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Sector Specific Valuation Guidelines: Discussion Paper-1

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VALUATION OF BIO-RESOURCES (MICROORGANISMS) FOR ABS: A STUDY BASED ON CROP PROTECTION PRODUCTS

BACKGROUND

Biodiversity refers to the variety of plants, animals and microorganisms, and the ecosystems in which they occur, and is inherently valuable to humanity. Biodiversity provides the basis for life on earth, and plays a vital role in sustaining and promoting business. In the manufacture of many products (such as food, medicines, fertilisers, pesticides, fibres, textiles, and cosmetics) bio-resources (includes a wide variety of plants, animals and microorganisms) play a significant role. The combined annual global market for the products derived from bio-resources is roughly between US$ 500 billion and US$ 800 billion (Kate and Laird, 2000).

With respect to the socio-economic significance of biodiversity, Environmental Economists have attempted to value biodiversity with a focus on the ecologically sensitive areas or biodiversity hotspots, such as forests, wetlands, mangroves, coral reefs, etc. A methodology has been established, particularly for valuing the non-marketed services of biodiversity / ecosystems and many empirical attempts have progressed in different parts of the world. However, the goods (in the form of bio-resources) derived from biodiversity, have been assigned values based on their current exchange rate or price (multiplying the quantity of goods with the price) at their collection point, such as the forest gate or sea coast, or the nearby local market.

Historically these resources, which include different genetic materials, are extracted by local communities with the help of their hard efforts and unique traditional knowledge on their use, and / or supplied to prospectors at low or negligible prices. Since there are no proper markets for such resources at their collection point, the existing price for the product does not reveal its actual value. Generally, the actual value may be more than the existing market price. A valuation of bio-resources would facilitate identifying the real value of bio-resources and obtaining a reasonably better share of the overall benefits of bio-resources related economic activities to the local communities, who are involved in their management (Nelliyat and Pisupati, 2014).

After extensive consultations and studies, NBA arrived with case / sector specific separate formulae for valuing the bio-resources (Table 1).

Table - 1

Suggested Economic Valuation Methods for ABS

	Category of Bio-resources	Possible Methodological Approach	Payment Detail
A A1	Bio Pharmaceuticals (modern drugs) *(Population status, Rare Endangered and Threatening (RET), Abundant, Endemic)*	Scarcity Rent (SR) + Information Rent (IR) (share a proportion attributable to the product). Endemic Rent (ER)	Initial payment + payment at the time of product development + payment at marketing stage. Monetary + Non- Monetary (for endemic and RET)
B	Bio-technology (Seed / Agriculture Related), Land races, Microorganisms,	Information Rent (IR) (share a proportion attributable to the product).	Initial payment + payment at the time of product development + payment at marketing stage Monetary + Non- Monetary (for endemic and RET)
C	Crop protection products	Information Rent (IR) (share a proportion attributable to the product).	Initial payment + payment at the time of product development + payment at marketing stage Monetary + Non- Monetary (for endemic and RET)
D	Botanicals (AYUSH)	Based on the proportion of Net Present Value (NPV) of the profit x the contribution of input to the out put	Initial payment + payment at the time of product development + payment at marketing stage Monetary + Non- Monetary (for endemic and RET)
E	Nutraceuticals / Personal care and cosmetic products	Based on the proportion of NPV of the profit x the contribution of input to the out put	Initial payment + payment at the time of product development + payment at marketing stage Monetary + Non- Monetary (for endemic and RET)

Source: Nelliyat and Pisupati, 2014

The sectors indicated in the above table were considered, based on the nature, availability, and potential uses of bio-resources. India is one of the 12 global mega diversity centres harbouring approximately 8% of the biodiversity existing in only 2.4% of the land area, which includes plants, animals and micro-organisms (Department of Bio-technology, 2014).

This policy brief examines the "crop protection products" sector with an emphasis on: (a) its significance and growth, (b) manufacturing process, (c) valuation, cost distribution and value chain analysis, and (d) ABS related concerns and challenges. Information has been collected primarily from secondary sources (such as literature and the concerned government department statistics), and primary sources (including discussions and interview with experts, interaction with the crop protection products manufacturing company's management, and a detailed case study of a Chennai based manufacturing unit).

PART 1

BIO-FERTILIZER AND BIO-PESTICIDES: AN EMERGING BIO-RESOURCES BASED INDUSTRY

Transformation of the Application of Chemicals to Bio-inputs in Agriculture:

In recent decades crop protection products' manufacturing companies are flourishing both in developing and developed countries. In this, the role of different actors such as, agriculture research and extension institutions, industrial and trading firms, farming communities and civil society representatives, and NGOs, is crucial. According to Kolanu and Sunil (2003), the growing demand for green agriculture products is a constraint as well as opportunity for Indian agriculturists, producers, suppliers and traders of agricultural inputs and outputs.

In India, after independence, the use of chemical fertilizers and pesticides has increased considerably. The green revolution during the 1960s and the subsequent intensification of agriculture were major causes behind this growth. The application of chemical fertilizers in the last 50 years has grown nearly 170 times. In 1950, the use of chemical fertilizers was 0.55 kilograms per hectare, but by 2001-2002 it increased to around 90.12 kilograms per hectare, and during 2012-13 again increased to 128.34 kilograms per hectare (Kolanu and Sunil, 2003 and Department of Fertilizers, 2013). The application of chemical fertilizers like Nitrogen, Phosphorus, and Potassium (N:P:K) in improper ratios is also a major problem in Indian agriculture.

Chemical pesticides are another major input considerably used in Indian agriculture. As the cropping pattern is becoming more intensive, the use of various pesticides like: insecticides, weedicides, fungicides, rodenticides, etc., is also increasing. The consumption of insecticides in agriculture has increased more than 100 per cent from 1971 to 1995. The estimated insecticide consumption in India during 1971 was in the tune of 22,013 tons and it increased to 51,755 tons by 1995 Kolanu and Sunil (2003).

One of the consequences of the indiscriminate use of pesticides is the adverse health impact on society in general, and on the vulnerable sections of the population like children in particular. Some well-known adverse health effects of this chemical pesticide exposure include acute poisoning, cancer, and neurological, reproductive and developmental problems (CSE, 2000). The major cause of concern in this respect is the bioaccumulation of pesticides, and the prolonged time period it takes to manifest the negative health consequences. In Indian agriculture, fertilizers and pesticides have become a major cost component along with other input costs like seeds and labour (Kolanu and Sunil (2003)). However, the quality of soil, the agricultural ecosystem and human health gets affected because of the continuous usage of chemical fertilisers and pesticides.

In brief, the green revolution brought impressive gain in food production but with insufficient concern for bio-diversity. Dependence on chemical fertilizers for future agricultural growth would mean further loss in soil quality, possibilities of water contamination, and an unsustainable burden on the fiscal system. Hence, there is a need to promote bio-fertilisers and bio-pesticides, for environmentally sustainable agriculture as well as for food and health security. A steady increase in organic input production infrastructure has contributed to a significant growth of organic agricultural areas in the country. Bio-fertilizers and bio-pesticides (organic inputs) are essential for organic farming, and their demand will continuously increase in the coming decades.

The government of India has been trying to promote an improved practice involving the use of bio-fertilizers. The government aims not only to encourage bio-fertilizers and pesticides use, but also to promote private initiatives and commercial viability of production.

According to TNAU, (2014) the increasing demand for bio-fertilizers and the awareness among farmers and planters in the use of bio-fertilizers have paved the way for fertilizer manufacture's and new entrepreneurs to get into bio-fertilizer production. A number of bio-fertilizer production units have been started recently, particularly in the southern states of our country. Nationalized banks have started Hi-Tech agricultural programmes providing loan and motivation to entrepreneurs to start their own production units. The Government of India is also encouraging low cost technology by providing a subsidy of up to Rs.20 lakhs, to start a production unit with the capacity of 150 metric tonnes per annum.

India has an excellent record in the production of bio-fertilisers and bio-pesticides. As on date, there are more than 225 bio-fertilizer and bio-pesticide production units, with an installed annual production capacity of more than 125,735 MT, in the country. With the continuous intervention of the Central and State Governments, the production of different organic manures in the country is increasing. During 2010-11 more than 37,997 MT of bio-fertilizers and 69,137 MT of bio-pesticides were produced in the country (Rana, 2013).

The following table (Table 2) provides the data on bio-fertilizer manufacturing in India in recent years and its share in the total fertilizer production in the country. The table reveals that the contribution of the bio-fertilizer is insignificant, but its production has increased over a period.

Table 2

Production of Bio-Fertilizer in India

Year	**Production Total Fertilizer** (Chemical + Bio-fertilizer) **(in tonnes)**	**Production Bio fertilizer (in tonnes)**	**Production of Bio fertilizer in %**
2008-2009	14,334,000	25065.04	0.17
2009-2010	16,221,000	20040.35	0.12
2010-2011	16,380,000	37997.61	0.23
2011-2012	16,363,000	40324.21	0.25
2012-2013	15,735,000	46836.82	0.29

Source: Department of Fertilizer, 2013

Currently, bio-pesticides represent just 1% of the global market for agrochemicals. 90% of the microbial bio-pesticides are derived from just one entamopathogenic bacterium (*Bacillus thuringiensis*). As early as 2013, there were approximately 400 registered bio-pesticide active ingredients, and more than 1,250 registered bio-pesticide products (Kumar and Singh, 2014).

According to Phadke (2001), the limited number of well established firms in this market today is because it is predominantly controlled by a large number of small and local producers of bio-fertilizers, vermicomposting and others. The estimated total potential demand for bio-fertilizers in India is 818,730 million tonnes, which includes *Rhizobium* (35,730 million tonnes), *Azotobacter* (162,610 million tonnes), *Azospirillum* (77,160 million tonnes), Blue Green Algae (BGA) (267,510 million tonnes) and Phosphate solubilizer (275,510 million tonnes) (Phadke, 2001).

The major attributable factors for the preference of bio-pesticides and bio-fertilizers includes: environmental safety, operator safety, public perception and acceptance, crop safety, organic farming, product effectiveness, and economic benefits. In brief, bio-pesticides and bio-fertilizers give health, and safety to the crops, and environmental benefits to the society. However, the major constraints in the development and application of bio-pesticides and bio-fertilizers are: not effective as chemical fertilizers and pesticides, higher cost, lack of public awareness on the overall benefit of bio-pesticides and bio-fertilizers, lack of research, limited availability and very slow functining.

Microorganisms: Key Bio-resource for Product Manufacturing

Microorganisms are very diverse and include all the bacteria and archaea, and almost all the protozoa. They also include some fungi, algae, and certain animals, such as rotifers. Many macro animals and plants have juvenile stages, which are also microorganisms. Some microbiologists also classify viruses (and viroids) as microorganisms, but others consider them as nonliving. Microorganisms live in every part of the biosphere, including the soil, hot springs, "seven miles deep" in the ocean, "40 miles high" in the atmosphere and inside rocks far down within the Earth's crust (see also endolith). Microorganisms, under certain test conditions, have been observed to thrive in the vacuum of outer space (Wikipedia, 2014).

