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A Study of Biopesticides and Biofertilisers in Haryana, India

Ghayur Alam

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The Gatekeeper Series produced by IIED's Sustainable Agriculture and Rural Livelihoods Programme aims to highlight key topics in the field of sustainable agriculture and resource management. Each paper reviews a selected issue of contemporary importance and draws preliminary conclusions for development that are particularly relevant for policymakers, researchers and planners. References are provided to important sources and background material. The Series is published three times a year – in April, August and December – and is supported by the Swedish International Development Cooperation Agency (Sida).

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Executive Summary

The use of chemical pesticides and fertilisers in Indian agriculture has seen a sharp increase in recent years, and in some areas has reached alarming levels with grave implications for human health, the ecosystem and ground water. It is therefore increasingly urgent that environmentally friendly methods of improving soil fertility and pests and disease control are used.

The potential of biopesticides and biofertilisers for promoting sustainable agriculture has been known for many years. A number of government agencies, including the Ministry of Agriculture and the Department of Biotechnology, are engaged in supporting research, production and application of these agents. However, in spite of these efforts, their use in India is small. This paper investigates the potential of and constraints in the use of biopesticides and biofertilisers, taking the state of Haryana as a case study. It explores the factors responsible for the limited use of these agents, based on detailed discussions with a large number of farmers, various agencies engaged in the promotion of biopesticides and biofertilisers, State Agricultural Department officials, and shopkeepers.

The study found that for the use of biopesticides, a key problem was that departments promoting Integrated Pest Management (IPM) have very little knowledge and experience of biopesticides, and most state agricultural universities, on whose recommendations pest control methods are promoted, do not tend to recommend biopesticides. In the absence of active promotion by the agriculture department, the demand for these products has not developed, and most private shops and dealers do not stock and sell biopesticides. The paper recommends that the agricultural departments and universities pay greater attention to the promotion of biopesticides, that IPM training is improved, and that there is a greater focus on cropping techniques and varieties which do not require such a dependence on pesticides.

In the case of biofertilisers, their poor quality and performance is a major factor in their limited uptake by farmers. This is primarily linked to inappropriate strains and inefficient production technology. As a result it is recommended that research and development to identify more suitable strains, to develop better production technology and quality control methods is greatly increased, and that in the meantime the various grants and subsidies on biofertilisers are diverted to support these R&D programmes.

A Study of Biopesticides and Biofertilisers in Haryana, India

Ghayur Alam

Introduction

The use of chemical pesticides and fertilisers in Indian agriculture has seen a sharp increase in recent years. In some areas, such as Haryana, Punjab and west Uttar Pradesh, it has reached alarming levels. The heavy use of these chemicals has already caused grave damage to health, ecosystems and ground water. It is therefore increasingly urgent that environmentally friendly methods of improving soil fertility and pests and disease control are used.

The potential of biopesticides and biofertilisers for promoting sustainable agriculture has been known for many years. A number of government agencies, including the Ministry of Agriculture and the Department of Biotechnology, are engaged in supporting research, production and application of these agents. However, in spite of these efforts, their use in India is small. This paper investigates the potential of and constraints in the use of biopesticides and biofertilisers, and explores the factors responsible for the limited use of these agents. It is based on a study in the state of Haryana, a state which represents the problem of excessive use of pesticides and fertilisers, common in many parts of India. The paper also suggests policy measures for the promotion of biopesticides and biofertilisers in the state. The study is based on detailed discussions with a large number of farmers, various agencies engaged in the promotion of biopesticides and biofertilisers, State Agricultural Department officials, and shopkeepers. The study was carried out in 1999 as part of a research project on agricultural problems, undertaken by the Agricultural Economics Research Centre, University of Delhi.

The Potential for Biopesticides

About 80,000 tons of pesticides are used in agriculture in India annually (Srinivasan, 1997), mostly in cotton and rice. While cotton is planted on about 5% of the total cultivable area (on about 8 million hectares out of a total of 170 million), it accounts for about 45% of pesticide application (Dhaliwal and Pathak, 1993). Rice accounts for another 23%. Vegetables and fruit also account for a significant proportion (Table 1).

Table 1. Cropwise consumption of pesticide in India (%)	
Cotton	44.5
Paddy	22.8
Jowar	8.9
Fruits and Vegetables	7.0
Wheat	6.4
Arhar	2.8
Other	7.6
Total	**100.00**

Source: Dudani and Sengupta, 1991

The intensive use of pesticides in agriculture is a cause of serious concern. The problem is especially serious because of the development of resistance to pesticides in important pests and the presence of pesticide residue in agricultural and dairy products.

Pesticide resistance in agriculture was first noticed in India in 1963 when a number of serious pests were reported to have become resistant to DDT and HCH (two of the most commonly used pesticides during the 1960s and 1970s). Since then the number of pests with pesticide resistance has increased. The most serious problem of resistance is witnessed in cotton, for which American bollworm is a serious pest. The bollworm has developed resistance to almost all pesticides in a number of regions, and is particularly serious in parts of Punjab, Haryana, Andhra Pradesh, Karnataka and Maharashtra. Other important pests of cotton, white fly and jassid, have also developed pesticide resistance in some places.

