf Dust

Dry Neem Leaf Dust used to control stored grain pest (wheat weevil).

Preparation

Neem leaves dry in the sun and then dust it for use. Usually the farmers of Bangladesh stored wheat in bags or container. They can use Neem leaf dust to control wheat weevil in stored period.

DEMONSTRATED IMPACT

Chemical insecticides and pesticides is not a sustainable way to control insects and pests in paddy, potato, and wheat fields. But bio pesticides are a sustainable way to control pest and diseases. Bio pesticides are not stand-alone products but work best as part of IPM. Not only this it increased crop production, decrease cost of production and finally the farmers get toxic free crop.

The effectiveness of practice management options to different organic and inorganic fertilizer was undertaken during June 2019 to December 2019 in the Hozuri Para Union under Paba Sub dristict Rajshahi in 10 villages in 41 plots in three treatments where Control=only chemical fertilizer T1=Organic pesticides,T2=half chemical +light trap, T3=halfchemical+perching were used under South Asia Environmental Capacity Building- Agriculture & Water Pollution project implemented by Caritas Bangladesh.

Results showed that an integrated use of organic fertilizers along with biopesticide significantly influenced the yield and yield contributing characters of BRRI dhan49. Grain yield ranged from 3.22t/ha to 3.82t/ha wherethe highest grain yield (3.82 t/ha) was observed in the treatment T1 where organic pestcides were applied and the lowest grain yield (3.22t/ha) was observed in the treatment control where only chemical fertilizer was applied which is significantly lower than all other treatments. In most cases, plant height, fresh weight/plant, Chlorophyll content, No. of non-effective tiller / hill, No. of grain/ Panicle, No. of effective tiller, panicle length, grain yield, straw yield were better performance when half chemical fertilizer with light trap and organic pesticides were applied. In the traditional faming system by using increased amount of fertilizer were lower than those two treatments. Biopesticide practice in the field is easily replicable. Many farmers already practicing this and securing disease-free crop and it is used

Group of farmers preparing bio-pesticides solution to spray in their paddy field. Photo: Caritas Bangladesh

effectively at the household level for better yield. Few non-government organizations are producing bio-pesticide for the farmers. In some cases farmers also can produce the bio-pesticide if they trained.

REPLICABILITY

Biopesticide practice is easily replicable. Many farmers are already practicing this and securing disease-free crop. Few non-government organizations are producing bio-pesticide for the farmers. In some cases farmers also can produce the bio-pesticide if they trained. Many farmers are producing *Neem Leaf Solution and Dry Neem Leaf Dust* enhanced composting technology using Neem (*Azadirachta indica*) leaf and household waste. It makes a great contribution towards development of safe environment and nutrient enriched fertilizer, a good element for improving soil health. It is very important to look at the performance of such bio-pesticides on soil health and farmer's livelihoods. There are very few research has been found regarding the livelihood improvement through bio-pesticide application in soil. So it is very important to determine the extent of livelihood improvement.

SUSTAINABILITY

Bio-pesticide is a very cost effective and environment friendly alternative to chemical pesticides. The government has encouraged to use bio-pesticides. Bio-pesticides help to ensure the sustainability of quality soil and water for the future generation. Consumers are interested to buy pesticides free foods. The demand for the pesticide free food has increased. Few non-government organizations are producing bio-pesticide for farmers. In some cases farmers can also produce bio-pesticide if they are provided a training. Many farmers are producing *Neem Leaf Solution and Dry Neem Leaf Dust* with enhanced composting technology using Neem (*Azadirachta indica*) leaf and household waste. Such practices contribute to improving soil and the development of safe environment.

Tricho-Compost

Dr. Md. Giush Uddin Ahmed, Department of Agronomy & Agricultural Extension, University of Rajshahi, Bangladesh

Md. Rathin Islam is preparing *Trichoderma* solution to spray in his paddy field. Photo: Caritas Bangladesh

ABSTRACT

Trichoderma naturally present in most soils. Commercialization of *Trichoderma* biofertilizer raises hope in farmers. *Trichoderma* is used in almost all type of crops. If *Trichoderma* biofertilizer is used as an amendment with compost may give better results than any other fertilizer. It minimizes the use of traditional NPK fertilizer. It improves the uptake of micronutrients to plants such as Cu, Zn, Fe, Na etc. and helps in solubilization of phosphate in soil and available to plants. *Trichoderma* improves overall plant health, by creating a positive environment with symbiotic relationship with plants and releases various types of secondary metabolites including, growth hormones, endochitinase, proteolytic enzymes and benefits the plants by taking advantage of plant-microbe interactions. The biofertilizer is also used as a soil conditioner, which increases the population of beneficial microorganisms in soil. It helps in mitigating greenhouse gases like Carbon dioxide and methane.

Keywords: *Trichoderma*, Compost, Biofertilizer, Biocontrol Agent, Fungi

Mr. Niren Sarkers used to spray chemical pesticides to protect his paddy. Photo: Caritas Bangladesh

CONTEXT

The organic matter (OM) status of soil in Bangladesh is one of the lowest in the world. The average OM content of Bangladesh soils is less than 1%, ranging between 0.05 and 0.9% in most cases affecting the government endeavors to ensure national food security. The ratio of organic matters in soil has decreased to even 0.6% in some places over the past 5-6 decades. Low organic matter supply in soil is one of the major constraints in agricultural productivity. The organic matter in the soil can be increased by application of organic fertilizer which contain living cell of different microorganisms. It has also been observed that the application of organic fertilizers increases yield and reduce environmental pollution. In such a context, there is an urgent need for motivating farmers to use organic fertilizer more to improve soil fertility so that they will be able to harvest benefit of accelerated production in the long run.

THE GOOD PRACTICE

Trico-compost preparation

The pit size should be 45 inch in length, 45 inch in width and 20 inch depth which is filled with six different substratums. Each of the substratums is well mixed with cowdung and first 06 inches layer of the pit is filled and sprayed with *Trichoderma* suspension followed by two other layers prepared the same way. The remaining 2 inches is filled with the substrates and the pit is covered with polythene sheet and left for a week. After a week, the whole material is mixed well in order to make a uniform decomposition and water is added if the substratum found dry and kept covered with polythene sheet. After 5 weeks, the compost becomes ready for field application.

Trichoderma as biofertilizer on growth and yield of wheat

Use of *Trichoderma* resulted in a slight increase in the plant height, panicle weight, number of grains, grain yield, biological yield, and biomass yield over control; while root length, number of leaves, tiller number, panicle number, panicle length highlight the negative impact of *Trichoderma* on the wheat plant. *Trichoderma* shows antagonism with inorganic fertilizer. In most of the parameters, the more the inorganic fertilizer with *Trichoderma*, the higher the level of antagonism. When *Trichoderma* and NPK are accompanied with farmyard manure, most of the growth and yield parameters shows the highest value, but the yield was slightly higher than NPK treatment alone. This finding indicates that while sowing seed, the use of *Trichoderma* with FYM and NPK may not improve the yield over NPK to a greater extent. Hence it is indicated that *Trichoderma* viride can be a growth promoter and can be used as a biofertilizer.

Trichoderma as biofertilizer for ammonia volatilization of alkaline soil

Compared to conventional fertilization, nitrogen loss through NH3 volatilization reduced by *T. viride* biofertilizer in alkaline soil planted with sweet sorghum. The biofertilizer treatment exhibits lower NH3 loss than conventional fertilizer (CK) and Sweet potato starch wastewater (SPSW) treatments. This is because: (a) *T. viride* biofertilizer decreased the soil pH during the peak period of ammonia volatilization, and soil pH was significantly lower in this treatment than in other treatments; (b) *T. viride* biofertilizer promoted the absorption of fertilizer nitrogen in sweet sorghum, and increased the utilization rate of fertilizer; (c) *T. viride* biofertilizer enhanced the nitrification by increasing the abundance of functional genes of AOA and AOB rather than changing the functional bacterial community consumption. In addition, the high-throughput sequencing analysis showed that the microbial community structure and composition were altered due to the application of *T. viride* biofertilizer, and bacterial diversity also increased as a consequence of biofertilizer application. In sum, *T. viride* biofertilizer increased fertilizer N-use efficiency, resulting in both environmental and agronomic benefits.

Tricho-compost for chili production

Tricho-compost has high nutrient values which can be used effectively as fertilizer or soil amended and this fertilizer also can reduce the application of organic fertilizer. Moreover, integrated application of fertilizer or combination of Tricho-compost and NPK showed better performance and gave the highest yield. So, Tricho-compost can play a vital role in reducing the use of chemical fertilizer or increasing of soil fertility, and this integrated approach can contribute to improve crop production as well.

Trichoderma-enriched biofertilizer enhances production and nutritional quality of tomato

Trichoderma-enriched biofertilizer played a significant role in both yield and quality improvement of tomato. Combined application of biofertilizer and chemical fertilizer (especially 50 % BioF 50 % N:P:K) enhanced vegetative and reproductive growth, yield and nutritional quality of tomato by slow and steady release of nutrients to the plants than the sole application of N:P:K fertilizer. The present findings, i.e., *Trichoderma*-enriched biofertilizer application could save at least 50 % N:P:K, i.e., urea, TSP, MOP can reduce cultivation cost of tomato while minimizing pollution by excessive use of N fertilizer.

Md. Anamul Islam holding bundle of rice in his paddy field. Photo: Caritas Bangladesh

Trichoderma-enriched biofertilizer for mustard (Brassica campestris) production

Seed yield per plant was increased by 5.34% when mustard plants were fertilized with 50% NPK along with 50% BioF/compost over the recommended dose of NPK fertilizer application. In contrast, only 7.3 and 6.62% decreased seed yields per plant were observed when mustard plants fertilized with BioF/compost and 75% BioF/compost along with 25% NPK fertilizer over the recommended dose of NPK fertilizer, respectively. Thus, there is a scope of using *Trichoderma*-enrich biofertilizer for higher yield, reduced cultivation cost and environmental pollution.

Trichoderma as a biopesticide in modern agriculture

Trichoderma-based biofungicides are booming in an agricultural market with more than 50 formulations registered products worldwide. Nowadays, there are more than 50 different *Trichoderma*-based agricultural products being produced in different countries and are sold to farmers to get better yields in different crops. Presently, *Trichoderma* spp. based products are considered as relatively novel type of biocontrol agents (BCAs). The size of current biopesticide market is vague and only scattered information could be obtained based on registered as well as non-registered biofungicides. Recently, *Trichoderma*-based BCAs share about 60% of all fungal based BCAs and an increasing number of *Trichoderma* spp. based BCAs products are registered regularly. *T. harzianum* as an active agent in a range of commercially available biofertilizers and biopesticides is being used recently. The inherent qualities of *Trichoderma* based BCAs are driving factors for their steadily cumulating success. There are numerous reports on the ability of *Trichoderma* spp. to antagonize a wide range of soil borne plant pathogens combined with their ability to reduce the incidence of diseases caused by these pathogens in a wide range of crops. The mechanisms that *Trichoderma* uses to antagonize phytopathogenic fungi include competition, colonization, antibiosis and direct mycoparasitism. This antagonistic potential serves as the basis for effective biological control

Md. Salim Reza is proud of his paddy yield. Photo: Caritas Bangladesh

applications of different *Trichoderma* strains as an alternative method to chemicals for the control of a wide spectrum of plant pathogens.