According to a new technical market research report on ‘Microbial Products: Technologies, Applications and Global Markets’ from BCC Research; “the global market for microbial products was valued at $117 billion in 2012 and is expected to grow to nearly $134 billion in 2013”. BCC Research projects the market to reach nearly $179 billion by 2018, and register a compound annual growth rate (CAGR) of 6% (BCC Research, 2013a).

The Biological Diversity Act, 2002 considered microorganisms as one of the bio-resources. The Act defined, "Bio-resources / Biological resources means: plants, animals and micro-organisms or parts thereof, their genetic material and by-products (excluding value added products) with actual or potential use or value, but does not include human genetic material" (National Biodiversity Authority, 2010).

Microbes were used for centuries to produce bread, wine, vinegar, and other common products without anyone knowing the scientific basis for the ingredient. The discipline known today as microbiology was not established until the late 19th century. The technology related to the microbial production of metabolites such as ethanol, lactic acid, butanol, and riboflavin, and enzymes such as protease, amylase, and invertase was developed as early as the first few decades of the 20th century. Large-scale production of the well-known antibiotic penicillin, derived from the *Penicillium* species was perfected during World War II, and the microbial production of other antibiotics, amino acids, nucleotides, and enzymes soon followed (BCC Research, 2013b).

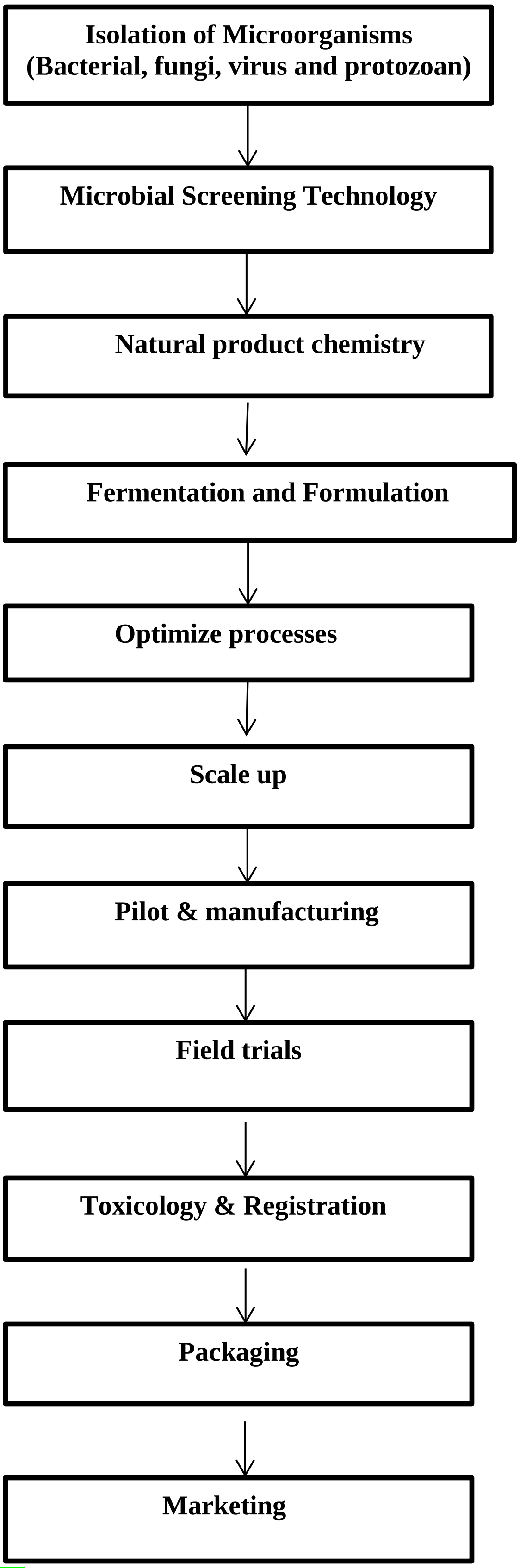
Today, genetically engineered microbes are used for the commercial production of non-microbial products such as insulin, interferon, human growth hormone and viral vaccines. Microbes are also used to produce energy (e.g., biodiesel and bioethanol) and to clean up environmental pollutants such as sewage and oil spills. Microbes are the basis of cost-effective methods of mining and metallurgy (Research BCC, 2013b).

As the active ingredient in bio-fertilizers and bio-pesticides, microbes contribute to increasing agricultural productivity. Indeed, the commercial possibilities of microbes appear endless. Currently only 5% microbes are culturable but there are others of considerable potential value that need to be characterised by new and novel techniques. The 5% culturable microbes have been a source of valuable products (Department of Biotechnology, 2013).

Microorganism as Bio-inputs

In bio-fertilizer and bio-pesticide manufacturing, research and development play a significant role, which is provided in the following figure (fig. 1).

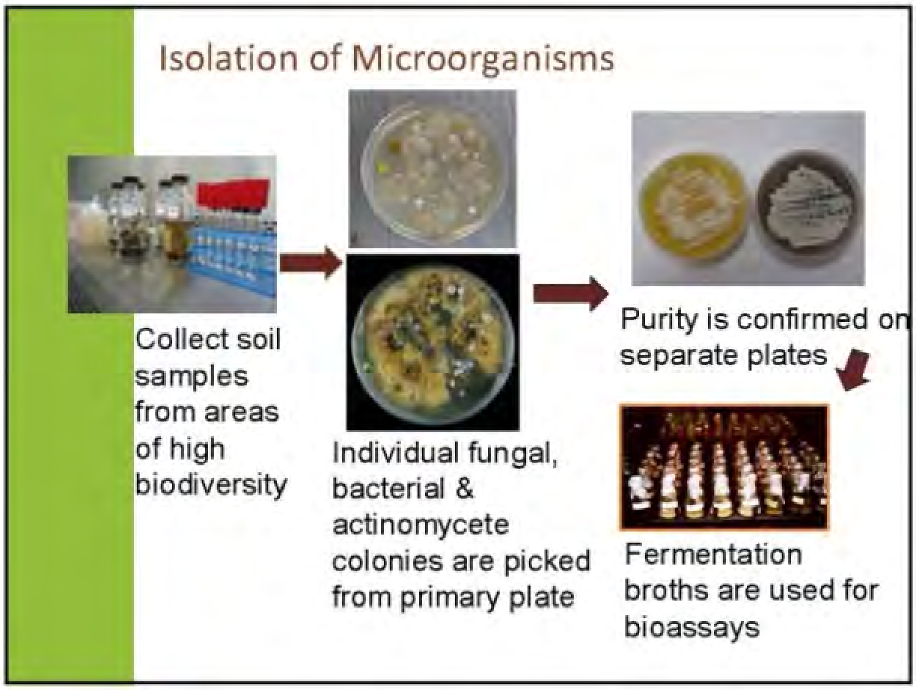
Figures 1: Research & Development Process in Bio pesticides Manufacturing



Source: Marrone (2014).

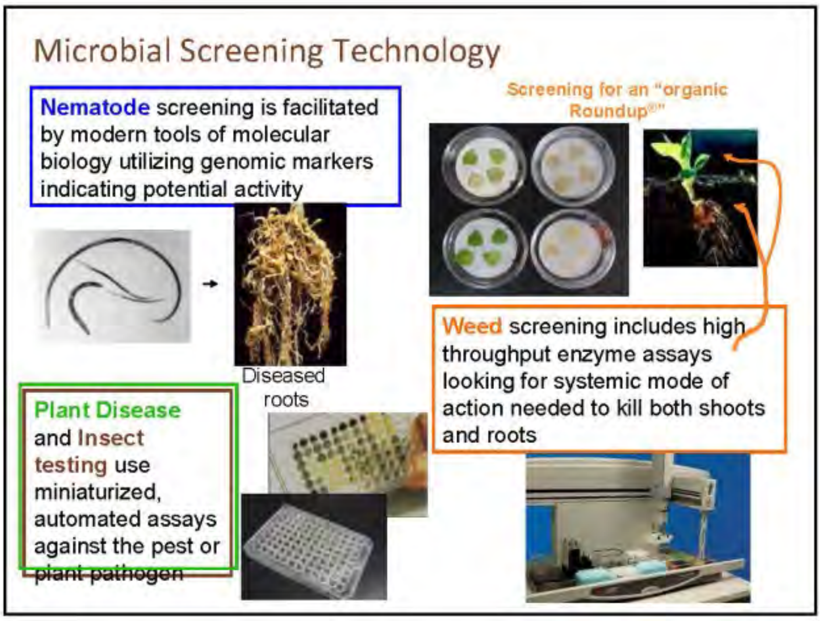
The following figures (figures 2 to 5) explain the major activities of the R & D division of a typical bio-fertilizer unit, with the basic scientific explanations.

Figures 2



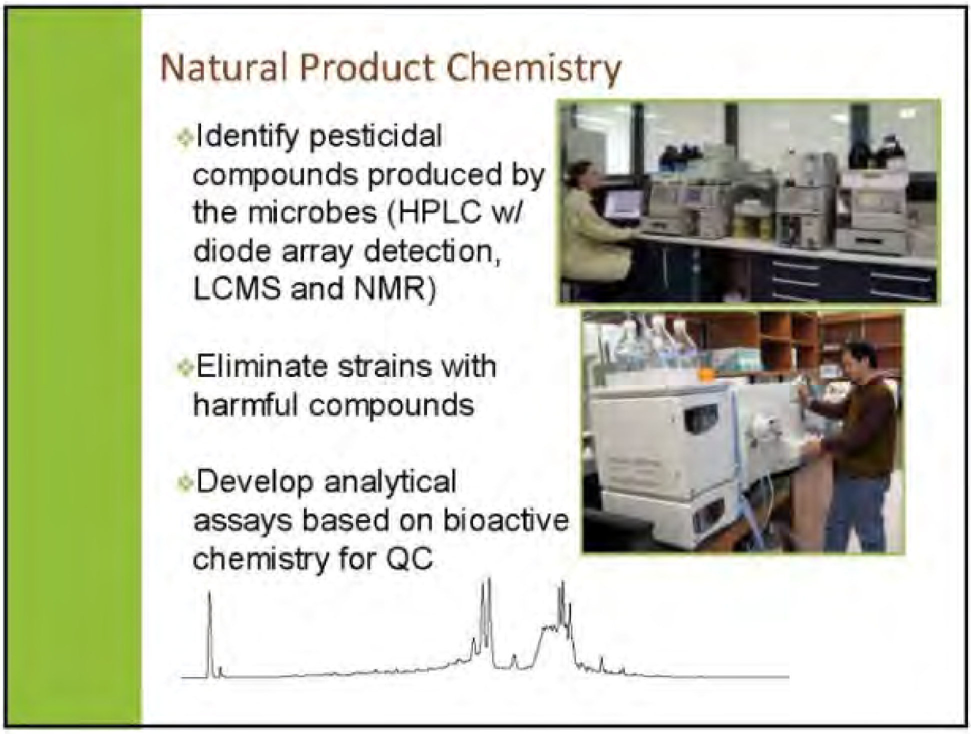
Source: Marrone (2014).