Growing pesticide resistance has meant that a large proportion of agricultural production is lost to pests. According to some estimates, these losses amount to between 20-30% of total production (Mehrotra, 1989). The losses are particularly serious in cotton. For example, cotton production in Punjab declined by about 50% during 1997 and 1998,[1] causing a number of cotton farmers to commit suicide in the affected areas.[2]

Pesticide resistance has mainly been caused by excessive and indiscriminate use of pesticides (Jayaraj, 1989). Pesticides of spurious quality, which are commonly sold in small towns and villages, have also contributed to resistance in many areas. For example, in Bidar (Karnataka) where the problem of pest resistance has become extremely serious, more than 50 brands of pesticides were found to be sub-standard in 1998-99. In another incident, the licenses of 115 pesticide producers were cancelled in Punjab for selling

1 *"Another bad season for cotton farmers"*, Hindustan Times, *September 17, 1998.*
2 *For example, in Punjab 133 farmers were reported to have committed suicide in 1998 due to crop failure caused by pest attack. "Another farmer in debt trap commits suicide"*, Hindustan Times, *October 4, 1998.*

sub-standard pesticide.[3] Sub-standard pesticides contribute to resistance as the pests are repeatedly exposed to a low concentration of pesticides. This contributes to the build-up of resistance, without destroying the pests.

The other important problem caused by the excessive and inappropriate use of chemical pesticides concerns the presence of pesticide residue in food. Many of the pesticides currently being used have a tendency to survive in plants for a long time. They also enter the food chain and are found in meat and dairy products. The problem of pesticide residue is already a serious threat to health and environment in India. The incidence of pesticide residue is much higher in India than in developed countries. For example, according to one study, more than 80% of milk samples tested in India were found to contain residues of DDT and HCH (Handa, undated). According to another study, residue of DDT and benzene hexachloride, both suspected carcinogens, were found in breast milk samples collected from mothers in Punjab. The amount of residue was very high and babies were ingesting 21 times the amount of these chemicals considered acceptable through their mothers' milk (Jumanah, 1994).

Compared to this, only 0.17% of samples tested in the US in 1990 were found to contain residues over the acceptable limits.[4] Similarly, in a study in the UK, only 1% of the samples were found to contain residues above the prescribed limit.[5]

It is clear that the excessive use of chemical pesticides in agriculture is a serious cause of concern. It is, therefore, important that alternative, environmentally friendly methods of plant protection are adopted, such as integrated pest management (IPM) techniques, including the use of biopesticides.

Biopesticides and Bio-control Agents

Biopesticides are derived from animals, plants and micro-organisms such as bacteria and viruses. The advantages of biopesticides are:

- They are inherently less harmful than chemical pesticides;
- They are more target specific than chemical pesticides affecting only the target pests and their close relatives. In contrast, chemical pesticides often destroy friendly insects, birds and mammals.
- They are often effective in small quantities. Also, they decompose quickly and do not leave problematic residues.

The most commonly used biopesticides include *Bacillus thuringiensis* (Bt), Baculoviruses and neem. In addition to these, trichoderma, which is a fungicide, is also used. Bio-control agents, such as Trichogramma, are parasites and predators of pests and their

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3 "Another bad season for cotton farmers", Hindustan Times, September 17, 1998.
4 "Current Pesticide Residue Levels in Food are Safe", Pesticide Outlook (5)1, Feb 94. Cambridge.
5 "Latest UK Pesticide Residue Results Published", Pesticide Outlook, Dec 1994, pp8. Cambridge.

eggs. These biopesticides and bio-control agents are briefly described below:

- *Bacillus thuringiensis (Bt). Bacillus thuringiensis* is the most commonly used biopesticide globally. It is primarily a pathogen of lepidopterous pests which are some of the most damaging. These include American bollworm in cotton and stem borers in rice. When ingested by pest larvae, Bt releases toxins which damage the mid gut of the pest, eventually killing it. Bt based pesticides are being marketed by three companies in India. The total sale in 1999 was about 70 tons.[6]

- *Baculoviruses*. These are target specific viruses which can infect and destroy a number of important plant pests. They are particularly effective against the lepidopterous pests of cotton, rice and vegetables. Their large-scale production poses certain difficulties, so their use has been limited to small areas. They are not available commercially in India, but are being produced on a small scale by various IPM centres and state agricultural departments.

- *Neem*. Derived from the neem tree *(Azadirachta indica)*, this contains several chemicals, including 'azadirachtin', which affects the reproductive and digestive process of a number of important pests. Recent research carried out in India and abroad has led to the development of effective formulations of neem, which are being commercially produced. As neem is non-toxic to birds and mammals and is non-carcinogenic, its demand is likely to increase. However, the present demand is very small. Although more than 100 firms are registered to produce neem-based pesticides in India, only a handful are actually producing it. Furthermore, very little of the production is sold locally, most being for export markets.

- *Trichoderma.* Trichoderma is a fungicide effective against soil born diseases such as root rot. It is particularly relevant for dryland crops such as groundnut, black gram, green gram and chickpea, which are susceptible to these diseases. Three companies are marketing trichoderma in India.