Bioremediation technology

Investigations on bioremediation of environmental toxicants are entering in a new era with the application of genetic engineering. However, the majority of the studies related to bioremediation have been conducted under the laboratory conditions. The concept of utilizing fungi for bioremediation of soil contaminated with certain pollutants is relatively older. There is evidence of various *Trichoderma* spp. contributing to polycyclic aromatic hydrocarbons (PAHs) degradation, even as affecting native mycorrhizal fungi both positively and/or, negatively. Degradation potential of rhizosphere-competent *Trichoderma* strains against several synthetic dyes, pentachlorophenol, endosulfan and dichlorodiphenyl trichloroethane (DDT) were demonstrated previously. Hydrolyses, peroxidase, lactases and other lytic enzymes produced by *Trichoderma* spp. are probable factors aiding in degradation of these contaminants. Therefore, application of some detoxifying agents along with *Trichoderma* spp. would provide healthy soil and environment. It may help to improve not only the health of soil and plant, but also a sustained crop yield protection. *Trichoderma* spp. inoculated in the soil can grow rapidly because of naturally resistant ability to many toxic compounds, such as fungicides, herbicides, insecticides and phenolic compounds.

Trichoderma strains may play an important role in the bioremediation of soil contaminated with pesticides and possess the ability to degrade a wide range of insecticides: organochlorines, organophosphates and carbonates. ABC transporter protein systems in *Trichoderma* strains may be involved in resistance mechanisms against tested noxious compounds.

Biocontrol agent

Several strains of *Trichoderma* have been developed as biocontrol agents against fungal diseases of plants. The various mechanisms include antibiosis, parasitism, inducing host-plant resistance, and competition. Most biocontrol agents are from the species *T. asperellum*, *T. harzianum*, *T. viride* and T.

hamatum. The biocontrol agent generally grows in its natural habitat on the root surface, and so affects root disease in particular, but can also be effective against foliar diseases.

Causal agent of disease

T. aggressivum (formerly *T. harzianum* biotype 4) is the causal agent of green mold, a disease of cultivated button mushrooms. *Trichoderma* viride is the causal agent of green mold rot of onion. A strain of *Trichoderma* viride is a known cause of dieback of Pinus nigra seedlings.

Toxic house mold

The common house mold, *Trichoderma* longibrachiatum, produces small toxic peptides containing amino acids not found in common proteins, like alpha-aminoisobutyric acid, called trilongins (up to 10% w/w). Their toxicity is due to absorption into cells and production of nano-channels that obstruct vital ion channels that ferry potassium and sodium ions across the cell membrane. This affects in the cells action potential profile, as seen in cardiomyocytes, pneumocytes and neurons leading to conduction defects. Trilongins are highly resistant to heat and antimicrobials making primary prevention the only management option.

Medical uses

Cyclosporine A (CsA), a calcineurin inhibitor produced by the fungi *Trichoderma* polysporum, Tolypocladium inflatum and Cylindrocarpon lucidum, is an immunosuppressant prescribed in organ transplants to prevent rejection.

Industrial use

Trichoderma, being a saprophyte adapted to thrive in diverse situations, produces a wide array of enzymes. By selecting strains that produce a particular kind of enzyme, and culturing these in suspension, industrial quantities of enzyme can be produced. *Trichoderma* reesei is used to produce cellulase and hemicellulose. *Trichoderma* longibrachiatum is used to produce xylanase. *Trichoderma* harzianum is used to produce chitinase.

DEMONSTRATED IMPACT

The effectiveness of practice management options to Tricho-Compost and inorganic fertilizer was undertaken during June 2019 to December 2019 in Hozuri Para Union under Paba Sub dristict Rajshahi in 10 villages in 41 plots in three treatments where Control = only chemical fertilizer T1=half chemical +Farm Yard Manure,T2=half chemical +Tricho-compost, T3=half chemical+ foliar spray were used under South Asia Environmental Capacity Building-Agriculture & Water Pollution project implemented by the Caritas Bangladesh. Grain yield ranged from 4.96t/ha to 5.39t/ha where the highest Grain yield (5.39 ton/ha) was observed in the treatment T2 where half chemical fertilizer with Tricho-compost were applied, and the lowest Grain yield (4.96) was observed in the control where only chemical fertilizer was applied. From the results it is noticed that the integrated use of manure (Tricho-compost) and inorganic fertilizer (half dozes) significantly influenced the yield and yield contributing characters of T. Aman rice. The higher values of growth parameters and yields contributing characters were also recorded in the treatments where half-dozes inorganic fertilizer plus trico-compost were used. Tricho-Compost practice in the field is easily replicable. Many farmers are already practicing this and securing disease-free crop and it is used effectively at the household level for better yield. Few non-government organizations are producing Tricho-Compost enhanced composting technology using cowdung and household waste.

The need for increasing agricultural productivity and quality has led to an excessive use of chemical fertilizers, creating serious environmental pollution. The use of biofertilizers and biopesticides is an alternative for sustaining agricultural production with low ecological impacts. Different soil-borne bacteria and fungi are able to colonize plant roots and may generate beneficial effects on the plant. Besides the classic mycorrhizal fungi and Rhizobium bacteria, other plant-growth-promoting rhizobacteria (PGPR) and fungi such as *Trichoderma* spp. And Piriformospora indica can stimulate plant growth by suppressing plant diseases. These micro-organisms can form endophytic associations and interact with other microbesin the rhizosphere, promoting protection from diseases, plant growth and yield.

REPLICABILITY

Many farmers are already practising this and securing disease-free crop for better yields. Few non-government organizations are producing *Trichoderma* enhanced composting technology using cow dung and household waste. It makes a great contribution towards development of safe environment and nutrient enriched fertilizer, a good element for improving soil health. It is very important to look at the performance of such compost on soil health and farmer's livelihoods. Few research has been found regarding the livelihood improvement through *Trichoderma* application in soil. So it is very important to determine the extent of livelihood improvement.

SUSTAINABILITY

This provides an excellent guide to the importance of *Trichoderma* as biological control agents (BCAs) in sustainable agriculture through reducing plant diseases and increasing production. *Trichoderma* can combine several advantages in one product – the control of different plant diseases, enhancement of plant growth, and the provision of a clean environment for the benefit of sustainable agriculture.

INDIA

In situ Sugarcane Trash Composting to maintain Soil Health and Minimize Pollution

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Farmers harvesting sugarcane, Tamil Nadu, India. Photo: The DHAN Foundation, India

ABSTRACT

Of late, decline in sugarcane productivity has been witnessed in traditionally sugarcane grown regions for several reasons. Among the various reasons, burning trashes and less crop residue amendment to soil are key to soil health deterioration in sugarcane farming. Enriching soil health and minimizing soil and air pollution through in situ trash composting is an effective approach to enriching soil fertility. Farmer's participatory research was conducted in 10 farmer's holdings with an area of 0.40 hectare each between 2013 to 2015 with an objective of improving soil fertility and cane productivity as part of NABARD funded Sustainable Sugarcane Initiative (SSI), operated at Villupuram district, Tamil Nadu. Field experiments were conducted at Vikravandi, Koliyanur and Kanai blocks of the Villupuram district. The imposed treatments were trash burning (T1), removal of trashes from the harvested field (T2), retaining the trashes in the field itself without treatment (T3), shredding the trashes +TNAU bio-mineralizer @ 2 litres per ton of trash (T4), shredding the trashes + TNAU bio-mineralizer @ 2 litres per ton of trash + Disc off bearer (T5) in a randomized block design with an area of 800 m2 as an individual plot size. This experiment was conducted in 10 farm holdings which were treated as 10 replications. The result revealed that shredding the trashes + TNAU bio-mineralizer @ 2 litres per ton of trash + Disc off bearer (T5) has significantly influenced soil organic carbon, available nitrogen, phosphorus and potassium.

Keywords: Sugarcane, Burning, Trash-composting, Soil-health, Mulching, Yield

CONTEXT

Sugarcane is an important commercial and ancient crop. It serves the second largest agro-based industry in India - sugar. As per one of the study conducted in 2014 by the World Bank, the expected sugarcane production loss will be around 30% in the future due to climatic change and soil fertility losses. Generally, sugarcane crop is facing a declining trend of productivity due to multifarious reason, of which soil fertility loss due to trash burning and climate change are key factors, which are greatly influencing the yield reduction in sugarcane.

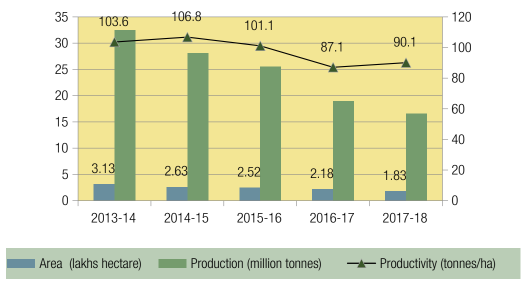


Fig 1. Facts about sugarcane cultivation in Tamil Nadu (> 5 yrs)

Productivity decline was about from 103.6 t/ha in 2013-14 to 90.1 t/ha in 2017-18 in Tamil Nadu, and 13 % decrease over 5 years' period. Ultimately area under sugarcane cultivation has also being shrunk due to reduced profit from sugarcane farming.

Sugarcane trash burning is practiced immediately after the harvest of the main crop in the same land, leading to loss of soil fertility and beneficial microorganisms due to excess soil heating (600-10000 c) in addition to environmental pollution (soil and air pollution).

Sugarcane trash burning, immediately after the harvest of the sugarcane crop, is releasing green house gas emission: 60 kg CO, 1460 kg of CO_2, 199 kg of ash and 2 kg of SO_2 in the air from 1 tonne of straw as per the study report by Centre for Sustainable Agriculture, Hyderabad (Source: Dhanuskodi V et al, Jounal of Krishi Vigyan, 2018)

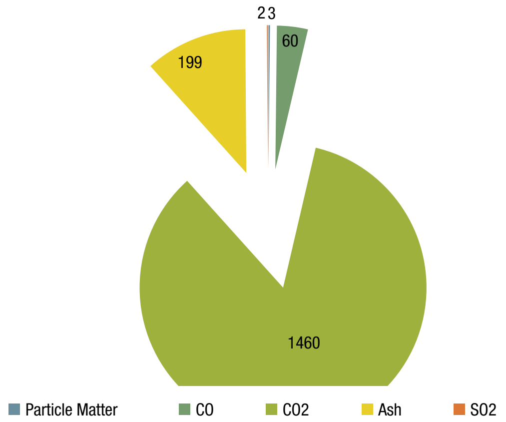


Fig 2. Trash burning leads green house gas emission (kg/ton)

The Punjab Agricultural University has conducted a study on loss of nutrients from burning of sugarcane trashes during 2010, found that 6-7 kg of N, 1-1.17 kg of P ,14-26 kg of K and 1.2-1.5 kg of S. This leads to an additional expenditure to replenish the soil with chemical fertilizers and as faces productivity decline.