Figures 3



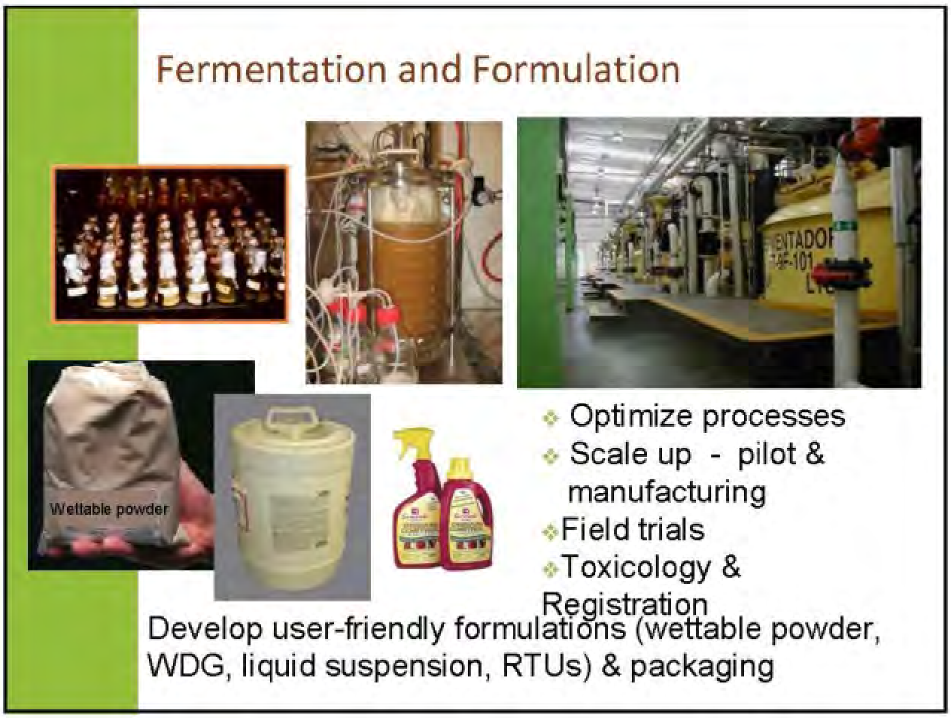
Source: Marrone (2014)

Figures 4



Source: Marrone (2014)

Figures 5



Source: Marrone (2014)

This section (part 1) explains various complexities of the applications of chemical fertilizers and pesticides in farming, and the significance of bio-input for sustaining our agriculture and achieving food and health security. In bio-fertilizer and bio-pesticide manufacturing, micro-organisms are the major bio-resources. However, the application of science is critical in isolation, screening and development. The manufacturing process of bio-inputs is discussed in a broader context based on the secondary information.

However, it is important to understand the bio-fertilizer and bio-pesticides manufacturing process, more in an ABS perspective with the help of a comprehensive case study, which has not been carried out so far either in the existing literature on microorganisms or ABS. Hence, a primary study on a Tamil Nadu based crop protection products manufacturing company (Main Bio-control Research Laboratory), and a bio-fertilizer company's generic model (cost estimation) developed by TNAU was considered for analysis.

PART 2

A. CASE STUDY ON CROP PROTECTION PRODUCTS MANUFACTURING COMPANY MAIN BIO-CONTROL RESEARCH LABORATORY

Brief Profile and Objectives

The Main Bio-control Research Laboratory (MBRL) is a unit that comes under the Tamil Nadu Co-operative Sugar Federation. The laboratory was established in 1982. Right from its inception, the unit has been serving the sugar cane growers in the state, primarily through bio-inputs namely, bio–fertilizers and bio-pesticides. This unit is one of the pioneers in Indian bio-fertilizers' production with a higher production capacity, exclusively for a mono crop, sugarcane. Its major supply is for its member co-operative and public sector sugar mills of this state. The unit is endowed with skilled man power and excellent infra-structural facilities, and simultaneously involved in catering to the needs of sugarcane growers through its innovative technological and R & D solutions. This laboratory is recognized by the Department of Scientific and Industrial Research (DSIR), Government of India, New Delhi.

The major objectives of this laboratory include:

1. To undertake mass production and distribution of bio-inputs through its member sugar mills to sugarcane growers of Tamil Nadu
2. To minimize the utilization of chemical fertilizers and chemical pesticides in sugarcane cultivation, and to enhance the soil fertility by the application of bio-inputs

3. To impart the technology on vermicomposting production by utilizing the indigenous earthworms to member sugar mills
4. To increase the awareness on organic farming, to popularize the production technology of bio-control agents for the control of sugarcane pests in the sugarcane ecosystem and to reduce the environmental pollution hazards, and
5. To give technical guidelines to increase the production to the member sugar mills (MBRL, 2012).

Research and Development and Production Processing

In crop protection product manufacturing, particularly microorganisms based bio-prospecting, research and development play a significant role. This laboratory is involved in rigorous research for isolating microorganisms and developing suitable bio-fertilizers and pesticides.

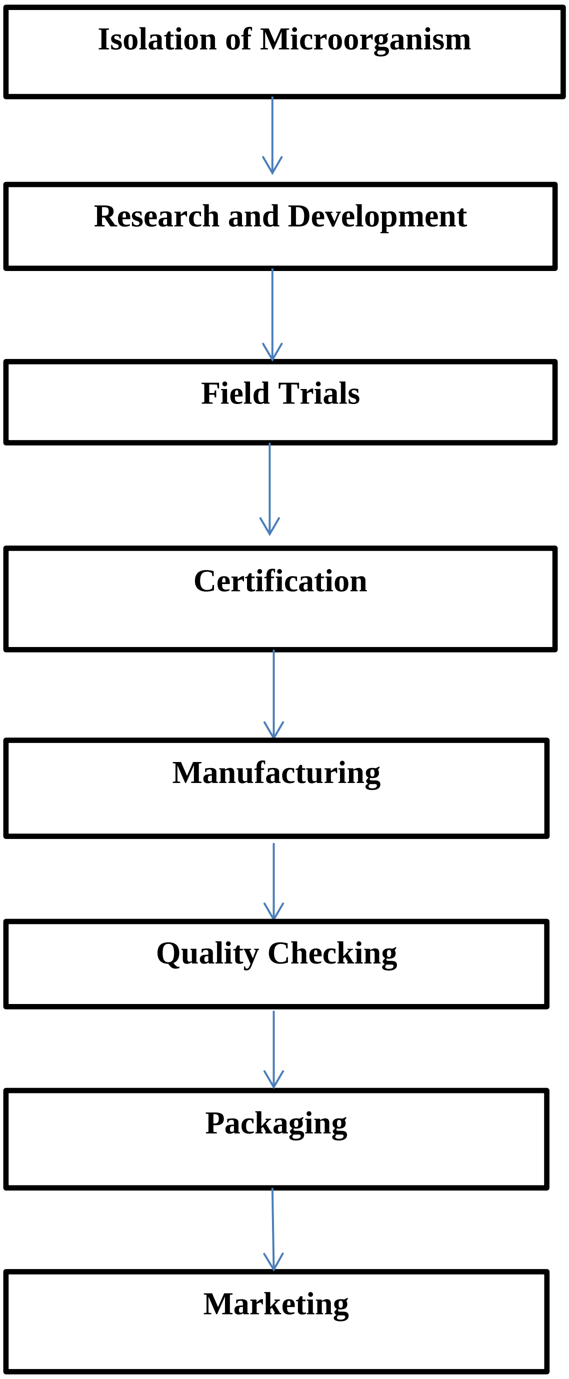
The major research activities of MBRL include:

- Research works on nitrogen-fixing *Gluconacetobacter diazotrophicus*, *Herbaspirillum spp.*, *Burkholderia spp*. etc., phosphate and potash solubilizing bacteria, *Arbuscular mycorrhizae*, and agricultural waste degrading / decomposing microorganisms.
- Research activities pertaining to bio-control agents like *Trichogramma* parasitoids, *Bacillus thurigiensis, Pseudomonas fluorescens, Trichoderma viride* and *Metarrhizium anisopliae.*
- Isolation of different nitrogen fixing bio-fertilizer strains, and maintaining a strain bank for the sugarcane crop in Tamil Nadu.
- Establishment of *Methylobacterium* as a new bio-fertilizer for the improvement of the sugarcane yield.
- Mass production of entomo pathogenic fungi *Beauveria bassiana,* and Metarrhizum for the control of sugarcane pests.
- MBRL is getting a financial grant for Research schemes from different funding agencies like the Tamil Nadu Co-operative Union, Department of Biotechnology, and the Sugar Development Fund, from the Government of India. Further, Collaborative Research Schemes are also being undertaken and submitted to the various funding agencies (MBRL, 2012).

The following figure (figure 6) reveals the broader steps involved in the crop protection products manufactured by MBRL.

Figure 6

Steps involved in Manufacturing of Bio-pesticide and Bio-fertilizer in NBRL



Source: Personal Interview (2013)

The major products manufactured by the unit include: Gluconoacetobacter diazotrophicus (Biofertilizer), Phosphobacterium (Biofertilizer), Trichoderma viride (Bio pesticide), Pseudomonas florescence (Bio pesticide), Arbuscular mycorrhiza (Fungicide), Metarhizium anisopliae (Fungicide), Bio inoculum and Granulosis virus/Bt.

Even if the above indicated broader steps (flow chart) are followed by the company there are some technical differences depending on the microbial strains that may occur based on the product / output.

The following Box (Box 1) briefly highlights the development process and requirement of *G. acetobacters*, in MBRL.

Box – 1

Nitrogen fixing root associative bacteria *Acetobacter* have been identified for commercial utilization. *Acetobacter* is an obligate aerobic, although it can grow under low O_2 concentration. The *endophytic diazotrophic* bacterium *G. diazotrophicus* is a nitrogen fixing acetic acid bacterium, first isolated from sugarcane plants. It occurred in high numbers in economically important grass sugarcane. Individual *endophytic diazotroph* can fix atmospheric N_2 in plants and convert it in to nitrates and nitrites. From unfertilised samples, microbial populations can be enumerated up to dilutions of 10^{-5} to 10^{-7} g^{-1} fresh weight in roots and stalks (Muthukumarasamy 2000). In general, the amount of N_2 fixed by *G. diazotrophicus* (nitrogen-fixing) microorganisms has been estimated to be 10^{11} kilograms per year, about 60% of the earth's newly fixed nitrogen.

Inputs (raw-materials) and Outputs (Products)

The following table provides the details on major bio-resources (microorganisms as input) and the different bio-fertilizers and bio-pesticides derived from them in MBRL. The bio-resources used for manufacturing different bio-products also require certain specific criteria. As per our investigation these are the standard ones, and are unanimously followed by all the manufacturing companies.