- *Trichogramma.* Trichogramma are minute wasps which are exclusively egg-parasites. They lay eggs in the eggs of various lepidopteran pests. After hatching, the Trichogramma larvae feed on and destroy the host egg. Trichogramma is particularly effective against lepidopteran pests like the sugarcane internode borer, pink bollworm and sooted bollworms in cotton and stem borers in rice. They are also used against vegetable and fruit pests. Trichogramma is the most popular bio-control agent in India, mainly because it kills the pest in the egg stage, ensuring that the parasite is destroyed before any damage is done to the crop. A number of countries produce Trichogramma on a large scale. For example, in the former Soviet Union more than 10 biological factories were reported to produce about 50 billion Trichograma and other parasites per season. Similarly, more than 50 commercial insectaries are reported

6 Dr MC Sharma, pers. comm. Director, Biotech International, New Delhi.

to be producing Trichogramma and other parasites in the USA and Canada. A number of communes in China are also known to produce Trichogramma on a large scale.

Whilst India does not have technology to produce Trichogramma on a large scale, they are being produced in small scale facilities for local use, mostly by sugar mills and cooperatives, state agricultural departments, IPM centres and agricultural universities. Recently, some companies have started marketing Trichogramma through direct selling. But the volume of sale is very small. Trichogramma eggs have to be used within a short period (before the eggs hatch). This limits their production and marketing on a large scale, and is also the reason why Trichogramma is not sold through dealers and shopkeepers.

Promotion and effectiveness of Integrated Pest Management and biopesticides

The Ministry of Agriculture and the Department of Biotechnology are responsible for promoting biopesticides, the former via the Central IPM Centre (Faridabad), the National Centre for IPM (NIPM) under the Indian Council For Agricultural Research (ICAR) and the Directorate of Biological Control. As a part of the Department of Biotechnology's demonstration programme, biopesticides have been demonstrated on about 55,000 hectares (Wahab, 1998). The Department has also supported a pilot plant at the Tamil Nadu Agricultural University (Coimbatore) to develop and demonstrate production and application technologies for baculoviruses, trichoderma and Trichogramma.

Some Integrated Pest Management (IPM) demonstrations have shown success in controlling pests without the use of chemical pesticides. For example, NIPM carried out a demonstration in rice in a village in west UP on 100 acres in 1999. NIPM totally substituted chemical pesticides with the bio-control agent Trichogramma, which is effective against both stem borer and leaf folder. According to NIPM, the control of pests was complete and the yields were between 6-7 tons/hectare. Compared to this, the yield in the area where chemical pesticides were applied was only 3.5 to 4 tons per hectare (Damodran, 1999).

In another successful demonstration by NIPM on cotton in Maharashtra during 1998-99, Baculoviruses, neem and Trichogramma were found to be more effective in controlling pests than chemical pesticides. The yield in these plots was about 1 ton/hectare, compared to yields of only 300 to 500 kilograms/hectare in the fields where chemical pesticides were used.[7]

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7 "Integrated Pest Management Module for Dryland Regions - ICAR Trials in Cotton Fields Successful". Hindu Business Line, *4.1.1999.*

The Potential for Biofertilisers

The growth in agricultural production during the last three decades has been accompanied by a sharp increase in the use of chemical fertilisers, causing serious concern (Marothia, 1997). Foremost among these concerns is the effect of excessive fertiliser (especially nitrogenous fertilisers) on the quality of soil and ground water.[8]

Biofertilisers are considered to be an important alternative source of plant nutrition. They are biologically active products, including bacteria, algae or fungi, with the ability to provide plants with nutrients. Most biofertilisers belong to one of two categories: nitrogen fixing and phosphate solubilising. Nitrogen fixing biofertilisers fix atmospheric nitrogen into forms which are readily useable by plants. These include rhizobium, azatobacter, azospirillum, blue green algae (BGA) and azolla. While rhizobium requires symbiotic association with the root nodules of legumes to fix nitrogen, others can fix nitrogen independently. Phosphate solubilising micro-organisms (PSM) secrete organic acids which enhance the uptake of phosphorus by plants by dissolving rock phosphate and tricalcium phosphates. PSMs are particularly valuable as they are not crop specific and can benefit all crops (Table 2).

Table 2. Major biofertilisers and target crops

Biofertiliser	Target Crop
Rhizobium	Leguminous crops (Pulses, oilseeds, fodder)
Azatobacter	Wheat, rice, vegetables
Azospirillum	rice, sugarcane
Blue green algae (BGA)	rice
Azolla	rice
Phosphate solubilising microorganisms (PSMs)	all

Production of biofertilisers in India

The idea of using micro-organisms to improve land productivity has been around in India for at least 70 years, but it was only in the 1990s that large scale production of various biofertilisers commenced. Presently, a number of agricultural universities, state agricultural departments and commercial enterprises produce various biofertilisers.

The promotion of biofertilisers is mainly carried out by the National Biofertiliser Development Centre (Ghaziabad), which was set up in 1987. The main objectives of the National Centre are to:

8 Water containing excess of nitrates can affect the blood's ability to transport oxygen, with serious health implications (WHO, 1963).