Table 1. Nutrient content in raw and burnt trash sugarcane

Sample	Total N %	Total P205 %	Total K20 %	Quantity (t/ha)
Raw trash	0.53	0.09	0.42	10-12
Trash Ash	Traces	0.11	0.56	0.75-1.0

(Source: Centre for Sustainable Agriculture, Hyderabad)

Trash ash samples showed more total phosphorous and potassium compared to raw trash, but the quantity of ash produced after burning is quite low compared to raw trash, which ultimately results in low input.

THE GOOD PRACTICE

This practice ensures addition of biological material on the soil and enhance soil organic carbon, soil fertilizer and water holding capacity. Sugarcane is a dominant crop in the Villupuram district (1.0 lakhs

Good harvest of sugarcane in Tamil Nadu, India. Photo: The DHAN Foundation, India

hectare) with a large number of sugar factories (8). Trash burning is common in the district because it is cheaper than manual removal of trash. The availability of machineries (Trash shredder) and TNAU bio-mineralizer has created an opportunity for in-situ trash composting. In-situ trash composting and bio-mulching are viable alternatives to mitigate the above issue and also conserving soil health for sustainable farming.

Soil health is vital for enhancing Cane Productivity through in situ trash composting cum mulching. Sugarcane trashes - 8-12 ton per hectare – are being burnt simply without knowing its multiple merits, on improving soil physical, chemical and biological properties. Rather in situ mulching of Sugarcane trash helps to enhance the soil fertility and reduces the environmental pollution.

In order to enrich soil health and minimize soil and air pollution, in situ trash composting was mooted. Action research with farmers was conducted in 10 farm holdings with an area of 0.40 hectare each from 2013 to 2015 with an objective of improving soil fertility and cane productivity in a sustainable approach way as part of National Bank for Agriculture, Research and Development (NABARD) funded Sustainable Sugarcane Initiative (SSI) project operated at Villupuram district, Tamil Nadu. Field experiments were conducted at farmer's holding in Vikravandi, Koliyanur and Kanai blocks of Villupuram district. The imposed treatments were trash burning (T1), removal of trashes from the harvested field (T2), Retaining the trashes in the field itself without treatment (T3), Shredding the trashes +TNAU bio-mineralizer @ 2 litres /t of trash (T4), Shredding the trash + TNAU bio-mineralizer @ 2 litres /t of trash + Disc off bearer (T5) in a randomized block design with an area of 800 m2 as an individual plot size. This experiment was conducted in 10 farmers holding which were treated with 10 replications.

Addition of bio mineralizer along with soil moisture hastens decomposition within 60 days, and it produces beneficial effects on soil and plant. Shredded trashes helps to conserve soil moisture by reducing evaporation and also smothering the weeds at early stage, which supports growth and development of the crop. The early shoot borer incidence in sugarcane is greater menace at early stage of the crop.

DEMONSTRATED IMPACT

The result revealed that shredding the trash + TNAU bio-mineralizer @ 2 litres per ton of trash + Disc off bearer has influenced soil organic carbon, available nitrogen, phosphorus and potassium. Organic carbon content increases by 0.09% over trash burn treatment.

Soil Nitrogen (N) increased by 6.8%, soil phosphorus increased by 5.7% and potash increased by 8.7% due to trash mulching. Of the five treatments from T1 to T5 as mentioned in the graphs below. The treatment T5 resulted to 132.6 tones sugarcane yield per hectare during 2013-14 and 158.4 tonnes sugarcane yield per hectare during 2014-25. Trashes addition along with bio mineralizer triggers decomposition and aid the release of organic compounds and nutrients to meet the crop requirement.

Trash Burning

Trash Shredder

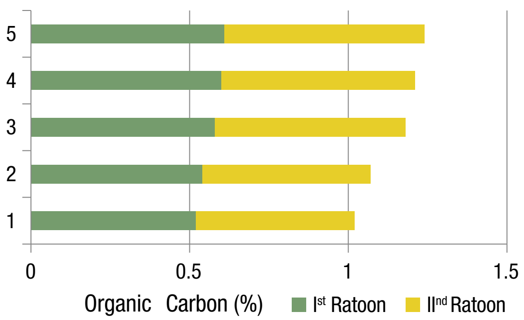
Sprouting

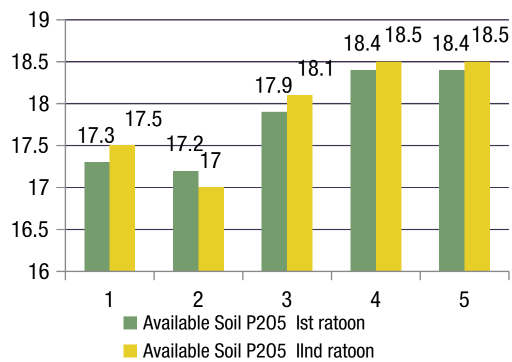
Disc Off Bearer

Awareness Creation

Trash Shredded

After decomposition (45-60days)





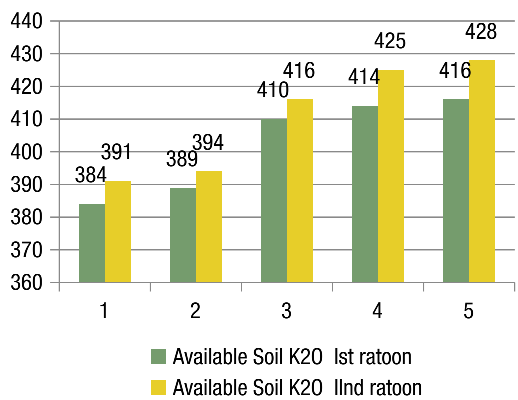
T2: Trash burning

T2: Removal trashes from the harvested field

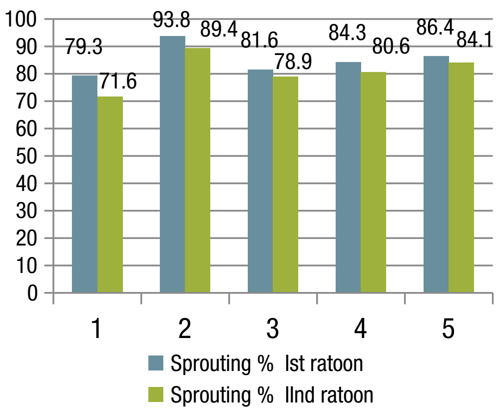
T3: Retaining the trashes in he field itself

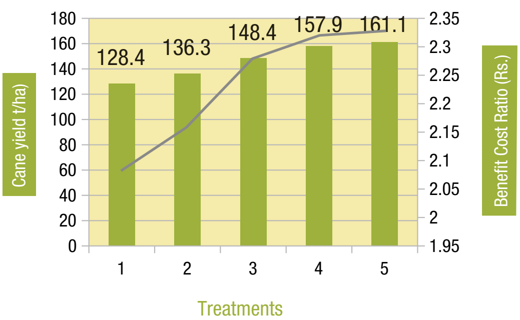
T4: Shredding the trashes + TNAU bio-mineralizer @ 2 litres/t of trash

T5: Shredding the trashes + TNAU bio-mineralizer @ 2 litres/t of trashes + Disc off bearer



10 Tonnes of sugarcane trashes contributes Kgs.of NPK





Sprouting increased to 7 % than trash burning which in turn ensures maximum number of millable cane and cane yield. In-situ addition of trashes with mineralizer enhances the microbial consortia in the rhizosphere and facilitate nutrient mobility and uptake. Higher return of Rs.2.3 per rupee invested was accrued from shredding the trashes and adding bio mineralizer with higher cane productivity. Wetting of trash and retention favors crop growth rate and devilment of yield attributes in sugarcane.

REPLICABILITY

Effective recycling by in situ trash composting helps to buildup soil microbial load and organic acids exudation during mineralization and paves ways for maintaining soil chemical properties such as pH, EC and CEC. It adds major nutrients and micronutrients to the soil. Besides, it also helps to act as bio-mulch, thereby facilitating soil moisture retention by minimizing evaporation and curbing the weeds emergence at initial stage of plant growth. Given these benefits, the demonstration of shredding trashes + TNAU bio-mineralizer @ 2 litres /t of trash + Disc off bearer in large scale was conducted among over 100 farmers' holdings at Villupuram district, which was also publicized through mass media for horizontal expansion of the technology among the sugarcane farmers. This practice helps to maintain soil fertility and add huge biological value while recycling the crop residue in situ.

SUSTAINABILITY

For enhancing wider adoption, it is important for the government to ensure the availability of shredder on subsidy for cane farmers/farmers association/ NABARD farmers club. The Practice of in-situ sugarcane trash mulching addresses the green gas emission from the cane fields and it also reduces impact on human health viz., skin disorder, nose itching asthma and breathing related issues. Massive adoption helps to increase the cane productivity and addresses the key issue of soil health deterioration and profitability from sugarcane farming. Educating farmers about the benefits of ISTC would enhance sustainability.

ADDITIONAL INFORMATION

Shredding the sugarcane trash and adding TNAU bio-mineralizer @ 2 litres per ton of trash with Disc off bearer operation produced the Cost Benefit ratio of Rs.2.35 per rupee invested than trash burning as traditionally practiced by the framers which have Cost Benefit ratio of Rs.2.21 per rupee invested. In situ trash composting improves soil health and curb environmental pollution through trash burning.

This can be practised for the row spaced crops as it is easier to handle the voluminous trashes and again it incurs additional cost. Hence, wherever the weeds menace and moisture stress are observed, the adoption of sugarcane trash bio mulching could be advisable. Scaling up of organic farming can control weeds and retain soil moisture. Addition of the crop residue and in situ decomposition improve soil properties, increase water holding capacity and minimize the emergence of weeds.

Shredding the sugarcane trash and adding TNAU bio-mineralizer @ 2 litres per ton of trash with Disc off bearer operation has positively influenced soil organic carbon, available nitrogen, phosphorus and potassium, resulting in 0.09% increase in organic carbon content over trash burn treatment.

The cane yield was163.8 t/ha in shredding the trash + TNAU bio-mineralizer @ 2 litres per ton of trash + Disc off bearer (T5) field over check (132.6 t/ha) during 2013-14 and 158.4 t/ha in (T5) over check (124.2 t/ha) during 2014-15). Regarding an additional productivity increase that the conventional practice (trash burning) by the farmers are 23.5 % cane increase in 2013-14 (1st ratoon) and 27.5 % in 2014-15 (2nd ratoon) over trash burnt.