Table 2

Bio-products derived from the Biological Resource

Biological resource (as an input)		Bio-product - Bio-fertilizer & Bio-pesticides (as output)	Category of Inputs
Category of Microorganism	**Scientific name of Microorganism (with viable count cell)**		
Bacteria	*Gluconoacetobacter diazotriphicus* (CFU count on minimum $5x10^7$ cell/g of powder, granules or carrier material or $1x10^8$ cell/ml of liquid)	Acetobacter	Fertilizer
	Phosphobacterium (CFU minimum $5x10^7$ cell/g of powder, granules or carrier material or $1x10^8$ cell/ml of liquid).	Phosphobacterium	Fertilizer
	Pseudomonas (The concentration of cell suspension was 4.6×10^8 CFU/ml or gm for *Pseudomonas florescence)*	Pseudomonas florescence	Pesticide
Fungi	*Tricoderma viride* (CFU count on selective minimum should be 2×10^6 per ml or gm for *Trichoderma* spp).	Tricoderma viride	Pesticide
	Arbuscular mycorrhiza (100 /g of finished product)	A. Mycorrhizae	Fungicide
	Metarhizium anisopliae (10^4 - 10^{10} spores/ml). Tween-80 is added @ 0.01% to get uniform spore suspension. Or 1×10^8 cells /g	B. Metarhizium anisopliae	Fungicide
Virus	*Granulosis Granulosis/Bacillus thuringiensis(Bt)* $5x10^9$ Capsules/ml or g. (minimum).	G. Virus/Bt	Pesticide
Microbial mixture	*Bio-inoculum* (CFU minimum $5x10^7$/g)	Bio-inoculum* – an Agro waste decomposing product	Decomposer

Note:*A composite mix of thermophilic microbes)

Source: Modified based on the MBRL, (Data) 2012

The following table (table 3) provides the input requirements (bio-resources and others) for manufacturing different bio-fertilizers and bio-pesticides.

Table 3
Inputs Requirements for Manufacturing 1 tonne of Crop Protection Products

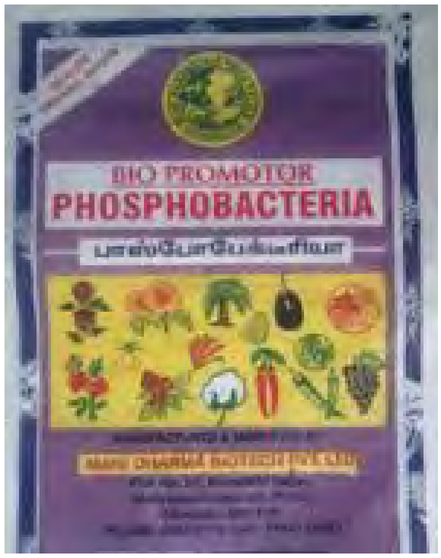
Sl. No	Name of the Bio-product	Inputs	
		Bio resource with criteria	**Other Inputs (chemicals/strain/medium)**
1	Gluconoacetobacter diazotrophicus (Biofertilizer)	**Bacterium:** *Gluconoacetobacter diazotrophicus* (CFU count on minimum 5×10^{13} cell/MT of powder)	1. Manitol (2kg) 2. Peptone (500g) 3. Yeast (625g) 4. Acetic acid (2.5 lits) 5. Lignite
2	Phosphobacterium (Biofertilizer)	**Bacterium:** *Phosphobacterium* (CFU count on minimum 5×10^{13} cell/MT of powder)	1. Glucose (2.5 kg) 2. K_2HPO_4 3. yeast (125 g) 4. Mannitol (12g) 5. $MgSO_4$ (25g) 6. Nacl (50g) 7. KCL (50g) 8. $FeSO_4$ (12.5g) 9. $CaCO_3$ (50kg) 10.Lignite
3	Trichoderma viride (Bio pesticide)	**Fungi:** *Trichoderma viride* (CFU count on selective minimum should be 2×10^{11} /MT)	1. Jaggery(4kg) 2. Yeast (1 kg) 3. Rigfemycin tablet (8 nos) 4. Talcum powder
4	Pseudomonas florescence (Bio pesticide)	**Bacterium:** *Pseudomonas* (The concentration of cell suspension was 4.6×10^{14} CFU/MT)	1. Peptone (5kg) 2. Glycerin (2.5 lts) 3. K_2HPO_4(375g) 4. $MgSO_4$(375g) 5. Talcum – 1 MT
5	Arbuscular mycorrhiza (Fungicide)	**Fungi:** *Arbuscular mycorrhiza* (100000000/MT of finished product)	1. Vermiculate 1 MT – 6900 + Transport charges from Tanin Godown 2. Hybrid Maize seeds 1 kg 3. Mother Culture 35 per kg 4. Labour cost for maintaining host plant maize for 60 days harvesting- Rs 250 per day * 60days)
6	Metarhizium anisopliae (Fungicide)	**Fungi** *Metarhizium anisopliae* (1×10^{14} cell/MT)	1. Dextrose 10 kg 2. Mycological peptone (2.5kg) 3. Chlorophenol tablet (8 nos) 4. Talc 1 MT
7	Bio inoculum	*Agro waste decomposing product* (CFU count on minimum 5×10^{10} cell/kg)	1. Bacteria 2. Fungi and 3. Actinomycetes
8	Granulosis virus/Bt	*Granulosis virus/Bt* (5×10^{15} capsules per MT)	1. D. Glucose (2.5 kg) 2. Yeast extract (1.25kg) 3. Soap oil 10

Source: NBRL, 2012 and National Centre of Organic Farming (2014)

Each bio-input has a unique procedure in the application in the field, and its influence on the crop in different ways, which is indicated in the subsequent secession.

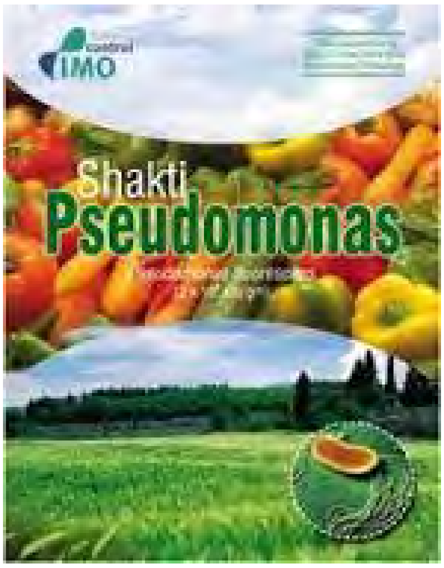
Gluconoacetobacter Diazotrophicus: *Gluconoacetobacter diazotrophicus* biofertilizer helps in nitrogen fixation. *Acetobator* have been isolated from the rhizosphere and roots of sugarcane. The bio-fertilizer *G. diazotrophicus* is tested in the field, and then used by the farmers in different districts in Tamilnadu. The proposed quantity of the acetobactor fertiliser for one acre of agricultural land is 4 kilograms. The sugar cane stem dipped in the fertiliser solution for 10 minutes (2 kg of acetobactor can be mixed with 100 litres of water) can be used. The rest of the 2 kg acetobactor can be used in the surroundings of the stem in the soil in the initial stage of the planting. This can also be applied with other fertilizers. Farmers can obtain extra benefits to the tune of 2 to 5 tons yield per acre (MBRL, 2013a).

***Phosphobacterium*:** Phosphobacterium is a bacterium which helps to solubilize complex phosphates molecule into simpler molecules, and make them available to the growing plants. The above bacterium can be mixed with other fertilisers and applied in the field. The proposed quantity of phosphobacterium fertiliser for one acre agricultural land is 2 - 4 kilograms. Generally, Phosphobacterium has to be mixed with 50 to 100 kilograms of dry compost and applied to the soil. Farmers have to follow the prescribed procedure when they apply phosphobaterium in the field. Farmers can obtain extra benefits in the tune of 2 tons yield per acre (MBRL, (2013b).



Trichoderma viride: *Trichoderma viride* is a fungus and is used as a biofungicide. This fungus is isolated from red rot diseased sugarcane, to control the red rot disease in sugarcane. The proposed quantity of *Trichoderma* is 1 kilograms per acre. To avoid *T.viride* pest attack the sugarcane stem should be dipped for 10 minutes, in a mixture of 200 litres of water, 1 kilogram of *T. viride* and 2 kilograms of Gaggery in the initial stage of planting (MBRL, 2013c)

Psuedomonas flurescens: *Psuedomonas flurescens* is a bacterium, which is isolated from the rotted root and stem of the pest attacked portion of the sugar cane. *P. flurecens* pesticide is developed to control the sugar cane pest in the root and stem of sugar cane. This pesticide can be used for sugarcane, vegetable & fruit plants, paddy crops, Banana, cash crops and other seed crops. The proposed quantity of P.flurescens is 1 kilograms per acre.1 kilogram pesticide has to be mixed with 100 litres of water. The stem has to be soaked in the mixed solution before planting. The application procedure should be followed as per the instruction given in the pack/pamphlet. It can be used with any bio-fertiliser, but not with chemical fertilizers and pesticides (MBRL, 2013d).



Bio-inoculum: Bio-inoculum is a mixture of thermophilic bacteria (30-55˚C), fungi, Actinomycetes and press mud. Bio-inoculum helps to decompose all kinds of agricultural waste**.** It also helps to breakdown/decompose hard sugar substances like cellulose, hemicellulose, pectin and lignin from agro-waste. The agro-waste from one acre of land can be decomposed with one kilogram of Bio-inoculum. The Bio-inoculum can be easily prepared by the farmers in their own land. 1 kilogram of bio-inoculum along with 500 kilograms of press mud, 2.5 kilograms of "Rock" Phosphate, 2 kilograms of Gypsum and 0.5 gram of urea has to be applied in one

acre of the crop field. Farmers are required to follow the application procedure in their fields (MBRL, 2013e).

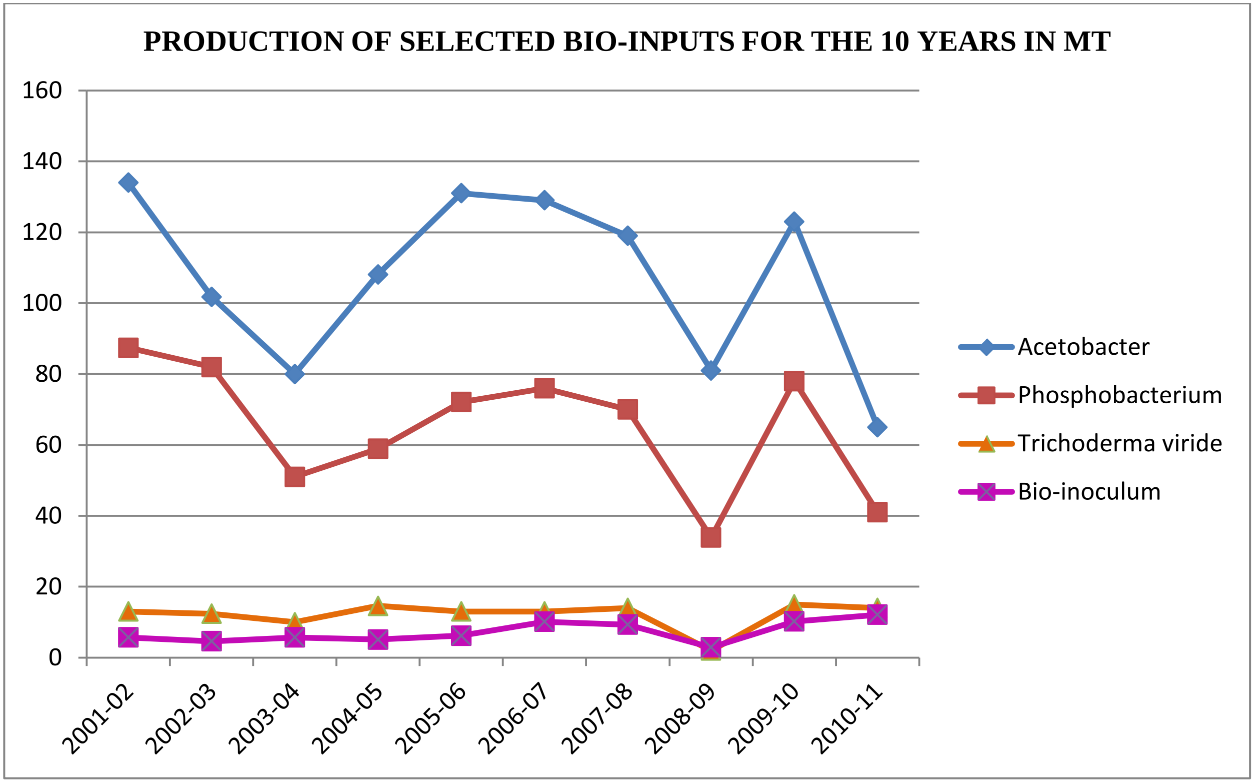
<u>G.virus/Bt:</u> Biotechnological techniques are used to isolate the *Granulosa virus* and *Bacillus thuringiensis(Bt)* to control the pest *Chilo infuscatellus* Snell of the sugarcane. Biopesticides are the best controllers of *G.virus* and *Bt. The proposed quantity of G.Virus/Bt for one acre is* 500 ml (250 ml each). These pesticides help to control the young shoot of the sugar cane. Both microorganisms will enter the worms and kill the pests. Particularly, *Bt* will produce a toxic protein. The toxic protein present in the cells of *Bt* will affect the intestine of the worm when it is consumed. Finally, the worm stops eating the young shoot of the sugarcane. *G.v/Bt* should be applied in the sugarcane field once in 15 days. In order to control the pest already present inside the stem, the remaining 250 ml of G.virus/Bt has to be mixed with 200 litres of water and sprayed, using a hand pump after 3 pm (MBRL, 2013f).