- produce and market biofertilisers of required quality;
- isolate and maintain biofertiliser strains suitable to various agro-climatic regions;
- train agricultural extension workers;
- promote biofertilisers through field demonstrations;
- prepare quality parameters;
- test samples of biofertilisers produced by others;
- provide technical and financial assistance to units producing biofertilisers.

The National Centre has the capacity to produce 375 tons of biofertilisers per year. In addition to this, 58 commercial production units have been set up with government support. India's total production in 1998-99 was reported to be 16,000 tons.[9] Rhizobium accounts for the largest proportion (40%) of the total production in India. This is followed by azatobacter. With the increase in the price of phosphate fertilisers, the potential for the use of PSM has also increased.

Effectiveness of biofertilisers

A considerable amount of research has been done to establish the effectiveness of biofertilisers on various crops, in different agro-climatic regions. Most agricultural universities, the ICAR and the National Biofertiliser Development Centre have carried out a number of field trials to document the effectiveness of these micro-organisms. These programmes show that the use of biofertilisers can have a significant effect on the yield of most crops. However, their effectiveness is found to vary greatly, depending largely on soil condition, temperature and farming practices. As an example, Table 3 shows the effect of azatobacter on yield.

Table 3. Effect of azatobacter on crop yield

Crop	Increase in yield over yields obtained with chemical fertilisers (%)	Crop	Increase in yield over yields obtained with chemical fertilisers (%)
Food grains		Other	
Wheat	8-10	Potato	13
Rice	5	Carrot	16
Maize	15-20	Cauliflower	40
Sorghum	15-20	Tomato	2-24
		Cotton	7-27
		Sugarcane	9-24

Source: Das, 1991

9 Dr. T. Singh, pers. comm., Director, National Biofertiliser Development Centre.

The Case Study: Karnal and Bhiwani Districts, Haryana

A field study was initiated in two districts in Haryana to try to understand why biofertilisers and biopesticides were not being adopted on a wide scale. The study focused on two districts: Karnal and Bhiwani. While Karnal represents intensive agriculture with a high degree of irrigation, Bhiwani represents dryland farming, with low level irrigation. The potential for biofertilisers and pesticides is described below, followed by the results of our interviews with farmers to establish why biofertilisers and biopesticdes have not been taken up more widely.

The Potential for Biopesticides and Biofertilisers in Haryana

The problems caused by excessive pesticide use are particularly serious in rice and cotton in Haryana, both important crops in our study districts. The American bollworm, jassid and white fly in cotton; and stem borer in rice; have developed resistance to chemicals in many parts of Haryana, including parts of the districts studied. In this situation there is great potential for biopesticides.

The potential of biofertilisers is evidenced by the fact that about 90% of Haryana's soil is deficient in nitrogen, indicating severe nutrient deficiency (Dahiya *et al.*, 1993). The dryland districts such as Bhiwani, Mohindergarh, Sirsa and Faridabad are particularly low in nitrogen, and soils are short of organic matter due to poor vegetative cover, high temperatures and the light texture of soil. Biofertilisers could play a role in providing the much needed nutrients and improving soil conditions in these dryland areas, which account for about 28% of the state's total cultivable area.

Biofertilisers can also reduce the intensity of chemical fertiliser consumption, especially in irrigated areas. With the increase in cropping intensity (see below), the use of chemical fertilisers has increased significantly in these areas. The use of organic manure, on the other hand, has not increased. As a result, many parts of Haryana face deteriorating soil conditions and increasing ground water contamination.

The suitability of biofertilisers for various crops grown in Haryana has been shown through demonstrations conducted by the Hissar Centre of the National Biofertiliser Development Centre (NBDC). Azatobacter and azospirillum, which can be used for a wide range of crops, are estimated to have particularly large potential. For example, NBDC experiments showed an increase in yield between 3 and 25% with the application of azotobacter in cotton. Similarly, in the case of wheat, use of azotobacter resulted in yield increases between 2 and 20%.[10]

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10 National project on use and development of biofertilisers. Biofertiliser News, *1(2), December 1993.*

The potential for the use of rhizobium is largely confined to the dryland areas of Haryana, where pulses are commonly grown, and where the soils show poor to moderate nodulation.[11]

Karnal District

In Karnal the main nutrient and pest problems relate to the district's high cropping intensity. Wheat-rice rotation has been common for some time now, and cropping intensity has recently increased further with the introduction of short duration rice varieties such as Govinda (90 days). Planting these varieties allows farmers to take two rice crops between April and October. The first paddy crop is planted in April-May, as soon as wheat has been harvested. This rice crop is ready for harvest by mid July. This is followed immediately by the transplanting of fresh paddy seedlings. The second rice crop is harvested by the end of October, to be followed by wheat, which is sown by early November.

This very high intensity of cropping has worsened both the soil quality and pest problem in parts of Karnal. It is extremely damaging to the soil condition, as large amounts of nutrients are used continuously without replenishment. As a new crop is planted as soon as the older crop is harvested (sometimes both activities are done simultaneously), there is no time for proper land preparation and for using organic manure. As the use of chemical fertilisers has increased to provide the required nutrients, soil and water conditions have deteriorated.