Biochar: An Ideal Soil Conditioner to Sustain Pulses Productivity in Rainfed Ecosystem

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Farmers mixing biochar in soil at action research plot, Tamil Nadu, India. Photo: The DHAN Foundation, India

ABSTRACT

Biochar is an anaerobic pyrolysis product derived from organic waste materials, resistant to further degradation and stored carbon in long-term in the terrestrial ecosystem. In order to understand the mechanism and harvest the benefits of biochar, field experiments were conducted using acacia biochar with required NPK (Nitrogen, Phosphorous and Potassium) fertilizers and other crop management practices. Soil physical changes, carbon build-up, nutrient availability and blackgram yield were recorded under rainfed condition. Application of acacia biochar 5t ha-1 increased the available soil moisture 3.1 and 3.4 per cent at 15 and 30 cm soil depth than control. Acacia biochar application showed positive trend in organic carbon content build-up (1.0 g kg-1) N, P, K availability in soil and utility by crops over the control. Batch process initial experiment data supported that biochar has property of P adsorption potential and it absorbed 240 mg of P per gram of biochar, indirectly reducing leaching loss of applied phosphate and slowly releasing into soil. Reduction of leaching loss of nutrient increases nutrient utility and hinders the eutrophication of water resources. Integrated application of biochar and phospho bacteria 2 kg ha-1 positively influenced the growth and yield attributes of blackgram and boost the yield to the tune of 29 per cent over NPK alone applied plot under water deficit environment.

Keywords: Biochar, Blackgram, Rainfed, Alfisol

CONTEXT

Sivagangai district is a backward region from the point of view of agriculture, industry and general economic conditions of the people, mainly due to the feudalistic history of the area. Several parts of this district are frequently hit by drought. In this district, out of the total geographical area (4, 61,862 ha), only 1, 20, 480 ha are under regular agricultural activities. Since there are no employment generating industries and hence, agriculture is the mainstay of livelihoods of the rural population. The farmers of Sivaganga District mainly depend on the rain-dependent cultivation. Farmers are facing risk of rainfed farming due to intermittent and terminal drought and low response of applied chemical fertilizers especially nitrogen and phosphorous.

For the past 10 years, uneven distribution of rainfall with high intensity has reduced the availability of applied chemical nitrogen and phosphorus to crops by leaching and volatilization process. The leached out nitrate and phosphate enter into the water bodies and cause eutrophication, which leads to environmental threats in irrigated and rainfed ecosystem. So in order to overcome the nitrate and phosphate contamination, moisture constrains and improves the carbon content in the rainfed ecosystem, biochar practice was introduced in this location. Experiments were conducted in an area of 2000 m2 size plot in Typic haplustalfs at Chettinad village of Sakkotai block, Sivagangai district, Tamil Nadu state (Figure 1). Blackgram (Vigna mungo) crop was raised under rainfed situation. Agriculture mainly depends on the rainwater and rainwater harvested in tank water and utilized for crops.

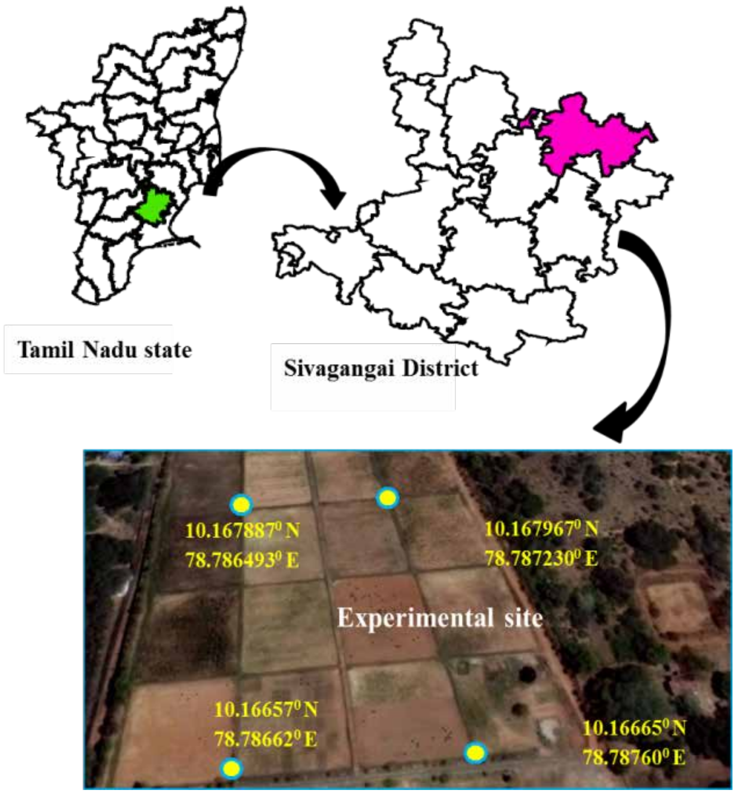


Figure 1. Location map of experimental site

THE GOOD PRACTICE

Biochar is an anaerobic pyrolysis product derived from organic waste materials and used as a soil conditioner to improve the soil heath and combat the climate vulnerability. In order to avoid the crop residue burning in the field and curtail the greenhouse gas emission, crop residue waste is converted into carbon rich biochar. Its surface properties and porous nature makes it useful to apply in rainfed ecosystem as soil water conserver. This practice is introduced to enhance the water retention and carbon content of rainfed Alfisol. The Acacia holocercia plant self-seeded and fast grown tree and pose serious problem in wasteland and cultivable lands of red soil area of Tamil Nadu. Acacia wood was collected in the farm and biochar was produced at 350-400°C pyrolysis temperature in absence of oxygen using TNAU biochar pyrolysis unit. After pyrolysis process, biochar was grinded to small granules and pass through 2 mm sieve in order to have the uniform particle size as that of the soil. Prepared biochar was applied as basal while applying ensures that uniform spread and mixing with soil particles. In order to reduce drifting loss during application biochar should be mixed with native soil in the field or apply in the pellet form. Soil test-based nitrogen, phosphorus and potassium (12.5:25:12.5 kg/ha NPK) were applied in control and biochar applied field. Intercultural operation and pest and disease management practices followed as per the crop production guide for both control and biochar field.

Biochar application was tested in low base saturation and surface crusted coarse textured acid soil. Biochar has more surface area of 87.3 m²/g and highly porous in nature with diverse organic functional groups, these properties were tapped for soil physical, chemical and biological improvement, which in turn influenced growth and yield attributes of pulse crop. Besides high surface area and different organic function group of biochar attract nitrogen and phosphorous by adsorption process and reduce the leaching and volatilization. This helped to curb the nutrient-induced eutrophication of water resources. Biochar versus soil interaction depicted in the Figure 2.

Figure 3. Biochar and soil interaction mechanism

		
Biochar Production	Soil Application & Impact	Crop Response
» Collection of farm waste » Coversion of waste into biochar through pyrolysis » Homogenise the size of the particle for soil application	» Basal application & ensure unifrom mixing with soil particles » Increase soil moisture 3 % » Reduce the soil bulkdensity 0.2 unit » Reduce the soil compaction » Increase the CEC 1.1-1.4 Cmol(p+)/ kg of soil	» Maintined higher relative water content of 61% » Incresed cholorophyll index 2.1(SPAD) » Regulated higher stomatal conductivty 2.7 S/c » Increased the growth attributes mainly root length 2.1 cm » Yield increase 29% noticed

Waste to wealth with environment and farmers prosperity

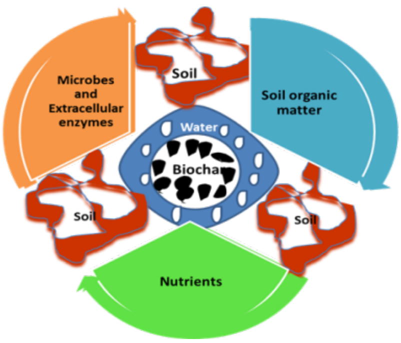


Figure 2. Biochar versus soil interaction depicted

This practice was recommended for wider adoption and popularized among the farmers through roll out programmes and farmers participatory demonstration to conserve water, enhance the N and P use efficiency and sustain the environment.

DEMONSTRATED IMPACT

Biochar production is a crop residue management and environmental clean-up technology. In this, waste was converted in to value added carbon material. The carbon rich material used as a soil conditioner for pulse crops. Impact of biochar application was tested during 2014-2017 in kharif season with blackgram variety VBN 6 and 8 in typic haplusalfs under rainfed situation. Before biochar application field should be ploughed and kept good soil tilth condition. Biochar applied as basal mixing with native soil to avoid drifting loss. The following diagram explained the biochar production, application and its impact on soil health and crop productivy.

Application of biochar increased the soil moisture retention 3.1 and 3.4 % at 15 and 30 cm soil depth, which extend the soil moisture availability 5-7 days than the without biochar. Biochar application enhances the nitrogen (7%), phosphorus (19) and potassium (11%) availability and N, P&K uptake utility (5, 24 & 7 %) over the control due to its surface and organic functional groups, thereby reducing the nutrient losses and protect the environment especially water resources from chemical fertilisers contamination. Biochar has potential to adsorp 240 mg of phosphate per gram of biochar, which increases the P utility and reduces the leaching of P their by protect water bodies free of eutrophication. Further biochar application increased organic carbon (4.2g/kg), bacteria population and improved the soil physical properties by reducing bulkdensity and soil compaction in rainfed soils. The positive impact of biochar on soil health helped to regulate the plant physiological attributes viz., relative water content (61%) and SPAD (44.9) value. Besides biochar favoured better root development (12.9 cm) and high leaf area (318 cm2/plant) over control (10.2 cm & 301 m2/plant). Biochar application improved soil health and regulated the plant physiological activity. It helped to result in better growth and enabled to reap higher produce of 542 kg/ha over control (421kg/ha) under water starved environment, which paved a way for better livelihood security for rainfed farmers under changing climate.

Fig.5. Soil carbon sequestration

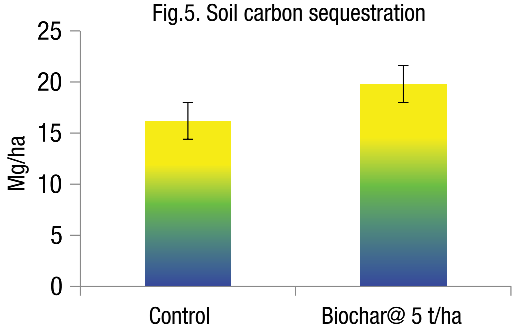


Fig. 3. Soil moisture increase over control

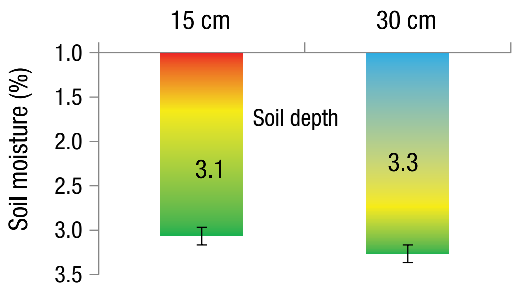


Fig.7. Effect of biochar on physilogical attributes

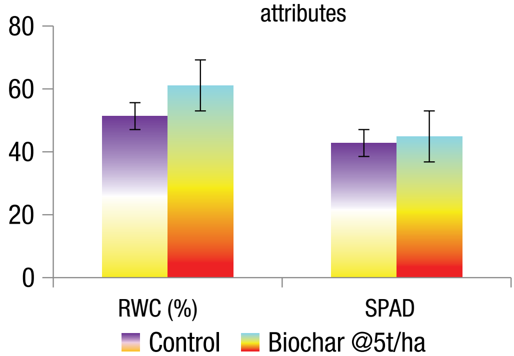
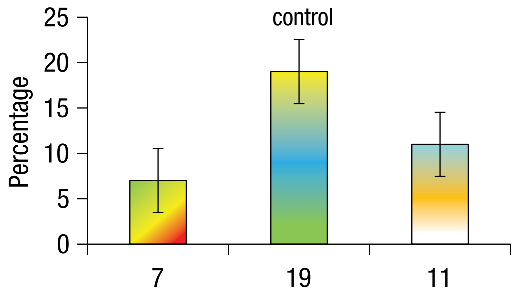
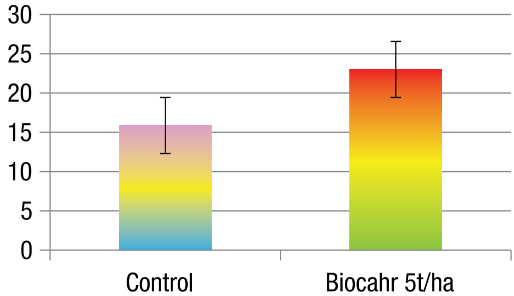