Production Trend and Sale Revenue of MBRL

MBRL made substantial progress in developing new bio-fertilizers and bio-pesticides for sugar cane growers. Since the laboratory is in the Sugar Cane Federation, the member unit's willingness for cultivation as well as its demand for bio-fertilizers and bio-pesticides influences the company's production. It is observed that substantial variation occurs in the production of different bio-inputs over the years.

The following figure (Figure 7) provides the manufacturing trend of the selected bio-fertilizer and bio-fertilizer in MBRL from 2001-02 to 2010-11.

Figure 7



Source: Based on the MBRL, 2012 report data

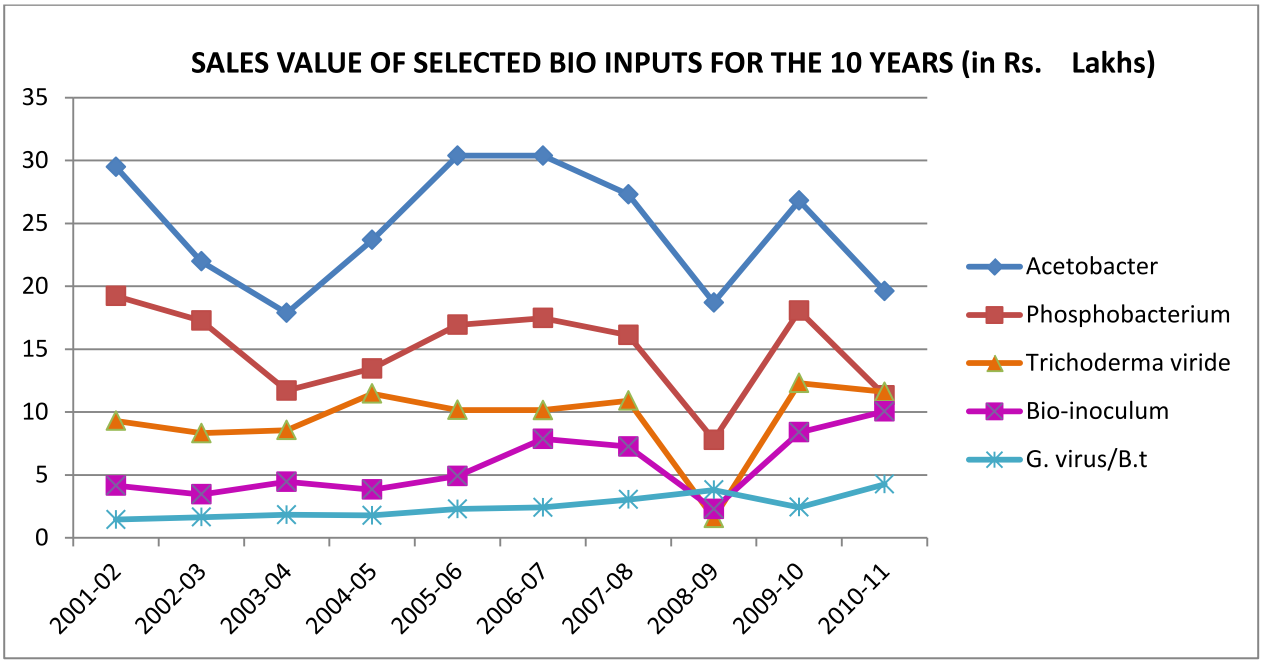
It is clear from the figure, that in the case of Trichoderma viride and bio-inoculum (bio-pesticides), there is not much variation in the production. But in the acetobacter and phosphobacterium's (bio-fertilizer) case, substantial variations (year wise) exist.

Generally, the manufacture of products (bio-fertilizer and bio-pesticide) will vary every month based on the seasons of sugar cane cultivation. The production will be less from January to April (non-cultivating season) and high from May to December (cultivating season).

The following figure provides the sale values of selected bio-fertilizer and bio-fertilizer supplied by MBRL from 2001-02 to 2010-11.

In proportion to the production trend, the sale value of bio-fertilizer and bio-pesticides also varies significantly over a period (fig 8).

F igure 8



Source: Based on the NBRL, 2012 report data

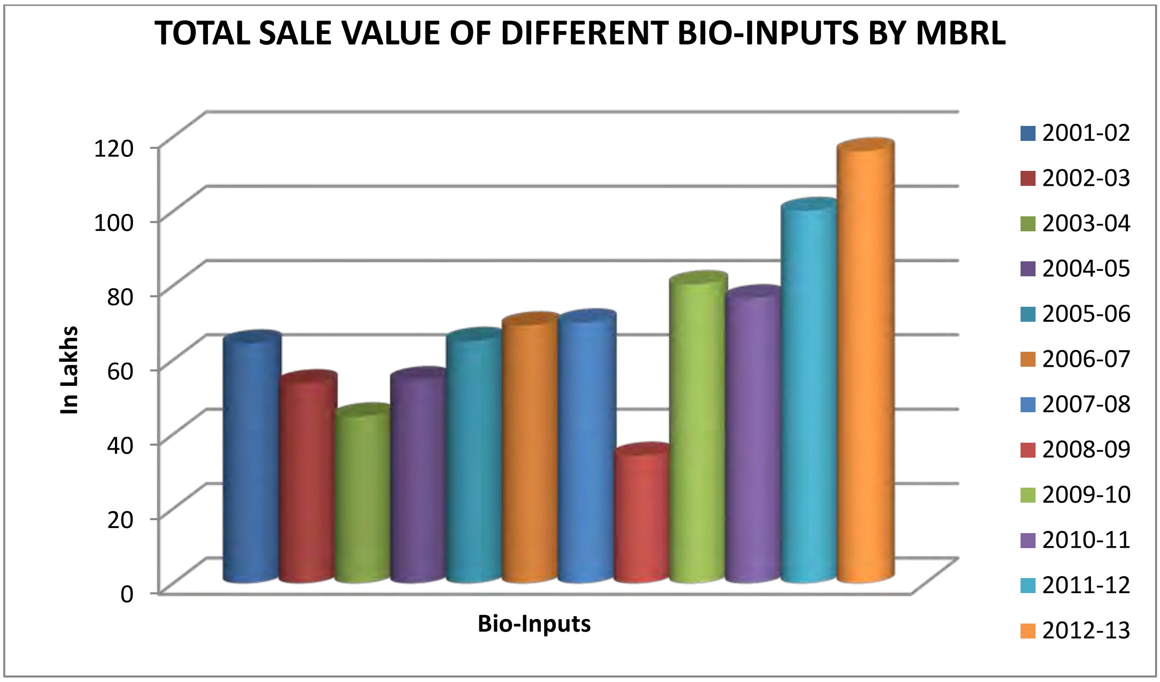
The production of different bio-inputs and sale achievement of the unit during 2012-13 is given in table 4 and figure 9.

Table 4

Production and Sales Statement for the Year 2012-2013

SL. NO	Name of The Product	Unit Price Rs.	Production Achievements in MTs	Sales Achievements	
				Rs. In Lakhs	% In Total Sale
1	Acetobacter	30 per kg	146.00	39.33	33.90
2	Phosphobacterium	30 per kg	80.00	22.35	19.26
3	T. viride	85 per kg	16.02	13.65	11.76
4	Pseudomonas	70 per kg	14.50	10.11	8.71
5	Bio-inoculum	83 per kg	18.41	15.50	13.36
6	B. Mycorrhizae	30 per kg	18.93	5.58	4.81
7	Metarhizium	70 per kg	5.00	3.50	3.02
8	G. Virus	45/250ml bottle	13608 bottles	6.01	5.18
GRAND TOTAL				**116.03**	**100.00**

Source: MBRL (2013)



Since MBRL is a non-profit (no loss) making unit, the bio-inputs' price is equitable with the cost of production. As the laboratory comes under government control, various crop development schemes initiated by the Agricultural Department and subsidies also influence the price fixation of the product.

However, the crop protection products manufactued by private companies are supplied at a high price. We realized that in a private crop protection product manufacturing company, which supply the same bio-input, which MBRL is supplying, at 100% price hike.

Achievements of MBRL

During the last 3 decades the laboratory has made substantial achievements, which help the sugarcane growers in the state in increasing their productivity and environmentally sustainable farming. The major achievements of the laboratory are:

1. MBRL was the first laboratory to mass multiply the *Trichogramma* parasitoid for the control of intenode borer in sugar cane.
2. MBRL was the first laboratory to isolate, identify and mass multiply the new bio-fertilizer *Gluconactobacter diazotrophicus* for sugarcane, to reduce 50% chemical N fertilizer application.
3. Mass multiplication of *Bacillus thuringiensis* for the control of Early Shoot Borer in sugarcane.
4. Introduction of bio-inoculum for hastening the decomposition of sugarcane trash and other agricultural wastes into organic manure.
5. Introduction of recycling technology in sugar mills through earthworms and bio inoculum for the production of Vermicompost, utilizing sugar industry by–products like bagasse and pressmud.
6. Mass multiplication of biopesticide *Metarrhizium anisopliae* for the control of white grub in sugar cane.
7. Mass multiplication of bio-fertilizer *Arbuscular Mycorrhiza* for sugarcane (MBRL, 2013).

MBRL also successfully come up with a strategy for the application of different bio-fertilizers and bio-pesticides to sugarcane and its advantages, which are summarised in table 5.