The problem of pests and pesticide use in Karnal is largely confined to rice. Growing two rice crops without a break is one factor. The continuation of rice plants in the same field, and the high degree of moisture, enable pests to multiply without a break, leading to particularly intense pest attacks in the second crop. Another reason is the popularity of certain basmati varieties which are highly susceptible to pests and diseases. This is particularly serious in one of the most popular of these varieties, called duplicate basmati. This variety was introduced about five years ago from West UP, and became very popular because of its high yields,[12] and totally replaced the desi (traditional) basmati variety in many areas. After performing well for three years, the variety began to be affected by pests (stem borer, leaf folder and white back plant hopper) and diseases (sheath blight, blast and bacterial leaf blight) two years ago. The attack was particularly severe last year, forcing many farmers to stop planting basmati in general, and duplicate basmati in particular. In one of the villages we studied, Kuuchhpura, farmers made up to 15 pesticide applications last year but could not save the crop. This year, very few farmers have planted basmati in the village.

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11 The assimilation of atmospheric nitrogen by the roots of pulse (and other leguminous) crops is carried out by the nodules formed in the roots of these plants. The low degree of nodulation suggests that their ability to assimilate atmospheric nitrogen is low and that they could benefit from the use of rhizobium.
12 Compared to the average yield of 10 quintal/acre from desi basmati, the yields of duplicate basmati were about 20 quintal/acre.

The problem of pesticide resistance in stem borer is now common in Karnal, largely caused by the indiscriminate and excessive use of pesticides. Another important reason relates to the fact that farmers in Karnal do not spray their fields themselves. This is done by professional workers who are sent by the shops selling pesticides. As these workers are paid by the area covered, they do a rushed job. The spraying is not uniform: while some parts of the fields get very little, others get excessive pesticides. Secondly, in order to save time they use about one third of the water prescribed to make the pesticide solution. The non-uniform spray of highly concentrated pesticide solution is reported to be a major reason for the development of resistance in rice pests in many parts of the district.[13]

Bhiwani District

In Bhiwani, the focus of the study is on cotton and gram, which, along with wheat and mustard are the main crops in the area. The use of chemical fertilisers is comparatively low in Bhiwani, being used only on wheat and cotton, and not at all on gram and mustard. But, as in Karnal, use of organic manure is not common and the condition of the soil is poor. Three biofertilisers have potential for Bhiwani: rhizobium for gram and azatobacter and PSM for wheat. The potential of rhizobium is reported to be particularly high in Bhiwani because the level of nodulation is very low.

The District Agriculture Department is responsible for the sale of rhizobium in Bhiwani. Being a major gram growing district, it was allocated the largest amount of rhizobium last year and its sale to farmers is subsidised at the rate of 50%.

The main pest problem in Bhiwani concerns cotton, which is attacked by American, pink and spotted bollworm, white fly and jassid. These pests have become resistant to most pesticides. According to a study of pesticide use in Bhiwani in 1998, about 70% of farmers reported that they were unable to control pests with pesticides (Saini and Jaglan, 1998). Some of these farmers had used up to 11 pesticide applications.

The pest problem in Bhiwani is closely linked with the spread of irrigation facilities. Large parts of Bhiwani district are irrigated by the Indira Gandhi Canal, which suffers from large scale seepage. This has led to a rise in the groundwater level from 50-60 feet below the surface in the past to 5-10 feet at present in many areas. As a result, water logging and high humidity are serious problems in many areas of the district. Apart from causing direct damage, this has also created favourable conditions for the growth of pests. Consequently, the problem of pests has become extremely serious in the district during the last five years.

The pest problem caused the area under cotton to decline in the second half of the 1990s from 57, 000 hectares in 1996-97 to 51,000 hectares in 1999-2000.[14] As in rice

13 Information from the District Agricultural Officers.
14 Information provided by the State Agricultural Department, Bhiwani.

in Karnal, the pest problem in cotton in Bhiwani is closely related to the susceptibility of the varieties being planted. The cultivation of cotton in this area is comparatively new: it was introduced in the 1970s. Most of the varieties introduced since then are long staple, American types. Although they fetch high prices, they are highly susceptible to various cotton pests. The problem of pests and the excessive use of pesticides in Bhiwani is mostly confined to the American varieties. Desi varieties, which are comparatively resistant to pests and diseases, require less use of pesticides.

We observed a shift back in favour of *desi* cotton in one of the divisions of Bhiwani following severe losses to pests to the American varieties. Whilst many more farmers would prefer to shift to desi cotton varieties, as they provide stable yields, their wholesale prices are too low. In addition it appears that the state agriculture department prefers to promote long staple American varieties, as they have large domestic and export markets.

Farmers' Perspectives

We selected 11 villages from the two districts, six villages from Karnal and five from Bhiwani, in which to interview farmers to establish their awareness and use of biofertilisers and biopesticides. A total of 74 farmers from these villages were interviewed, and were mainly selected because they had attended one of the demonstration programmes carried out by government agencies to promote IPM, biopesticides and biofertilisers (58 of the farmers, or about 80% of the sample). However, some farmers who had not been to the programmes were also interviewed (16 farmers). All the farmers were men; only men had participated in the demonstration programmes, and we were told that men take the decisions about the types of fertilisers and pesticides to be used.