Fig. 4. Available nutrients increase over control





REPLICABILITY

Biochar has great scope to extend in other crops in low pH soils. Waste recycling and environmental protection potential of biochar are key factors influencing to replicate other situations. Large quantum solid waste and its environmental menace pave way for biochar production. Biochar application is a carbon negative technology and it improves water conservation, quality and soil heath. Biochar application practiced 10 acres of pulse and groundnut crop are being practiced in Kothamangalam, and Ammeyenthal villages of Sakkotai and Thirupathur block. Crop residues are freely available in the farm holdings and it can be converted to biochar and apply as a soil conditioner. For conversion of crop waste into biochar a low cost biochar pyrolysis unit is needed.

SUSTAINABILITY

Farmers are convinced to use biochar but biochar production units and biochar are not available at an affordable price. Farmers should be provided a subsidised biochar unit for converting their own farm waste into biochar. Innovative farmers have started to produce biochar in small kiln and practicing 10 acres of pulse and rice crop are being practiced in Kothamangalam, of Sakkotai block. Biochar produced from bio waste has a greater scope to reduce the greenhouse gas emission, and improve water conservation and soil quality, providing ecological sustainability and livelihood security. To ensure sustainability and upscale this practice government should promote biochar as an organic input for soil health management and provide a low cost pyrolysis unit for converting crop waste into value added biochar.

ADDITIONAL INFORMATION

Application of biochar along with soil test based inorganic nitrogen, phosphorous and potassium fertilizer for black gram resulted higher gross return of Rs.2.10 per rupee investment. Farmers practice of inorganic fertilizer alone application gave gross return of Rs. 1.60 per rupee investment. Biochar application increased an additional net return of 50 paise over the famer practice

Biochar application can be recommended for green gram, cowpea, groundnut and red gram cultivated in low pH Alfisol under rainfed condition.

Application of biochar with inorganic fertilizer increased black gram productivity by 121 kg/ha compared to the application of inorganic fertilizer alone.

NEPAL

Cultivation of Disease-and Insect-Pest-Resistant Crop Varieties: A Good Agricultural Practice for Reducing Agricultural Water Pollution

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A farmer demostrating his potato field in Panchkhal, Kavre, Nepal. Photo: LI-BIRD, Nepal

ABSTRACT

A large-scale cultivation of disease-and insect pest-resistant crop varieties can significantly reduce the application of agrochemicals, thereby reducing land-based water pollution. Selective breeding for developing disease-and insect-pest-resistant cultivars is the major preoccupation of modern-day plant breeding. For farmers, use of such varieties is the easiest and most cost-effective means to reduce application of agrochemicals in targeted crops while ensuring sustained yields. A few disease-and pest-resistant crop varieties have been developed and are cultivated in Nepal. However, the number is limited and such varieties are not available for a myriad of crops that farmers grow. This good practice will have to be used in conjunction with judicious application of agrochemicals to control disease and pest outbreaks. In the future, crop improvement research must focus on developing more disease-and pest-resistant varieties across crop species. Conservation of crop landraces and their wild relatives must also receive priority in government programs as they comprise a valuable genepool for resistant genes to be used in breeding programs. Finally, efforts are needed to reduce the time lag between the formal release of new crop varieties and wider adoption by farmers for producing wider impacts.

Keywords: Disease-resistant, Insect-resistant, Pest-resisant, Crop-varieties

INTRODUCTION

Crop improvement programs worldwide have primarily focused on yield improvement, disease and pest resistance, abiotic stress tolerance (for drought, flood, salinity, cold, etc.), and quality trait improvements such as nutrition content, cooking time, and taste. Selective breeding for developing disease- and insect-pest-resistant cultivars has been the major preoccupation of modern-day plant breeding. In Nepal, the government-run Nepal Agricultural Research Council (NARC) is the apex research institution mandated to develop farmer-preferred varieties and breeds in a wide range of cereals, pulses, vegetables, oilseeds, forage crops, fruits, and livestock. In addition to NARC, LI-BIRD is one of the few NGOs engaged in crop breeding research to have successfully registered and released crop varieties for commercial cultivation. Box 1 presents two specific cases where breeders have developed insect pest- and disease-resistant crop varieties in Nepal.

Makwanpur-1 is a rice variety released in 1987 for the Terai region where the rice stem borer pest is a major issue. Makwanpur-1 is a coarse-grain, medium-long duration (150 days), stem-borer-resistant, high-yielding (4.3 t/ha) variety popular in the Terai and river basins up to 500 masl.

Pokhareli Jethobudho is a neck-blast-tolerant rice variety developed through selection from the Jethobudho landrace. The variety was released in 2006 for cultivation in and around Pokhara of Kaski district (600-900 masl). It is an aromatic rice with a long growth period (180-185 days) and a yield potential of 2.6 t/ha.

METHODOLOGY

Cultivation of disease-and insect-resistant crop varieties to a large extent depends on: I) how quickly and effectively the agricultural research system is able to produce farmer-preferred varieties, and ii) how quickly the extension system is able to disseminate new plant materials. Unlike other good practices included in this compendium, use of disease- and pest-resistant varieties does not follow a set methodology. Rather, farmers and extension agents (the government, I/NGOs, cooperatives, and farmer groups, etc.) will have to keep track of the following in order to promote their application:

» Keep abreast of the latest developments in crop improvement research by NARC and other relevant organizations.

» Closely follow updates from the Seed Quality Control Centre (SQCC) regarding the latest releases and registrations of crop varieties, and breeder and foundation seed balance sheets.

» Access quality seeds of disease-and pest-resistant crop varieties from reliable sources (agro-vets, seed companies, and community seed banks) for cultivation.

DEMONSTRATED IMPACT

A large-scale adoption of disease-and insect-pest-resistant crop varieties is by far the easiest and most cost-effective means to reduce the application of agrochemicals while ensuring sustained yields. This can have a positive impact not only on the health of farmers and consumers, but also on farmers' livelihoods, by allowing them to save on agrochemicals. Finally, the reduction in use, or in some cases the complete elimination, of agrochemicals minimizes agriculture-based water pollution.

Farmer using yellow sticky trap to disctract insects that hamper their crops at Panchkhal, Kavre, Nepal. Photo: LI-BIRD, Nepal

SUSTAINABILITY

Farmers can continue growing disease-and insect-pest-resistant crop varieties by using their own saved seeds or by buying quality seeds from the market. There is no additional financial burden associated with the adoption of this practice. Farmers are likely to realize benefits so long as crop varieties do not lose resistance due to co-evolution of pest biotypes.

For crop varieties to maintain disease-and insect-pest-resistant traits over a long period of time, it is important for farmers to maintain on-farm crop diversity as well as varietal diversity. This effectively delays pathogens' interaction with their hosts, increasing the time it takes for virulent biotypes to evolve. The government and research and extension agencies must convey this message to farmers and refrain from encouraging mono-cropping, which can lead to quicker breakdown of host resistance.

LESSONS LEARNED AND RECOMMENDATIONS

Farmers should utilize available disease-and pest-resistant varieties as far as possible. However, because such varieties do not exist for many crops, farmers will sometimes have to resort to the application of agrochemicals to control diseases and insect pests. In such cases, judicious and safe application of agrochemicals becomes important.

Crop improvement research is a time-and resource-intensive process, requiring sustained public-sector funding. Additionally, conservation of landraces and their wild relatives, which serve as a genepool to draw from for disease-and insect-pest-resistant traits, needs to be prioritized. Finally, there is a need to develop a robust extension mechanism to promote resistant varieties once they are formally released so that farmers can maximize benefits immediately, with positive impacts on human health and the environment.

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Use of *Trichoderma*: A Biological Tool for Crop Disease Management

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Trainer demonstrating farmers on the use of *Trichoderma viridae* as a biocontrol agent. Photo: LI-BIRD, Nepal

ABSTRACT

Trichoderma spp. one of the most commonly-used biocontrol agents for management of plant diseases. *Trichoderma* are soil-inhabiting fungi that can multiply rapidly. While they can establish themselves in various environments, they are more effective under protected farming conditions (greenhouses) than under open field conditions, and are more effective against soil-borne pathogens than others. *Trichoderma* can be applied by seed treatment, seedling treatment, foliar applications, soil applications, or as bio-fertilizer. They help establish an antagonistic microbial community in the rhizosphere that suppresses pathogens, promotes plant growth, increases nutrient availability and uptake, and enhances host resistance. In Nepal, commercial use of *T. harzianum* and *T. viride* is most common, although other species are utilized as well. Because *Trichoderma* cannot fully control pathogens on their own, their use should be integrated with other measures, including chemical fungicides.

Keywords: *Trichoderma*, Biocontrol Agent, Disease Management

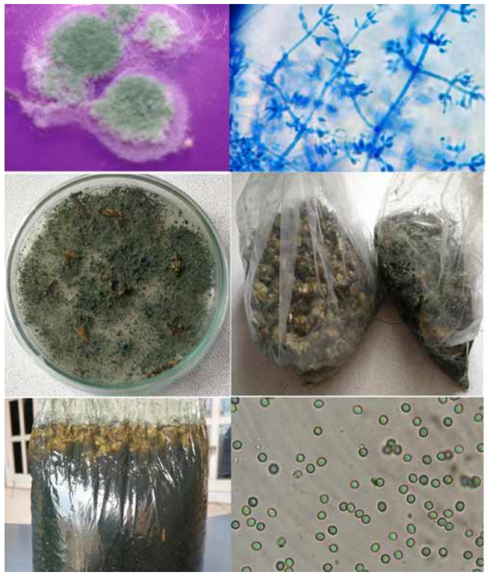
INTRODUCTION

In 1932, Weindling for the first time reported *Trichoderma* lignorum (now known as *T. viride*) as a parasite of other soil fungi. Since then, *Trichoderma* spp. have been extensively studied and used in management of plant diseases. Generally, *Trichoderma* are reported to be more effective under greenhouse conditions than under field conditions. They need time to adapt in new ecological niches and open fields, where adverse and variable conditions prevail. Because they are soil inhabitants, their use is most effective against soil-borne pathogens such as *Rhizoctonia* (root rot/ damping-off), *Sclerotinia sclerotiorum* (stalk rot/ white rot), *Fusarium* (wilt and root rot), *Sclerotium rolfsii* (collar rot), *Phytophthora* (crown rot/ root rot), and *Plasmodiophora brassicae* (clubroot). *Trichoderma* spp. function through mycoparasitism, hyphal lysis, antibiosis, inactivation of pathogens' enzymes, competition, enhancement of root growth, and induced resistance (Kumar et al., 2017; Ghazanfar et al., 2018; Singh et al., 2018).