Table 5: Bio-Inputs and their Appropriate Usages

Name of Bio-inputs	Recommended dose/acre	Usage
Gluconacetobacter diazotrophicus	4 Kgs	To reduce usage of 2 bags of urea/acre (50% of recommended dose of inorganic nitrogen) in cane cultivation and to increase yield by 2 – 5 tonnes/acre (Developed at MBRL)
Phosphobacterium	2 Kgs	To reduce 25% of inorganic phosphate application
Trichoderma viride	1 Kg	To contain red rot disease in sugarcane
Pseudomonas fluorescens	1 Kg	For the control of sett rot disease and growth promotion in sugarcane
Bio-inoculum (A composite mix of thermophilic microbes)	1 Kg	For conversion of sugarcane trashes, pressmud, bagasse and any plant wastes into enriched compost (Developed at MBRL)
Arbuscular mycorrhiza	5 Kgs	To enable easy uptake of nutrients, especially phosphate from soil by plant crops
Bacillus thuringiensis	500 ml	For the control of Early Shoot Borer of Sugarcane
Metarrhizium anisopliae	2 Kgs	For the control of White grub borer in sugarcane

MBRL, 2012

MBRL plays a significant role in awareness generation among the sugarcane growers about the superiority of bio-fertilizers and bio-pesticides application. As part of the capacity building, they are organizing a series of training programs and seminars, emphasising on the technologies of bio-inputs and their effective applications. They also prepare leaflets and distribute them widely among the farmers. MBRL is publishing a bimonthly home journal "*Karumbu Karangal*" in Tamil and distributes it to nearly 3000 sugar cane growers.

The active involvement of the unit provides commercial benefits to the sugarcane growers in the state by reducing the cost of sugarcane cultivation by advocating the use of bio-fertilizers and bio-pesticides, increasing the sugarcane yield to fetch more net income to the farmers and improving the soil health.

Continous research for achieving effective bio-inputs for sugar cane farmers is a major motto of MBRL. The Future Research Plan of MBRL emphasises on the following aspects:

- The development of *Methylobacterium* as a new bio-fertilizer for sugarcane to improve the cane yield.
- Establishment of location specific N_2 fixing strain bank for the supply of biofertilizer for better sugarcane productivity.
- Mass multiplication of sugarcane through tissue culture
- Isolation and mass multiplication of *Bacillus thuringiensis* and *Metarrhizium anisolpliae* for the control of termites and white grubs in sugarcane.
- Development and promotion of a liquid bio-fertilizer for sustainable sugarcane production.
- Development of a microbial consortium for Plant Growth Promoting *Rhizobacteria* (PGPR) for the control of red rot and sett rot disease of sugarcane and reducing the utilization of chemical fertilizers.
- Promotion of pheromone traps for pest control.
- Effective cellulolytic, pectinolytic and lignin degrading microbes, isolated and identified by using different substrates. Analysing the effectiveness of these microbes on different agricultural wastes. Also to conduct field trials in the sugar mills to test the usefulness of Bio inoculum for composting.
- To identify heat tolerant strains of *sturmiopsis inferens* to control the shoot borer.
- To conduct field trials using the fungus *Fusarium sp.*, for the control of the scale insect, which is a serious pest in sugarcane.

Value Chain Analysis and Cost of Production Estimation

Generally, value addition for bio-resources (raw) and bio-resources based products occurs either through transaction costs or / and processing or manufacturing costs. Transaction costs are the costs of particular bio-resources' movement from their collection point to the company gate, and those that occur through transportation charges and brokers or dealers' profits. Normally, the bio-resources' transaction may take place through different agencies such as federations, wholesalers, and retailers at different locations before reaching the final consumer and the price spread for the resources will occur. The ABS concern is whether the price spread is reasonable or not, and if not, what are the abnormalities, and how will it bounce back to the communities or providers of the resources.

Further, certain bio-resources are basic raw-materials for manufacturing the final consumer products. Besides, many other products (inputs), and knowledge/ skill (research and development), also contribute to an output production. Hence, the processing or manufacturing costs at different stages are significant. Through an amortised (remunerated) pricing technique, one can estimate the real price of the bio-resources. The same approach is applicable in the case of bio-prospecting based research and development.

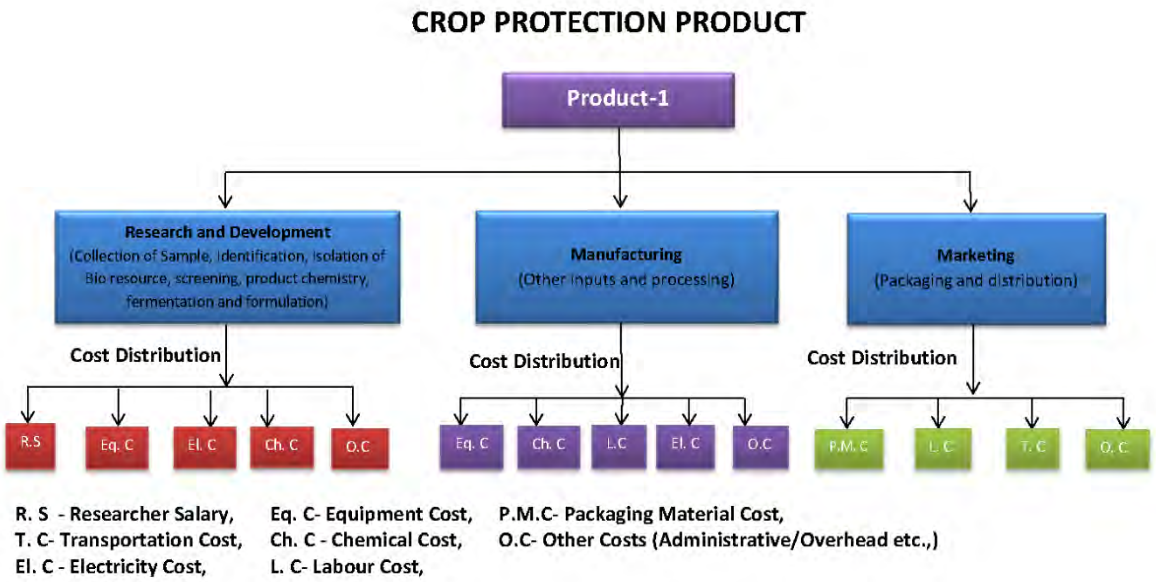
In the case of our case study unit (MBRL), the transaction cost of bio-resources (microorganisms) is insignificant, since it is collected by the company officials directly from the soil as a onetime sample. Otherwise, the mother collection of microorganisms can be done either from TNAU or from other collection centres, where the unit is spending or paying around Rs. 5000. However, the manufacturing process and its value addition analysis are significant.

The following figure (Figure 10) showed a broader example of the microorganism's value addition through production costs.

Figure 10

For our convenience, crop protection products value addition has been estimated based on the cost escalation under 3 heads: research and development, manufacturing, and marketing. Under each head different cost distribution criteria were indicated (the format is shown in figure 11).

Figure 11



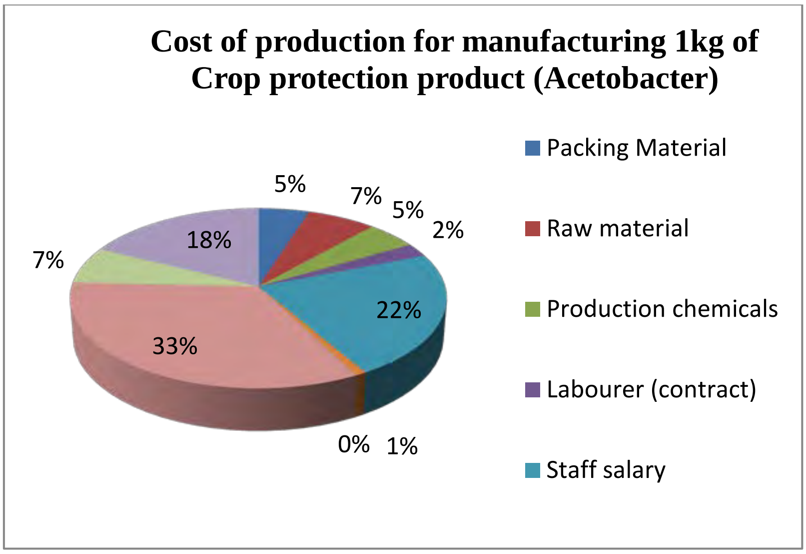
Further, with the assigned format, we approached the MBRL officials for detailed information. The officials appreciated the format and guaranteed that they will furnish the information in the prescribe format, since it is extremely useful for the laboratory also. However, they indicated the complexity in cost estimation. But at the end we received the information in a different manner. Table 6 and figure 12 provide a rough estimation of the different costs incurred for the manufacturing of 1 kg of *Acetobacter* .

Table 6: Rough Estimation of the Cost of Production of (1 kg *Acetobacter*)

Sl. No	Particulars	Cost (Rs./ kg)	Percentage (%)
1	Packing Material	1.48	4.93
2	Raw material	2.00	6.67
3	Production chemicals	1.50	5.00
4	Labourer (contract)	0.73	2.43
5	Staff salary	6.73	22.43
6	Electricity charge	0.26	0.87
7	Telephone charge	0.02	0.07
8	R & D with equipment cost	10.00	33.33
9	Building cost	2.00	6.67
10	Other cost	5.28	17.60
Total		**30.00**	**100.00**

Source: Personal Interview with MBRL Scientists

Figure 12



Source: Personal Interview with MBRL Scientists

It is clear from the table, that the research and development cost (33.3%) and staff salary (22.3%) are the major cost components in bio-resources' production. Since the laboratory is under government control, it functions with the motto of 'non-profit and non-loss', and there is no profit or benefit head in the cost distribution. But our investigations reveal that private companies supply the acetobacter at double the price of MBRL, that is, with a high benefit ratio.

B. <u>Benefit / Profit Estimation: A Generic Model by TNAU</u>

Generally, the success of the bio-fertilizer and bio-pesticide project depends entirely on its economic viability. With this objective, the Tamil Nadu Agricultural University – TNAU - (Department of Microbiology) made an approximate estimation on the overall economics of the bio-fertilizer production and sales. The following table (table 7) and the figure (figure 13) provide the total estimate for starting a bio-fertilizer production unit with the capacity of 150 metric tonnes / annum.