The farmers included in the study represent the range of small, medium and large farmers. While 29% of the farmers have less than 5 acres of land, 46% have between 5 and 20 acres. 25% of the farmers have landholdings larger than 20 acres. In terms of education, about one third of the farmers have studied up to class 10 or more. A semi-structured questionnaire was used for interviews, which were conducted in farmers' homes.

Findings: Biopesticides

Although biopesticides and bio-control agents are important components of IPM, the IPM programmes being conducted by various agencies put very little emphasis on these agents. None of the farmers we interviewed had ever used biopesticides, and few were even aware they existed. We found that none of the farmers had even used neem, widely believed to be commonly used by Indian farmers.

In fact, we found that IPM itself was not being practised by most farmers. While some of the farmers were aware of IPM practices, such as the need for monitoring and augmenting natural enemies of pests, very few farmers have adopted these practices. None of the farmers practised IPM fully, but about 15% practised partial IPM. In most cases this meant delaying the first spray of pesticides until damage by pests becomes evident. The situation is particularly bad in Bhiwani, where 85% of farmers reported not using IPM at all and only 9% reported using some aspects of IPM. Compared to this, 20% of farmers reported using limited IPM in Karnal. This is despite the fact that most of the farmers included in the study participated in the IPM demonstration programmes conducted by the Central IPM.

Why is IPM not practised?

We found four important reasons for the low acceptance of IPM:

1. **Lack of awareness.** This reason was found to be particularly important in Bhiwani, where 77% of farmers were unaware of the concepts of IPM. Compared to this, fewer than 3% of farmers in Karnal were unaware of IPM. Clearly, there is a big district-wise difference in the success of IPM demonstration programmes and state agricultural extension workers in familiarising farmers with IPM. In Karnal these agencies have been successful in at least making farmers aware of the need to practise IPM.

2. **Lack of skills.** Almost all the farmers, including all of those who were aware of IPM, reported that they lacked the skills necessary to practise IPM. Their ability to practise IPM was, for example, severely constrained by the fact that most of them could not differentiate between harmful and beneficial insects. In fact, many farmers thought that all insects were a potential threat to their crop and had to be destroyed. They were also not able to work out economic thresholds[15] to determine the timings of pesticide application.

3. **Lack of faith in IPM.** This factor was found to be very important amongst 60% of farmers in Karnal. Although almost all of them were aware of IPM, they felt that they did not have sufficient faith in it to reduce the use of chemical pesticides. Many of them felt that the support from the agricultural department was not adequate for them to try IPM practices, which were considered risky. As the CIPM personnel do not keep in touch with the farmers after IPM demonstrations, they felt that they would not get adequate advice and support if things went wrong. Similarly, the local extension workers (ADOs) are not sufficiently trained in IPM to instil confidence in the farmers.

   The issue of skills and confidence is obviously linked to the intensity of training provided by the IPM agencies to farmers and extension workers. We found that the training is very basic and superficial, being conducted for three to four days in a village, during which 30 villagers and five extension workers are trained. The farmers felt that the training was not intensive and did not impart sufficient skills for them to feel competent and confident in following IPM practices.

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15 The economic threshold is the level of pest population at which the damage to crop justifies the use of pest control methods.

4. **IPM practices are difficult and cumbersome.** About 70% of the farmers in both districts who were aware of IPM, felt that the IPM practices were too cumbersome and time consuming to be used regularly. Both the monitoring of pest populations and the calculation of economic thresholds were considered by farmers to be impractical. In Karnal, where cropping intensity is high, the farmers felt that they did not have time to keep a close watch on their fields to monitor pests and calculate economic thresholds.

Whose advice is taken?

An important reason for the failure of the IPM programme, and the lack of biopesticide use, is related to the fact that most farmers depend on shopkeepers for advice on pesticide application. More than 80% of the farmers reported that shopkeepers, dealers and representatives of pesticide manufacturers were their most important sources of information about pest control methods (Table 4).

Table 4. Importance of source of advice for pesticide application

	Other Farmers	Extension workers and agricultural university	Shops/manufacturers/ dealers
Karnal	12 (30)	18 (45)	33 (83)
Bhiwani	10 (30)	9 (26)	27 (80)
Total	22 (30)	27 (36)	60 (81)

Number of responses=74. Note that some farmers listed more than one source of advice as being equally important

Note: Figures in parenthesis indicate percentages.

Compared to the manufacturers and sellers of pesticides, agricultural extension workers play a small role, especially in Bhiwani, where only 26% of farmers reported them to be important.

The role of shopkeepers and dealers is particularly important because many farmers (58%) purchase their pesticides on credit. This gives the shopkeepers strong control over the amount and choice of pesticides used. It also makes it easier for the shopkeepers to sell spurious pesticides.

Finally, we found that the knowledge of the State Agricultural Department about biopesticides was extremely limited. This was particularly true of the village level workers (ADOs), but also the case even in the Central IPM office in Faridabad. Considering the importance given to the use of biopesticides by national government agencies, the neglect of biopesticides at the state and district level is difficult to understand. The main emphasis is on the monitoring of pest populations and the use of economic thresholds, which farmers find too difficult and time consuming. Further, the Haryana

Agricultural University recommends the use of only two biopesticides (Bt and neem) on only one vegetable crop. On all other crops, including cotton and rice, the recommendations include only chemical pesticides.