Research on *Trichoderma* in Nepal has shown the following: *T. harzianum*, *T. aureoviride* and one native isolate of *Trichoderma* reduced damping-off of radish by 50-80% (PPD, 2001); *T. harzianum* and *T. asperellum* reduced clubroot of cauliflower by 35-40% under field conditions (Timila, 2011); a native isolate of *T. harzianum* (T69) was found as effective as chemical fungicides, copper oxychloride and fluazinam, in managing *Phytophthora* blight of chilli under field conditions (Timila and Manandhar, 2016); *T. viride* reduced botrytis gray mold of chickpea (Joshi 2001). *Trichoderma* has also been used for better composting (Khadge, 2003).

METHODOLOGY

Trichoderma spp. are used as a biopesticide and also as a biofertilizer. *Trichoderma* can be multiplied locally



Isolation, identification and growth of *Trichoderma* in different media. Photo: Hira Kaji Manandhar

in a suitable substrate or bought from commercial producers in powder or liquid forms. They can be used for seed treatment, seedling treatment (root dipping), soil applications (drenching around the plant) and foliar applications (Cumagun, 2014). *Trichoderma* are used in compost making for fast decomposition; this compost can then serve as both a biocontrol agent and biofertilizer in soils (Kamal et al., 2018).

In Nepal, many commercial formulations, especially of *T. harzianum* and *T. viride*, are registered and marketed under various trade names (PRMD, 2017). These include Ecosom-TH, Niprot, and Tricho-HR for *T. harzianum*, and Peak Tricho, Astan-TV, Bhoparistricho, Biocure-F, Biocide Trivi, Carrier, Ecosom, Nicoderma, Nisarga, Sanjevani, Sanjivani, Trichostar, and Tristar for *T. viride*. These can be used as per the instructions given on their labels. A fact sheet on *Trichoderma* use as an anatagonistic fungi in Nepal is available here: (http://www.idenepal.org/what/Tecnos/IPM_documents/*Trichoderma*_Factsheet_english_2015.pdf).

Farmers preparing compost fertilizer mixing Trichoderma in Panchkhal, Kavre. Photo: LI-BIRD, Nepal

DEMONSTRATED IMPACT

Use of *Trichoderma* as a biocontrol agent can have positive impacts on human health and the environment by reducing or replacing the use of chemical pesticides. Indiscriminate use of chemical pesticides has created a human health hazard, polluting the environment and water sources. In contrast to chemical pesticides, which require repeated use, *Trichoderma* is not a pollutant and, under ideal conditions, may require just one or a few applications due to their self-perpetuating nature.

SUSTAINABILITY

Use of *Trichoderma* is a sustainable choice for several reasons. First, they are free-living fungi and can be isolated, evaluated and used locally. Various government and non-government agencies have been supporting the production of *Trichoderma* at the local level through centers (previously known as IPM source centers) located in Panauti in Kavre, Topgachhi in Jhapa, Mangalpur in Chitwan, Kopuwa in Kapilvastu, Naubasta in Banke, and Aanbukhaireni in Tanahu (www.youtube.com/watch?v=hbpd3-5b5UU&feature=share). Private companies are also involved in producing *Trichoderma*, such as Agricare Nepal and Phytocare International in Chitwan, and Intensive Multipurpose Agriculture Development Company in Lalitpur. Second, since many hazardous chemical pesticides have been banned, *Trichoderma* has become increasingly attractive for plant disease management. Preference for organic or minimum use of chemical pesticides and fertilizers is increasing gradually. Finally, *Trichoderma* have the ability to reproduce and establish themselves in the soil. This means that the biological control can be kept in place for a much longer time than other methods of pest control.

LESSONS LEARNED AND RECOMMENDATIONS

While *Trichoderma* can reduce various plant diseases, they may not be sufficient on their own. Therefore, *Trichoderma* should be integrated with other compatible management options, including chemical fungicides. Some reports suggest thiram, mancozeb, and copper oxychloride are compatible with *Trichoderma* (Bagwan, 2010; Meena, 2018). Research by the Plant Pathology Division at NARC showed that copper oxychloride (100 ppm) was compatible with *Trichoderma* harzianum (T69) (PPD, 2014).

There are several considerations which farmers should pay attention to before using *Trichoderma*. First, *Trichoderma* takes longer to produce effects compared to chemical fungicides, so patience is important. Second, *Trichoderma* are living agents that must be alive when applied; their viability is lost during inappropriate transportation or storage. *Trichoderma* should be tested for viability before use if the source is unknown or doubtful. Third, because *Trichoderma* are commonly introduced to new areas from outside sources, it is important to keep in mind that the efficacy of *Trichoderma* is influenced by new environments, including temperature, soil type, moisture, and microbial communities present. To the extent possible, locally-isolated *Trichoderma* should be used as they are the local inhabitants. Fourth, the appropriate dose of *Trichoderma* to be applied depends on the product, its formulation, and the conditions in which it has been stored.

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SRI LANKA

Providing Surface Water for Drinking and Avoiding Indiscriminate Use of Agrochemicals

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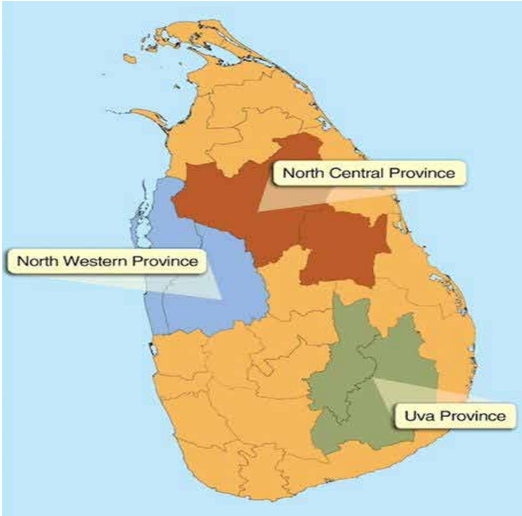
Eutrophic village tank in Sri Lanka. Photo: Arthacharya Foundation, Sri Lanka

ABSTRACT

Findings suggest that agrochemicals especially phosphate fertilizers are a major source of inorganic arsenic in CKDu endemic areas in Sri Lanka. Increased arsenic contamination of soil and ground water can adulterate food and drinking water. Arsenic content in the organic fertilizer available in Sri Lanka is comparatively low. Most of the rural community who suffer from the kidney diseases used to drink well waters (ground water) during the recent past. However, investigations and experimental evidences indicated that ground water contains higher soluble salt than surface water resources in the area. The communities that source drinking water from shallow wells in close proximity to irrigation systems developed for agriculture with demonstrable seepage from irrigation system to the wells are more affected by CKDu compared to the communities without irrigation seepage into wells. Affected villages are often located below the level of the water table. In contrast, communities living in geographically close proximity to irrigation systems who obtain drinking water from wells sourced by natural springs appear to be less affected by CKDu. Fertilizer run-off from upstream agricultural activities in the hill country and consequent changes in the ionicity causing a Hofmeister-type protein denaturing nephropathy has been postulated to be linked with CKDu. Therefore, it is suggested that providing safe drinking water seems to be one solution for the problem with the development of surface water resources available in the area.

Keywords: Agrochemicals, Arsenic, Fertilizers, Ground Water, Drinking Water, CKDu



Map 1. The North Central, North Western and Uva Provinces of Sri Lanka are seeing a dramatic rise in kidney disease, mosty among male farmers.
Source & Photo credit: National Water Resources & Drainage board of Sri Lanka

CONTEXT

Country: Sri Lanka

Province: North Central Province (NCP)

Districts: Anuradhapura and Polonnaruwa

DS division/GN area: Medawachchiya, Girandurukotte, Mahiyanaganaya, Padaviya, Sripura, Medirigiriya, Hingurakgoda, Dehiattakandiya.

Total population of the NCP (North Central Province) is 1,259,567 and the population under poverty line (out of total population) is 5%.

The North Central Province (10,472 km2) is the largest province in the country, covering 16% of total country's land area. The endemic occurrence of the kidney disease was recognized in the 1990s in the Province, situated in the dry zone of Sri Lanka, and this has been increasing over a period of 10–15 years. High prevalence of CKDu is observed in two main districts of the North Central Province - Anuradhapura and Polonnaruwa (10,472km2). The prevalence is now spreading to the adjoining districts of North Western province, Uva province, Eastern province, Central province and the Northern Province. Recently this epidemic has been found in the Southern province near Hambanthota as well.

Dental fluorosis is considered to be an outcome of water quality problem in many parts of the dry zone of Sri Lanka, notably in the North Central Province. Hypertension and diabetes are known to be the main causes for renal failure, a commonly observed in the country, but over the last decade a high prevalence of Chronic Kidney Disease (CKD) has become an environmental health issue of national concern in Sri Lanka.

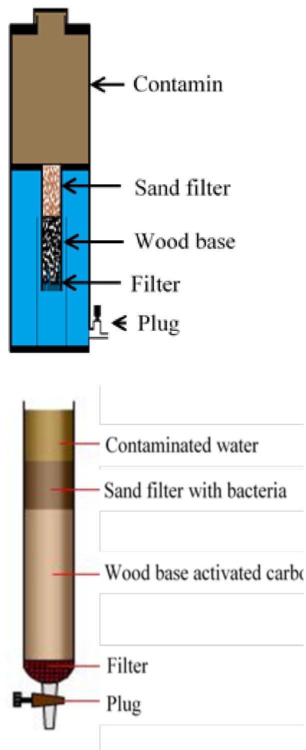


Fig 1. Improvement of water quality of Cyanotoxin contaminated surface and dug well water through controlled interventions-(Active charcoal water filter developed by SJP University, WP).
Photos Credit: Professor Pathmalal, SJP University SL

The SAECB-AWP project awarded two research projects for empirical studies to investigate further. The developed domestic filter showed complete removal of antibiotics, pesticides, Geosmin, 2-MIB and cyanotoxin. Therefore the developed filter is recommended as cost effective domestic filter to produce clean water. Many useful recommendations have been made by both projects (Figure 1).