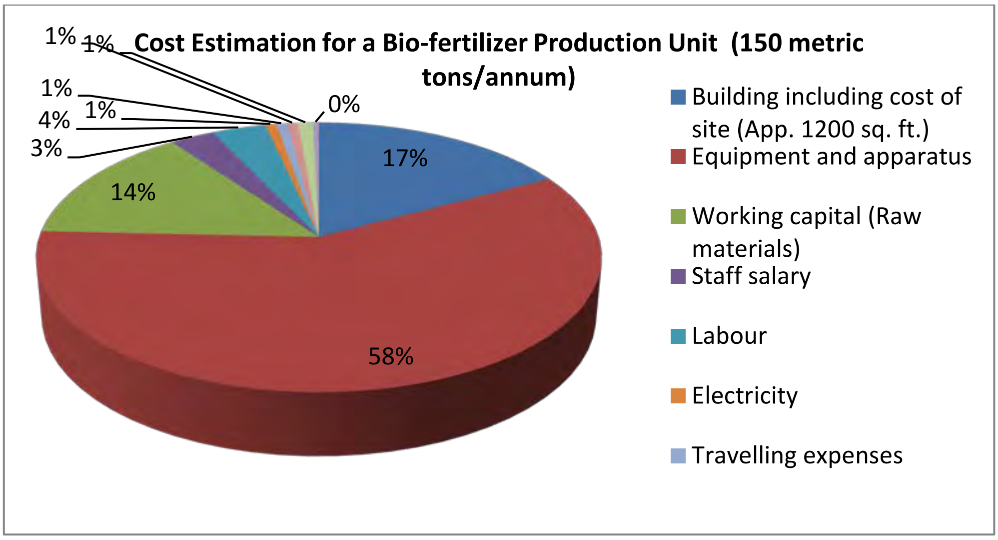
Table 7: Cost Distribution of a Bio-fertilizer Production Unit (Capacity of 150 metric tonnes/annum)

Particulars / Expenditure*	Amount (Rs. in lakhs)	%
Capital Investment (Fixed Cost)		
Building including cost of site (App. 1200 sq. ft.)	12.00	
Equipment and apparatus	41.00	
A. Total Capital Cost	***53.00***	***75.71***
Operational Cost (Variable Cost)		
Working capital (Raw materials)	10.00	
Staff salary	2.04	
Labour	2.50	
Electricity	0.50	
Travelling expenses	0.50	
Administrative expenses	0.50	
Interest on loan and depreciation	0.70	
Miscellaneous expenses	0.26	
B. Total (variable cost)	**17.00**	**24.29**
Total Cost (A+B)	**70.00**	**100.00**

* The expenditures does not include the marketing expenses

Source: TNAU, 2014

Figure 13



It is clear from the table that the capital costs (75.71%) are more significant than the variable costs (24.29%). In the costs, those of the equipment and apparatus, building rent, and working capital (raw materials) are the major ones. Tables 8 and 9 provide the details on the equipment and apparatus, and working capital (raw materials).

Table 8: Expenditure on Equipment and Apparatus

S.No.	Equipment and apparatus	Qty (Nos.)	Amount (Rs.in lakhs)
1.	Fermentor (200 lit. capacity)	4	26.00
2.	Shaker	2	1.50
3.	Laminar air flow chamber	1	0.60
4.	Autoclave	2	0.30
5.	Hot air oven	1	0.10
6.	Incubator	1	0.10
7.	Refrigerator	1	0.30
8.	Microscope	1	0.75
9.	pH meter	1	0.15
10.	Physical balance	1	0.10
11.	Electronic balance	1	0.75
12.	Counter-poise balance	5	0.25
13.	Sealing machine	5	0.25
14.	Work benches	4	0.30
15.	Plastic trays	50	0.25
16.	Trays (Zinc/Aluminium)	10	0.20
17.	Trolley	1	0.10
18.	Automatic packing machine	1	9.00
	Total		**41.00**

Source: TNAU, 2014

Table 9: Expenditure for Working Capital (raw-materials)

S.No.	Raw materials	Amount (Rs.in lakhs)
1.	***Cost of mother culture***	***0.05***
2.	Glasswares	0.70
3.	Chemicals	2.50
4.	Polythene bags	3.50
5.	Carrier materials	3.00
6.	Miscellaneous items	0.25
	Total	**10.00**

Source: TNAU, 2014

It is clear from the above table, that the bio-resources' (mother culture) cost is only Rs. 0.05 lakh for manufacturing 150 tonnes of bio-resources per annum. Here, the bio-resources' cost comes to only 0.5 % of the raw-material cost and 0.07% of the total cost of production. Generally, the production of bio-resources depends on the capacity of the unit (table 10).

Table 10; Production Variation

Capacity	Quantity / Year
60%	90 MT
75%	112.5 MT
90%	135 MT
100%	150 MT

Source: TNAU, 2014

Profitability variation also depends on the capacity of the plant. This model considered Rs. 25.00 as the cost of 1 kg. of bio-fertilizer (which is also the present government rate), and estimated the receipt and expenditure to come up with the benefit of the unit.

Table: Production Variation

Year	Production Capacity	Receipt (Lakh Rs)	Expenditure (Lakh Rs)	Gain / benifit (Lakh Rs)
First	60%	22.50	50.00	-27.50
Second	75%	28.13	18.70*	9.43
Third	90%	33.75	20.57*	13.18
Fourth	100%	37.50	22.63*	14.87

* *Every year 10% increase in the expenditure is calculated to balance the price escalation*

Source: TNAU, 2014

Economics of AM (Arbuscular Mycorrhiza) bio-fertilizer – Mass production

1	Capital cost (for construction of pits size of 4x 3x1.5 ft including construction material sand labour cost)	Rs.3,000/-
2	Inoculum cost (from TNAU) 20 KG @ Rs.20/- per kg	Rs.400/-
3	Vermiculture cost (including transport charges) 500kg@ Rs.6.50	Rs.3,250/-
4	Labour cost-Since it is a single pit, family members can look after	NA
5	Seed materials and mesh for covering for pits	Rs.100+100
6	Quality control charges at TNAU (This will be done after 1 year and before selling the product & need not be carried out after each harvest)	Rs.1,000/-
7	Bag- cost of packing the materials-30 @ Rs.10 each Labour cost of harvesting and packing	Rs.300/- Rs.200/-
	Total	Rs.8,350/-
8	Benefit expected by the sale of produced inoculum 500kg @ Rs.20/- per kg (In TNAU) Rs.35/- per kg (In Private)	Rs.10,000/- Rs.17,500/-
	Net Income (First harvest) Rs.10,000-8,350(Sl.No.8 – Sl.No 1 to 7) Rs.17,500-8,350	Rs.1,650/- Rs.9,150/-
	For the II harvest the cost will be	Rs.4,950/-
	From the second harvest benefit will be of Rs.10,000/ - Rs.4,950/ Rs.17,500/ - Rs.4,950/	Rs. 5,050/- Rs.12,550/-
	The Net Income for one year will be Rs.50,000/ - Rs.24,750/ (5x1000 – 5x4950) Rs.87,500/ - Rs.24,750/ (5x17500 – 15x4950)	Rs.25,250/- Rs.62,750/-

Source: TNAU ……

In the above bio-fertilizer manufacturing case, the benefit generation varies with respect to the harvest, and the net income for one year will be Rs.62,750/- in private companies, when compared to the public ones.

PART – 3

MICROORGANISMS AND ABS CONCERNS

Microorganisms: As a Primary Bio-resource (input) for Crop Protection Products:

Generally, microorganisms are present in the soil (barren or cultivated), water and air. As a first step, the microorganism has to be isolated and screened through the R&D and a rigorous laboratory process; micro-organisms multiply fast. Further, they are added to other prescribed inputs (chemicals), to produce different bio-fertilizers and pesticides.

In the case of MBRL, the pest attack details (generally for sugar cane) come from the farmers. Farmers report the cases to the Chief Area Nursing Officers (CANO), who are the responsible field officials working under the Department of Agriculture. Whenever, some cases occurred or reports emerge from a particular part of the state, the research lab scientists go to the field and investigate the situation and collect the microbes, which hinder the crop or contribute to the problem. Further, through the regress laboratory analysis, appropriate bio-inputs are developed.

Nowadays, microbial screening is a very rare phenomenon, since it involves time and money. Mostly microbes are collected from the culture centre of recognised Institutes. In the case of MRBL microorganisms are collected from the Tamil Nadu Agriculture University (TNAU), Coimbatore and / or the Microbial Culture Collection, Pune. Generally, microorganisms are not scarce; they are available in the atmosphere in large quantities. However, certain microorganisms are endemic, and are available only in particular environmental conditions. However, microorganisms play a vital and significant role in crop protection products' manufacturing. Since there are no substitutes for microorganisms in bio-inputs manufacturing, their real value is also very high.

How Microorganisms Differ from the Normal Biodiversity Goods?

Microorganisms are very diverse small organisms that include all the bacteria, archaea, some fungi, algae, and certain animals. Since microorganisms are microscopic; they differ from the normal kind of bio-resources, like cereals, vegetables, fruits etc. from agricultural ecosystems; timber and non-timber forest products such as medicinal plants, honey etc. from forest ecosystems; and fish, sea weeds, etc. from the wetland / marine ecosystems.

Generally, these bio-resources are goods from the ecosystems, which are visible and tangible under normal conditions. Historically, these resources are collected and / or cultivated by the community / farmers and supply to the users directly or indirectly through middle men. For commercial users, such as companies, these resources are primarily raw-materials for manufacturing the final product. The Values of these resources are assigned on their physical quantities.

But genetic resources including microbial resources are different. Morten and Tomme (2007) stated that 'genetic resources are something more than simply the raw-materials for bio-technology'. Generally, genetic resources have additional value beyond the bulk value (unit value) of the particular bio-resources.

Hence, genetic resources like microorganisms have value. Since microbial-resources are those items which are not visible and tangible, their market in the first stage (nature to the user – organization who isolate and multiply) practically dos not exist. But in the second stage, from the cultural centre to the company, there is a market.

<u>Valuation of Microbes for ABS: With Respect to Pharmaceutical concerns:</u>

Even if microorganisms have immense economic potential through contribution to product manufacturing, environmental economists has not attempted to value this resource. Their free availability in nature and the possibilities in multiplication (indicates not revealing the scarcity value) might be the reasons. In the microbial resources case, screening / identification and multiplication are crucial elements, which are purely the domain of the scientific community with scientific knowledge. Further, in microbial resources based product manufacturing, Research and Development (R&D) also plays a significant role.

A detailed review of literature with respect to the valuation of bio-resources has been carried out, in which we come across only one study about microbial resources. This study highlighted some issues on microbial resources based benefit sharing from the ABS perspective also, which is summarised below.

Masahiro Miyazaki's (2006) study on the "Economic value of microbial resources" emphasized the undiscovered biological and genetic resources, in particular microbial resources, preserved in natural habitats, and their potential as valuable sources for the future innovation of pharmaceutical and other industrial products. Further, the study attempted to understand the possible benefit sharing mechanism for the microbial resources based manufacturing industries.

The economic value of microbial resources used as screening materials for developing new pharmaceuticals, was estimated based on the sum of an initial charge and the expected royalties obtained from pharmaceutical companies. This would vary from the US$ 2-60/strain, depending on their quality and value-added information attached to the strains.

This study estimated the economic value of *ex-situ* microbial resources collected from natural habitats. Since pharmaceuticals represent one of the biggest potential markets for microbial resources, the economic value when used as screening materials for developing new pharmaceuticals, has been emphasized.