Findings: Biofertilisers

Few (19%) farmers have ever used biofertilisers in the two districts. Their number was especially small in Karnal, where only three out of 40 farmers had used them. In Bhiwani about 75% of farmers were not even aware of biofertilisers; the proportion of such farmers was even higher in Karnal (85%).

The most important reason for this lack of awareness is the fact that agriculture extension workers do not promote biofertilisers. On the whole, only 15% of farmers had been told about biofertilisers by the extension workers. The emphasis on biofertilisers was particularly low in Karnal, where only one farmer out of 40 had heard about them from extension workers.

The District Agricultural Departments do not have a positive attitude towards biofertilisers. They feel that their quality is poor, and their performance totally unreliable. Therefore, they are not prepared to risk their reputation and good will with the farmers by recommending them. The extension services run by the Haryana Agriculture University *(krishi vigyan kendra)* feel that in areas of wheat/paddy rotation, such as Karnal, the potential of biofertilisers is low. The farmers in these areas can get the same yield by using the recommended dose of chemical fertilisers. As these fertilisers are easy to use, the farmers prefer them. Biofertilisers have to be stored and applied in conditions which are suitable for the multipication of micro-organisms. This requires special facilities and care, which farmers are often unable to provide. Chemical fertilisers, on the other hand, can be stored and applied without special care. In fact, the KVK in Karnal does not recommend the use of biofertilisers at all.

Nevertheless, the extension workers in Bhiwani are required to sell a fixed number of rhizobium packets. This explains the larger number of farmers who are aware of biofertilisers, and have used them in this district. But we found that a large proportion of the rhizobium allotted to the district is not sold to the farmers, and is allowed to go to waste. The ADOs say that the quality and performance is so poor that the farmers are not interested in buying it. The quota is shown as sold in official records, and the payment is made by the ADOs from their salary.[16] The fact that the rhizobium meant for sale in various pulse growing districts is not being used by farmers is widely known to both the State Agricultural Department and the National Biofertiliser Development

16 For example, one of the ADOs in Bhiwani was given a quota of 2000 packets of rhizobium this year. He could manage to sell only about 200 packets, mostly to his contact farmers. But these have not actually been used by the farmers. He feels that the contact farmers accept biofertilisers because they want to stay in the good books of the ADOs, from whom they receive subsidised or free goods, such as seed kits. He will have to pay to the Agricultural Department Rs. 8,000/- (@Rs. 4.00 a packet).

Centre. However, every year the practice of fixing quotas and reporting of sale is carried out, as if rhizobium is actually being used.

Out of 19 farmers who were aware of biofertilisers, 14 had used them, showing that farmers are prepared to try biofertilisers. However, most of these farmers stopped using them after one crop - only three were still using them. Two reasons were reported to be important for the discontinuation of use: lack of availability and poor performance.

Availability

Many farmers who stopped using biofertilisers reported that this was partly because the supply was extremely unreliable. This was largely because biofertilisers were not being sold by most shops. While none of the shops stock biofertilisers in Karnal, two shops in Bhiwani do. The shopkeepers, in turn, say that they do not stock biofertilisers because sales are poor. One of the Bhiwani shops, for example, has been stocking biofertilisers from National Fertilisers Ltd. for the last four years but has sold only 30 packets.

Quality

It is clear that the poor quality and performance of biofertilisers present serious problems. Most studies suggest that the biofertilisers being sold in the market are contaminated and have a low count of micro-organisms. It is therefore not surprising that their performance is poor and uneven. For example, in a survey of rhizobium carried out by ICRISAT, 90% of samples from India were found to have a rhizobia count lower than that required for effective performance (Singleton *et al.*, 1996). Incidentally, this problem exists in most developing countries. For example, in a survey of 12 developing countries, only 19% of the samples met the standards prevalent in developed countries (Singleton *et al.*, 1996).

The poor performance of biofertilisers in India is primarily linked to inappropriate strains and inefficient production technology. Essentially, the production of bacterial biofertilisers requires the selection of strains appropriate for a particular crop in a given agro-climate. These strains are mass multiplied by adding bacterial culture to a suitable sterilised broth, either using the shake flask method (for small scale production) or the fermenter method (for large scale production). When an adequate growth of bacteria is achieved, the solution is mixed with a carrier such as lignite or charcoal and is packaged.

As agro-climatic conditions and soil characteristics vary widely, a large range of strains of each biofertiliser needs to be isolated for each area. The problem of identifying suitable strains is particularly serious in north India, as many of the strains do not survive the very hot temperatures prevalent in these areas. Until strains which can tolerate wide variations in temperature can be identified, the performance of biofertilisers will remain uneven. The Haryana Agriculture University is reported to be working in this direction and has developed improved strains for pearl millet, wheat, mustard, potatoes, and flowering plants. These are, however, yet to be used in large scale production.

Furthermore, the production of biofertilisers is prone to contamination, which reduces the effectiveness of micro-organisms. It is, therefore, vitally important that throughout the process extreme care is taken to maintain sterile conditions. It is also important that precautions are taken to avoid contamination during the packaging, storage and application of biofertilisers.