Figure 5 Experimental models of the water filter developed under an empirical study-"Improvement of Water Quality of Cyanotoxin contaminated surface and dug well water through controlled interventions by the Researcher/CEO,Prof. M. M. Pathmalal,SJP University, Colombo,Sri Lanka"

The suffered farmers in major rice growing districts in Anuradhapura and Polonnaruwa, attributed to the use of pesticide as one of the main causes of concern of Chronic Kidney Disease (CKDu). Existing hypotheses suggest that exposure to occupational and environmental toxins in agriculture as a primary trigger and dehydration caused by inadequate fluid intake in a hot environment as a contributory factor of this disease. Previous research suggests cadmium, aluminium, fluoride, Na^+/Ca^{2+} ratio, algal toxins and glyphosate complexation with hardness of water as possible CKDu-causing factors in the NCP. However, agricultural communities in CKDu endemic areas obtain drinking water mainly from shallow wells.

Rice, field crops (maize, Soya, Mung bean), cash crops such as chilies, onions, also most vegetables and fruits such as mango, banana. Cattle rearing for milk and meat. Poultry farming. Inland fresh water fish are the main products. Details on sector specific agrochemicals usage are not available. However, paddy sector uses higher percentage of fertilizers and other agrochemicals in the area.

Over 70% of the population is engaged in these sectors. Among the different practices and most of them are basically involved in agricultural activities.

While detailed statistics are not available, farmers generally use over dosages of agro-chemicals on traders or agrovets advice. High level of nitrogen as nitrate in drinking water can be harmful to young infants or young livestock. Excessive nitrate can result in restriction of oxygen transport in the bloodstream. Infants under the age of 4 months lack the enzymes necessary to correct this condition ("blue baby syndrome" in the NWP). Therefore, the necessity for restricting levels of nitrogen application to approximate crop needs is obvious to avoid such an adverse effect on the environment and water sources..

When excessive phosphate is present in the water the algae and weeds will grow rapidly, may choke the waterway, and use up large amounts of precious oxygen (in the absence of photosynthesis and as the algae and plants die and are consumed by aerobic bacteria). The result may be the death of many fish and aquatic organisms.

Farmer spraying chemical pesticide in paddy field.
Photo: Global Research Foundation, Sri Lanka

Rajangana Reservoir water during the bloom (Source: Dr. Wasantha Welianga & Prof Ivan Silva-WREST)

Occurrence of algal bloom (photo below left) in the Rajangana Reservior, Anuradhapura district, NCP is a classic example. Snails and Mussels are possible indicators of Pollution.

Environmental consequences of pesticide use in all instances are possible where pesticides- dependent pest control practices are not properly adopted.

Pesticide misuse is known to be common and results in a number of environmental consequences that can threaten water pollution and lives itself depending upon localities they are used. Some of the key consequences that have been eminent are as follows:

Industrial pollution in Sri Lanka.
Photo: Department of Agriculture,Sri Lanka

Destruction of pollinators of crop plants leading to poor crop yields, elimination of the natural enemies of pests and consequent loss of natural pest control that keeps the population of crop pests very low, development of pest resistance to pesticides, encouraging further increases in use of chemical pesticides, contamination of the soil and water bodies, pesticide poisoning of farmers and deleterious effects on human health, loss of bio-diversity in environment, particularly of aquatic species present in the inland water bodies.

Phosphate contaminated water body in Sri Lanka.
Photo: Department of Agriculture,Sri Lanka

Indiscriminate use of farm chemicals and ad-hoc disposal leads to CKDu. Photo: Arthacharya Foundation, Sri Lanka

Characterization of labour in Agriculture) Describe the main causes of over application of chemical fertilizer in the area

Mostly men are affected as they take the lead role in pesticide administration to crops. The disease therefore is more common in males between the ages of 40 and 69 years, in farming communities in rural Sri Lanka, with conflicting evidence of familial clustering. Studies using geographical mapping show that villages with a high prevalence of CKDu are often related to irrigation water sources and/or located below the level of the water sources..

THE GOOD PRACTICE

Surface water for drinking and avoiding indiscriminate use of agrochemicals

In the past two decades, Sri Lanka's disease pattern has shifted toward non-communicable diseases (NCDs). CKDu is a NCD of great concern that now poses a significant challenge to the health of people. Several studies have speculated about the causative role of agrochemicals in this NCD.

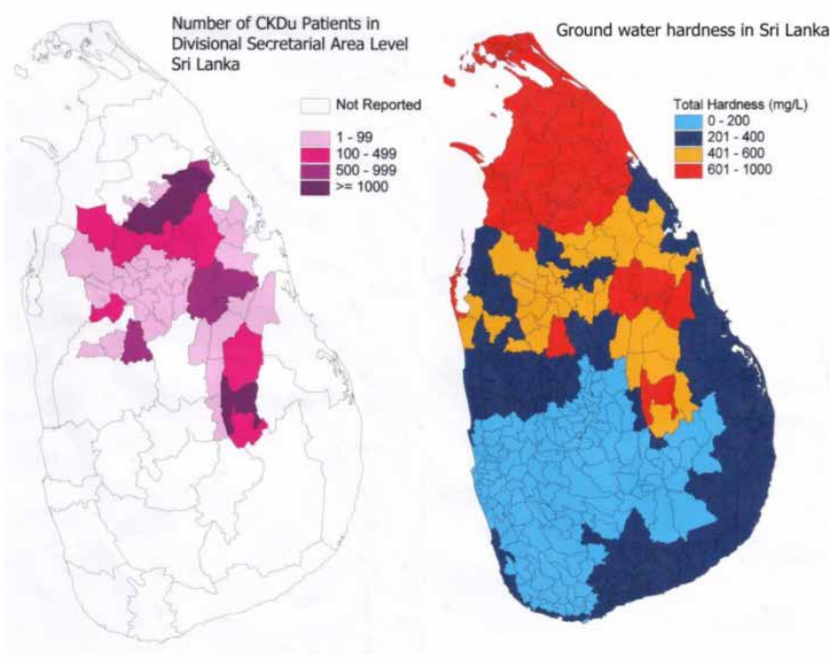
Although Sri Lanka is noted for its strong public health system, data on NCDs and CKDu death and disease cases have many gaps. In response, Sri Lanka's Ministry of Health (MoH) established CKDu disease registries at district hospitals in the dry zone provinces in 2009. Given its unknown origin, the emerging CKDu crisis has spurred a variety of investigative efforts in recent years, and a number of studies have collected and analyzed environmental and biological samples.

It was observed that by providing clean fresh water the CKDu could be minimized. Farmers were educated by the DOA and the Ministry of Health. The DOA, Ministry of irrigation, Health department are the key players. It is suggested that providing safe drinking water seems to be one solution for the problem by development of surface water resources in the areas concerned. School awareness programmes are also being held in affected areas.

Specific issue addressed by the practice

Findings suggest that agrochemicals especially phosphate fertilizers are a major source of inorganic arsenic in CKDu endemic areas in Sri Lanka. Increased arsenic contamination of the soil and ground water can adulterate food and drinking water. Arsenic content in the organic fertilizer available in Sri Lanka is comparatively low and hence the farmers should be encouraged to minimize the use of imported chemical fertilizer and use organic fertilizers in order to avoid further environmental damage and human health hazards.

It was also observed that the most of the rural community who suffered from kidney diseases were used to drink well waters (ground water) during the recent past. However, investigations, experimental evidences were made that ground water contains higher soluble salt than surface water resources in the area.



Map 2. The level of ground water hardness in various part of Sri Lanka.
Source: Jayasumana et. al. 2011 and Jayasumana et. al. 2013

Communities that source drinking water from shallow wells in close proximity to irrigation systems developed for agriculture with demonstrable seepage from irrigation system to the wells are more affected by CKDu compared to communities without irrigation seepage into wells. Affected villages are often located below the level of the water table. In contrast, communities living in close proximity to irrigation systems who obtain drinking water from wells sourced by natural springs appear to be less affected by CKDu. Fertilizer run-off from upstream agricultural activities in the hill country and consequent changes in the ionicity causing a Hofmeister-type protein denaturing nephropathy has been postulated to be linked with CKDu. Therefore, it is suggested that providing safe drinking water seems to be one important solution for the problem by developing of surface water resources in the areas. Water harvesting technology has been introduced and practiced as a good practice.

DEMONSTRATED IMPACT

The farmers suffering from kidney diseases' in major rice growing districts in the dry zone areas including Anuradhapura and Polonnaruwa, attributed to the use of pesticide as one of the main cause of concern of Chronic Kidney Disease (CKDu). They have benefitted from introducing water harvesting technologies, and shallow wells as well as by awareness creation.

Unfortunately, there is no unequivocal evidence to recognize the possible environmental causative factors. The prevalence of the disease is mostly among paddy farmers and agriculture laborers of 70% of farming community of the area. Many of these farmers die simply because they cannot afford the cost of treatment. Apart from the cost, it is the lack of availability of dialysis facilities in nearby hospitals that makes it extremely difficult for the poor to avail treatment. In most cases, people found they are sick at a very late stage, so that it is not possible to reverse the situation. By 2019 several hospitals are provided with Dialysis facilities, and also the Government has established a hospital for Kidney patients in the Dry zone.

Supply of clean water is a practical solution to the problem and it is being practised now. It has been observed that those who use potable surface water has lesser incidences of disease.

The government has a long term plan to supply drinking water by diversion schemes from major reservoirs to the NCP. Ground water hardness is another possible reason for the disease in the dry zone. Installation of deep tube wells has now been discouraged for drinking purposes. Surface shallow wells are being promoted, in areas where the water table is high.

Map 2 shows the level of ground water hardness in the country. Mostly the low country dry zone has hard water.

The good practices described above are mostly on government influence. Few NGO's are also working in the affected areas introducing good practices such as rainwater harvesting. Disease is more common in males (between the ages of 40 and 69 years old) in farming communities in rural Sri Lanka, with conflicting evidence of familial clustering. Studies using geographical mapping show that villages with a high prevalence of CKDu are often related to irrigation water sources and/or located below the level of the water table.

Sri Lankan CKDu patients include both men and women, but a majority of the late-stage patients are men. Additionally, the majority of patients are low-income farm workers. Patients range in ages from 17 to 70 but are most commonly men aged 30 to 60. There appears to be a link between CKDu and people working in the farm as agricultural workers. Risk factors include environment, agricultural work and farming practices, diet and nutrition, and genetics.

Clean drinking water supply to this area has been identified as an important issue by the Government of Sri Lanka and non-government agencies as well.

REPLICABILITY

It is important to identify key social, economic, political, demographic and cultural dynamics that favored or impeded the transformation process of the relevant practices. Geographical mapping indicates a relationship between CKDu and agricultural irrigation water sources. Health mapping studies, human biological studies, and environment-based studies have explored possible causative agents. Most studies focused on likely causative agents related to agricultural practices, geographical distribution based on the prevalence and incidence of CKDu, and contaminants identified in drinking water. Nonetheless, the link between agrochemicals or heavy metals and CKDu remains to be established. No definitive cause for CKDu has been identified in the ionicity causing a Hofmeister-type protein denaturing nephropathy has been postulated to be linked with CKDu. Therefore, it is suggested that providing of safe drinking water seems to be one solution for the problem by development of surface water resources in the areas concerned.