Economic value of Microbial Resources:
Methodology (Equation or Model)

$$Ve = c + \sum_{i=n}^{m} \frac{p \, . \, r. \; Si}{(1+d)^{i}}$$

Ve : Economic value of microbial resources (*ex situ* conservation) (per strain)
c : initial charge (per strain)
p : expected probability of success in developing a new pharmaceutical product
Si : expected pharmaceutical sales in the ith year (per drug)
r : royalty (rate of pharmaceutical sales)
d : discount rate
n : the year when pharmaceutical sales will start (i = n)
m : the year when pharmaceutical sales will end

Masahiro Miyazaki's (2006)

Many of the pharmaceutical companies, when they obtain microbial resources from resource providers, often offer royalties for such microorganisms after the product launch, in addition to an initial charge. Therefore, the sum of an initial charge and the expected royalties obtained from pharmaceutical companies, were considered in the model applied on the economic value of microbial resources. The paper comes up with the following conclusions:

- Since there is no established method for evaluating the economic value of microbial resources collected from natural habitats, the benefit-sharing agreement on microbial resources, in the context of implementing the Convention on Biological Diversity (CBD), is difficult to arrive at.
- The estimation of the economic value of *ex-situ* microbial resources collected from natural habitats for screening bioactive materials for developing new pharmaceuticals has resulted in a relatively low value (US$2-60/strain).
- For the source countries to gain a greater share of the benefits from microbial resources, they should, for example, build human and technological capabilities to isolate, preserve and characterize microorganisms and provide users with more value-added resources, in the country.
- This could be comprehended through scientific and technological education and training, scientific research, and technology transfer, as provided for in the relevant articles of the CBD.
- For this purpose, priority should be given to non-monetary benefit-sharing rather than monetary benefit-sharing, in negotiating an ABS agreement with resource users in the context of implementing the CBD.

Even if the above study comes up with a formula for valuing the microorganisms, it indicated the complexity in valuation particularly for ABS. Improving the source countries' human and technological capabilities to isolate, preserve, and characterize microorganisms, and provide more value-added resources to user countries, may be an option. But it requires a long time and huge preparation for developing countries like India.

The study attempted the valuation of microbial resources with respect to the pharmaceutical company, where the product development success rate is limited. However, such extreme uncertainties do not exist, when microbes are used in Crop Protection Products.

<u>Challenges in Microbial resources Valuation for ABS</u>

Microbial resources are generally collected by the companies from the nature once in a while, and multiplied with the help of their in-house facilities. Here, the one time / the first time collection from nature is important, since it acts as a source material for further multiplication. Sometimes, the companies collect the concerned microorganisms from the authorised culture collection centres. This case of microorganisms is just like any other inputs purchased and used in product manufacturing. Nowadays, microbial screening by the user company is a very rare phenomenon, since most of the microbes required for manufacturing are available with the culture centres. Microbial resources culture centres (generally the institutions come under the central and state governments, universities, and international organizations (like ICRISAT), collect the microbes from nature. Sometimes, researchers deposit the microbes in the culture centres. These centres also act as the national and international depository authorities (IDA).

In the case of our study unit, (MBRL) collects the required microorganisms from institutes like the Tamil Nadu Agriculture University (TNAU) and / or Microbial Culture Collection Centres, and stored in the form that could be retrieved or reproduced. This trend was also observed during our investigation in a Government of India undertaking (Ministry of Health and Family Welfare), company that produces vaccines for the National Immunization Programme and other new generation vaccines. They purchase microbial strains from the National Centre for Cell Sciences (NCCS), which collects the strains from nature in a limited quantity. Using the very small quantity of the initial collection of the strain, the required amount is cultured and maintained by the company for further use (Nelliyat and Pisupati, 2013).

It is also important to investigate the criteria in fixing the rates for microorganisms by the different culture centres. For example, the Microbial Type Culture Collection and Gene Bank (MTCC) Chandigarh, fixes separate rates for different microbes, considering to whom they are supplying the microbes to. The current supply rate of freeze-dried culture (Bacteria, Fungi and Yeast) for educational / government research institutions is Rs. 800, while for other organizations (private sectors) the rate is Rs. 4000 (MTCC, 2015).

It is very clear from the above figures that, when the educational / government research institutions obtain the microbes at a highly subsidised rate (Rs. 800), private companies are paying a high rate (Rs. 4000). May be the criterion in fixing a high rate for the private sectors is their profit motive. Since the public sector targets on social welfare, eligible for obtaining microbes at a lower rate.

In brief, the discussion with the microbial resources based companies concluded that, some of the companies collect bio-resources, such as strains from the authorized culture centres (as discussed above), and propagate them as per their requirements. According to these companies, they are not 'destroying the bio-diversity', since their initial collection from the parent institutions is negligible (Nelliyat and Pisupati, 2013). However, the initial collection from nature is extremely significant from the ABS perspective. Without this, no company can manufacture the products and obtain benefits.

Assigning the value to a microorganism is a complex challenge on the following grounds:

- Whenever a company or an authorised culture centre collects and maintains the microbial resources from nature, it is in a limited quantity (may be a few living cells).
- At this stage, there is no market or exchange of microorganisms. Since, there is no defined provider, it is just collected as a sample from the universe.
- This sample collection may not affect the microorganisms' overall stock in the environment, and incur any sustainable issues. However, this should be scientifically investigated.
- But, when the company / cultural centre starts to multiply and supply to the commercial users, its value also multiplies.
- The ultimate users such as the drug or crop protection manufacturing companies buy the microorganisms like any other commodity, for which the market determines the price.
- When companies use microorganisms (further multiplication and / or use as an input in the production process), they multiply the benefits / profits.

According to Morten and Tomme (2007), the value of "genetic resources" must be discussed from the perspective of both drawing benefits from using the units of heredity (micro-physical material), and the utilization of the genetic information that they contain. The valuation must target the new resource value, separating the bulk value of the biological resource from the value of its tangible and intangible genetic resources. This would include, for example, DNA sequences and biochemical formulae, whether contained in whole specimens, prepared samples, extracts, or written scientific notations or descriptions.

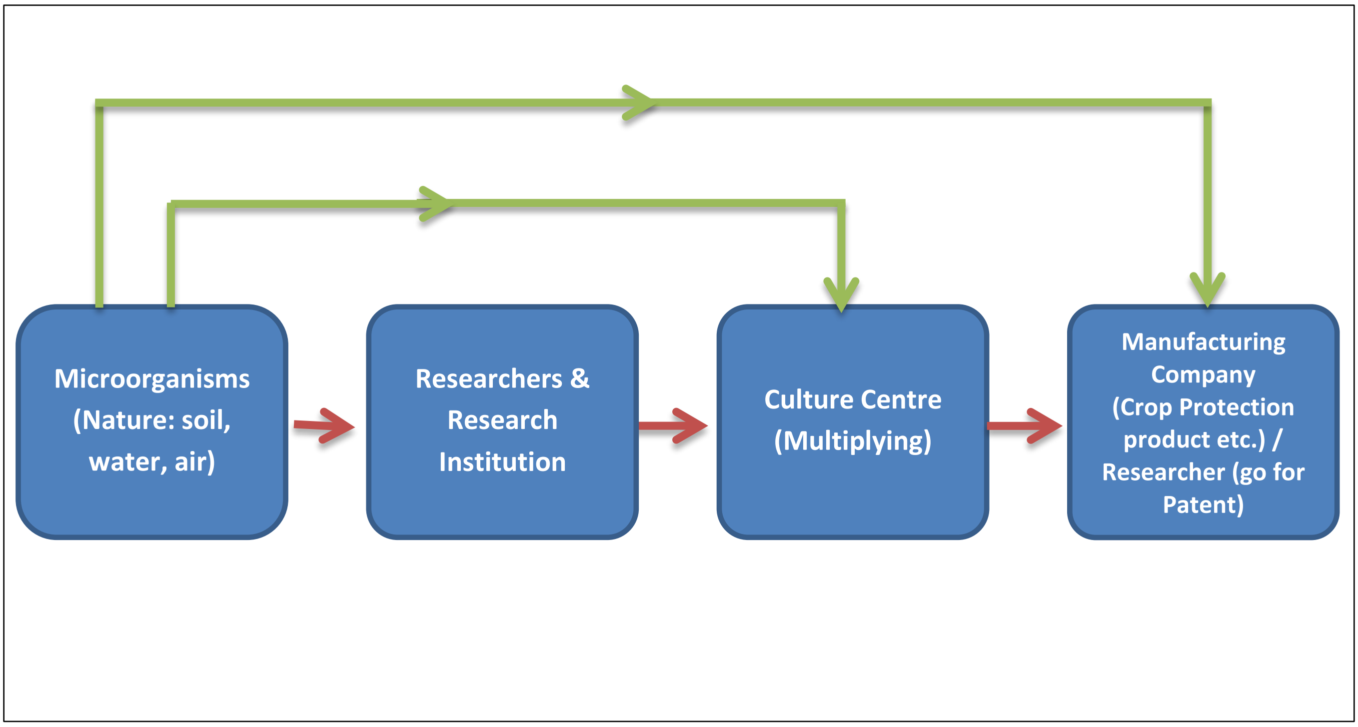
In the valuation of bio-resources, property rights and the nature of the goods (public or private) play a significant role (Nelliyat and Pisupati, 2013-WP1). However, a complex question emerges; are genetic resources excludable or non-excludable? This question may have different answers, depending on which of the two aspects of the genetic resource concept (micro-physical or intangible/informational) is primary in each situation.

When considering the micro-physical genetic material, the excludability discussion should be considered at different levels. In order of specificity, those levels are: (a) Individual gene; (b) Gene sequence; (c) Expressed characteristic (enzyme, protein, etc.); (d) Genome (variety or subspecies); and (e) Shared characteristics (within a higher taxon) (Morten and Tomme, 2007).

How do the ABS Mechanisms Operate in Microbes Based Final Products?

It is clear from the above discussions, that a microbial resource (as a bio-resource or an input) based unit may obtain / collect the microorganism, (a) directly from nature, or (b) from the authorized culture centres as indicated in the following figure. However, the culture centre obtains / collects the initial sample from nature.

Fig: Microorganisms Movement / Exchange



In the first case, when the company directly collects from nature, it should obtain prior permission from the competent authority (NBA, SBB, BMC) for collecting the bio-resources. Subsequently, they should come forward for benefit sharing as per the microbial resources based benefit. Since it is not a bulk collection, (or a sample collection) the BMC or the community may not be aware of the collection process.

When the company is buying from a culture collection centre, a market exists and it determines the price. Since the culture centres have some monopoly on their possessiveness of the microbial resources, they can try to get the maximum willingness to pay from the users, and bounce back that money to the SBB or BMCs.

In the above case, the initial collection of microorganisms may be done from the eco-system / biodiversity (soil / water etc.) or from a private property or public land. However, the provider of the microorganisms is very vague, since it is not exchanged like a commodity such as medicinal plants. Here, the users (industry / culture centres) are informally collecting the microorganisms from the convenient region or spot, may be in a limited quantity.

Conclusion

Even if microorganisms are high ABS potential and commercially significant bio-resources, their valuation is different from the normal kind of bio-resources, which are tangible and visible. For microorganisms based bio-products, the role of scientific knowledge is extremely important, and R&D efforts and costs come under top priority.

Through a comprehensive value chain analysis, one can assess the bio-resources' value. One should obtain the cost components from different segments of the microorganism's process and products development. For collecting this information good cooperation from the industries is required. Through this analysis, one can get a picture of the total rent (benefit / profit) as well as the microbial resources induced profit in it. The latter will be the criterion for operationalizing the access, and benefit sharing (ABS).

Whenever microorganisms are provided by the culture collection centres (microbial repositories), they should aim towards obtaining the 'maximum willingness to pay' from the users (industries) for the different kinds of microorganisms they supply. In this regard, we need to develop on institutional mechanism through the initiatives of the NBA / SBB, to facilitate the ABS mechanism and transfer the additional returns (revenue) to the local area BMCs, where the microorganisms' initial collection has been done.

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