The production technology employed in India is inefficient and is responsible for most of the contamination common in Indian biofertilisers. Generally, production is undertaken by the flask method, which is unsuitable for large scale production. Although some firms use fermenters, they lack the sophisticated controls and monitoring facilities necessary to regulate factors such as pH, temperature and aeration. As a result the quality of the bacterial broth is often poor and uneven.

Another problem relates to the fact that Indian producers do not sterilise the carriers used for mixing the bacterial solution. For example, both the producers in Haryana, the Hissar Biofertiliser Centre and the HAU, use non-sterilised charcoal, as they do not have facilities to sterilise large amounts of charcoal in a short time. This is an important cause of the poor quality and short shelf life of these biofertilisers (Singh *et al.*, 1999). Although India has ISI (Indian Standards Institution) standards for some of the biopesticides (rhizobium and azatobacter), they are not enforced. This is reportedly because the ISI lacks facilities to test biofertilisers.

Conclusions

Biopesticides

The problem of pests, the development of pesticide resistance and the excessive use of pesticides need to be seen in the totality of the agricultural system. Our study shows that in Karnal and Bhiwani the problem is linked to the increase in cropping intensity (three crops in Karnal), the expansion of irrigation facilities (Bhiwani), the release and adoption of susceptible varieties (govinda and basmati rice in Karnal, and American cotton varieties in Bhiwani), purchase of pesticides on credit (in both the districts) and inappropriate agricultural practices (the use of contract labour for pesticide application, using power spraying machines in Karnal). In the circumstances, mere reliance on pest control, without correcting the basic problem in the system, will not produce sustainable results.

The efforts of various government agencies to popularise integrated pest management (IPM), and the use of biopesticides have had little impact. IPM departments have very little knowledge and experience of biopesticides, and most state agricultural universities, on whose recommendations pest control methods are promoted, do not include the use of biopesticides in their recommendations. In the absence of active promotion by the agriculture department, the demand for these products has not developed. It is for this reason that most private shops and dealers do not stock and sell biopesticides.

The following policy measures need to be taken urgently in order to reduce excessive use of chemical pesticides.

- Focus on sustainable agriculture by promoting: a) disease and pest resistant, and especially traditional, varieties; b) judicious inter-cropping and c) reduced crop intensity.
- Improvement in the intensity of training for IPM. The focus should be on the quality of training and not on the number of farmers trained. The training should be followed by regular contact with the trained farmers for providing continous support.
- Promotion of the use of biopesticides by the state agricultural departments and IPM workers. The state agricultural universities, which have decisive influence over what pest control methods are promoted by governmental agencies, should pay greater attention to biopesticides.

Biofertilisers

Despite the Indian government's efforts to promote the production and use of biofertilisers, our study found that biofertilisers have found little acceptance among farmers in Haryana. The problems of unavailability of biofertilisers and their poor quality are linked. On the one hand, we find that both the State Agriculture Department and shopkeepers are unwilling to stock and sell biofertilisers as they feel that their quality is unreliable. On the other hand, the low demand for biofertilisers has prevented large investment in advanced production and storage facilities, which are required for improving the quality. It is, therefore, clear that the two problems have to be seen in their totality, and a new policy is needed, some elements of which are as follows:

- The present policy of providing grants and low interest loans to biofertiliser producers should be abolished; this has resulted in the setting up of a large number of inefficient plants, which cannot produce good quality biofertilisers.

- The policy of marketing biofertilisers at very low prices should also be stopped. These prices are too low to attract adequate investment in modern manufacturing facilities. Take the example of rhizobium. A 200 gram packet of biofertiliser, which is supposed to replace about 30 kilograms of urea (a commonly used chemical fertiliser), is purchased by the Agricultural Department for Rs. 8/ packet. This price is not enough to justify investment in facilities such as charcoal sterilisation plants and cold chain for storage and transportation. Rhizobium is sold to farmers at a subsidised rate of Rs. 4/-. Our discussions with farmers suggest they feel that nothing so cheap can provide much nutrition to the plants, and do not value it. The price of biofertilisers should have some relationship with the price of the chemical fertiliser it replaces. Only then will the producers, the shopkeepers and the farmers begin to take biofertilisers seriously.

- The storage and application of biofertilisers require special facilities and skills, which most producers, shopkeepers and farmers do not possess. It is important that greater

R&D efforts are focused on developing biofertilizers which are easier to store and apply.

- Research and development to identify more suitable strains, and to develop better production technology and quality control methods has to be increased greatly. The money saved through the abolishment of various grants and subsidies should be invested in these R&D programmes.

We recommend that the promotion and production of biofertilisers should be suspended until these steps are taken. The present government policy of promoting biofertilisers without ensuring good quality and performance has actually harmed their cause, creating a widespread feeling among farmers and extension workers that biofertilisers do not work. It will be better if the production and promotion of biofertilisers is suspended until biofertilisers of improved quality can be made available in adequate quantity. Until then all efforts should be focused on developing technology, setting up modern production facilities and developing infrastructure that will produce and deliver biofertilisers of the required quality.

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