SUSTAINABILITY

Clean drinking water supply to this area has been identified as an important issue by the Government of Sri Lanka and Non-Governmental Agencies. Farmers' organizations, the Agrarian development officers and Agriculture extension officers support the farmers through awareness creation and education. The Health Ministry has its own program through their hospital network and through the Public Health Inspectors serving the affected areas.

Good Agricultural Practices, provision of safe drinking water, and occupational safety precautions are recommended by the World Health Organization. Creation of educational programs for the village community and general public on CKDu and preventive measures are increasing, with improved health facilities.

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Influence of GAP and IPM on Irrigated Agriculture to Mitigate Water Pollution

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Farmer explaining method of making bio-pesticides. Photo Credit: Rajrata University, Sri Lanka

ABSTRACT

The National Aquatic Resources Agency (NARA) also studied the water quality of downstream irrigation network of the Mahaweli system during 1992/93 (NARA, 1993). The reservoirs connected to the Mahaweli system H 'are mostly located in the Anuradapura District and the extent of new land area under this system is 28,000 ha. In addition, due to the existing water conveyance system from upcountry to reservoirs in North Central Province (NCP) through diversion of river Mahaweli, it was also revealed that Cadmium, derived from contaminated phosphate fertilizer dissolved in irrigation water finds its way into reservoirs, and finally to the food, causing chronic renal failure among consumers (Bandera et al, 2010). The Implementation of Integrated Pest Management (IPM) program under guidance of the extension services of the DOA was started in mid 1990s to minimize the adverse effects from agricultural chemicals used by farmers. It has been identified that the use of resistant varieties is the safest, cheapest, easiest and effective pest and disease management measure. The GAP certification program was started by the Department of Agriculture several years ago.

Keywords: Pesticides, Inorganic Fertilizers, Water Pollution, Irrigated Agriculture

CONTEXT

Country: Sri Lanka
Province: North Central Province (NCP)
District: Anuradhapura & Polonnaruwa

Based on the 2016 statistics total population of NCP is 1,259,567 and the population under poverty line of the total population is about 5%.

During the last 2600 years, farmers inhabiting dry zone of Sri Lanka were adapted to cultivation of rice using tank based irrigation water and application of organic fertilizers for their paddy lands. With the development of Mahaweli river diversion to the North Central Province (10,472 km2) in late 1980s the agricultural practices in the area have changed rapidly to irrigated agriculture, with intensified agricultural practices using improved cultivars and agrochemicals. Newly improved varieties of rice and other cultivated upland crops require a large amount of fertilizer such as Urea, Triple super phosphate (TSP) and Muriate of potash (MOP or potassium chloride). The chemical fertilizers used by farmers are subsidized by the government of Sri Lanka (Ekanayake 2009). Therefore, the application of chemical fertilizers has increased in the country. It was reported that Sri Lanka was the leading country in fertilizer usage in the South Asia (Sri Lanka 230.8; Pakistan 217.1; Bangladesh 184.4; India 178.9; and Nepal 23.2 kg per hectare respectively of arable land in 2010) (World Bank 2010).

The mail agricultural products are rice, other coarse grain cereals, legumes, fruits, vegetables, fresh water fish in raw or dried form, milk, poultry products, timber, firewood. Farm labour is mostly from the family itself; rarely hired during planting and harvesting.

A large proportion of rural families in the dry zone of Sri Lanka live close to agricultural fields and are not only exposed to pesticides, but also they often use the irrigation canals, rivers and lakes as a free source of fresh water for bathing and other domestic purposes. This water source is likely to be contaminated with pesticides, not only due to agricultural run-off but also as a direct consequence of malpractices such as incorrect use of pesticide sprayers. Generally, it is reported that 50% to 90% of pesticide pollution in ground and surface water comes from point pollution sources in agriculture: for example, spillages, incorrect cleaning of spraying equipment or illegal disposal of leftover spray solutions. Diffused water pollution through pesticides occurs due to spray drift, surface runoff, drainage losses or leaching to groundwater. In addition, the Dry Zone of Sri Lanka has several areas in which the ground water is high in mineral content and rich in fluoride. It has also been shown that the dissolution of aluminum from poor-quality cooking utensils is high in the presence of fluoride in the water. The village people use aluminum pots and utensils to store and boil water (Herath et al., 2005).

Published figures on fertilizer usage by district are not available. Farmers are motivated by agrochemical dealers and they anticipate higher yields by using excessive levels of agrochemicals. It was reported that during the recent past, Sri Lanka is the leading country in fertilizer usage in South Asia.

Environmental consequences of pesticide use in all instances are possible where pesticides- dependent pest control practices are not properly adopted. Pesticide misuse is known to be common and results in a number of environmental consequences that can threaten subsistence agriculture, water pollution and lives itself depending upon localities where they are used. Some of the key consequences that have been eminent are as follows:

Destruction of pollinators of crop plants leading to poor crop yields, elimination of the natural enemies of pests and consequent loss of natural pest control that keeps the population of crop pests very low, development of pest resistance to pesticides encouraging further increases in use of chemical pesticides ,contamination of the soil and water bodies, pesticide poisoning of farmers causing deleterious effects on human health, and loss of Bio-diversity in environment, particularly of aquatic species present in the inland water bodies.

THE GOOD PRACTICE

The DOA has been implementing several IPM programs in collaboration with farming communities in the areas to overcome the existing problems of pests and diseases.

The Implementation of Intergraded Pest Management (IPM) program under the guidance of the extension services of the DOA was started in mid-1990s to minimize the adverse effects from agricultural chemicals used by farmers. However, it was observed that IPM also needs constant follow up and guidance until the farmers become experts. It was also identified that the use of resistant varieties is the safest, cheapest, easiest and effective pest and disease management measure. Therefore, plant pathologists and entomologists gave priority to identify and select resistant germplasm and work collaboratively with plant breeders to produce resistant crop varieties for pest and disease problems along with other desirable characters. In addition, research activities were conducted in farmers' fields for introduction of crop rotation and conservation farming methodologies to eliminate pest problems.

Specific objective for the introduction of the practice

It was revealed that excessive usage of Agro Chemicals with undesirable ways of application would cause some serious concern to the environment and endanger to the country's water resources. Therefore, the importance of monitoring irrigation water quality in reservoirs has been recognized and addressed in many instances (IIMI,1995, Silva,1996, Madduma Bandara,2000,Shortt,2001,SOE,2001). However, the status and trend in irrigation water quality in Sri Lanka is poorly understood. The National Water Supply and Drainage Board (NWA&DB) undertakes a regular analysis of basic drinking water quality parameters in some irrigation reservoirs which are being used as a drinking water supply in NCP. The National Aquatic Resources Agency (NARA) also studied water quality of downstream irrigation network of the Mahaweli system during 1992/93 (NARA, 1993). The reservoirs connected to the Mahaweli system are mostly located in the Anuradapura District and the extent of new land area under this system is around 28,000 ha. In addition, due to the existing water conveyance system from upcountry to reservoirs in the North Central Province (NCP) through diversion of river Mahaweli, it was also revealed that Cadmium, derived from contaminated phosphate fertilizer dissolved in irrigation water, finds its way into reservoirs, and finally to the food, causing chronic renal failure among consumers (Bandara et al, 2010.). In the view of this problem, the DOA had been implementing several programs in collaboration with the farming community in the areas to overcome the existing problems of pests and diseases. The Implementation of Intergraded Pest Management (IPM) program under the guidance of the extension services of the DOA was started in mid-1990s to minimize the adverse effects from agricultural chemicals used by farmers. However, it was observed that IPM also needs constant follow up and guidance until the farmers are well trained.

It was also identified that the use of resistant varieties is the safest cheapest, easiest and effective pest and disease management measure. Therefore, plant pathologist and entomologists give priority to identify select resistant germplasm and work collaboratively with plant breeders to produce resistant crop varieties for pest and disease problems with other desirable characters. In addition, research activities are being conducted in farmers' fields for introduction of crop rotation and conservation farming to control pest problems.

The GAP certification program has also been started by the Department of Agriculture for certifying good agricultural practices in crop production under standard methods of continuous agricultural production process from seed / planting stage up to marketing, while securing and protecting the human health and nutrient values. This certification should be done by independent partner and it should be done under the guidance of the Director General of Agriculture at the certification unit under the Department of Agriculture.

Research activities were also conducted adopting organic farming technologies and use of site specific fertilizer recommendation based on crop demand. Pesticides are used with correct selection, preparation and application according to the guidelines. Moreover, the importance of education and training of farmers a vehicle to a safe use of pesticides is being recognized. Therefore, the program on Education of Communities about the pollution impacts of the use of fertilizers and other agro chemicals on water quality and food safety have been conducted by the Extension division of the DOA.

The Implementation of Intergraded Pest Management (IPM) program is being carried out as a continuous exercise under the guidance of the extension services of the DOA. This practice was conducted to minimize the adverse effects from agricultural chemicals used by farmers by reducing frequent use of agrochemicals.

In addition, crop rotation and conservation farming practices was introduced to eliminate pest problems mainly in crop cultivation in upland areas. Adopting organic farming technologies and use of site specific fertilizer recommendation based on crop demand was introduced to the farmers. The education programs of farming communities about the pollution impacts of the use of fertilizers and other agro chemicals on water quality and food safety and also detrimental effects to environment were implemented by the DOA and also in relevant government and non-government agencies as well.

Bagging the mango fruits to u protect from fruit flies.

Bagging the guava to protect from fruit flies.
Photos: Arthacharya Foundation, Sri Lanka

DEMONSTRATED IMPACT

Guidelines have been prepared to develop soil-based fertilizer application system and safe uses of pesticides to avoid overuse of agrochemicals. Training and demonstration activities for using agrochemicals with right selection, preparation and application according to the guidelines, which have led to significant improvement in safe use of agrochemicals. GAP program and organic farming technologies are popular among farmers in many parts of the country with an emphasis in terms of high economic values and food safety of agricultural products.

The importance of education and training of farmers as a vehicle to a safe use of pesticides is being recognized by the government and non-government institutions. Therefore, training activities are being conducted in many parts of the country in the recent past. Direct beneficiaries from the programme are farming communities (70%) in the village areas.

REPLICABILITY

The implementation of Intergraded Pest Management (IPM) program under the guidance of the extension services of the DOA led to the minimization of adverse effects of agricultural chemicals used by farmers.

In addition, crop rotation and conservation farming practices were introduced to eliminate pest problems mainly in crop cultivation in upland areas. Adopting organic farming technologies and use of site specific fertilizer recommendations based on crop demand was introduced to the farmers. The education programs of farming communities about the pollution impacts of the use of fertilizers and other agro chemicals on water quality and food safety and also detrimental effects to environment were implemented by DOA and also in relevant government and non-government agencies. Therefore, these activities can be replicated in many parts of the other countries as well in order to reduce impact on water pollution by heavy use agrochemicals.

SUSTAINABILITY

Farmers should be encouraged and incentivized to use the aforementioned GAPs to reduce excessive use of agrochemicals and thus to reduce their ill effects on human health and ecological as well as environmental sustainability while protecting rural agriculture.

Fruit and vegetable display in the supermarket of Sri Lanka under GAP program. Photos: Arthacharya Foundation, Sri Lanka

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