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Increase of Productivity of Crops: Control of Pre- and Post-Harvest Losses (**)

ABSTRACT — The role of pest control in past and future green revolutions is discussed, with particular reference to events in India. Pesticide use was not an important factor in the last revolution which involved wheat and rice. However, it is anticipated that the next revolution will involve pulses and oilseeds, particularly chickpea, pigeonpea and groundnuts, which are much more prone to pest caused losses than the cereals. The potential for host plant resistance, biocontrol, cultural practices and chemical pesticides in pest management on these crops is assessed.

Introduction

In looking towards the next green revolution, we should first analyze the factors that promoted the previous rapid increases in agricultural production, and then try to determine what further changes will be required for future progress. Although the phrase "The Green Revolution" is often quoted as if it refers to a single event, it has been used to describe events in several developing countries where there was a sudden spurt in the production of one or more crops. For example, it was used to describe rapid increases in soybean production in Brazil, and the dramatic increases in maize and cotton yields in some countries of Africa. However, equally rapid and substantial increases in the productivity of several crops in North America and Europe, that led to mountains and lakes of surpluses did not receive the accolade of "Green Revolution"!

Perhaps the best known of the green revolutions was in India and S.E. Asia where wheat and rice production increased rapidly from the late 1960s. The need

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to import substantial quantities of cereals in most years was replaced by stocks of stored grain and thriving exports even in the face of increasing populations. As a short presentation such as this cannot deal adequately with the diverse needs in agriculture of the many countries that make up the developing world, I will concentrate upon the situation in India, and attempt to draw lessons from the Indian experience that may be applied elsewhere.

The Green Revolution in India

The "Green Revolution" in India is said to have taken off in 1966 (Johnson, 1972). Between 1965 and 1984 there were substantial increases in the areas sown with wheat and rice, and in the yields (Table 1). Post-hoc analyses provide us with a diversity of views concerning the relative importance of the various factors involved (Bayliss-Smith and Wanmali, 1984). Most accounts attribute this green revolution to a number of improvements including increases in irrigation, in fertilizer application and in the use of new high yielding varieties. However, the basic foundations were political stability, a firm local currency, and a well organized and trusted system of marketing that gave farmers remunerative prices for their produce. Farmers will only invest in inputs and produce beyond their own needs if they are confident that they have a profitable market for their excess production.

Agricultural research, both national and international, contributed substantially to this success. The short-statured wheats that originated from the Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT) and high yielding rices, some of which came from the International Rice Research Institute (IRRI), provided a stimulus to farmers to invest in fertilizers and to use improved agronomic practices that were introduced by the Indian Council of Agricultural Research (ICAR).

TABLE 1 - Production, in thousands of tonnes, and yields in kg ha-1, of crops in India in 1965 and 1984 (from FAO, Production Statistics).

	Production (× 1000 t)		Yield (kg ha−1)	
	1965	1984	1965	1984
Wheat	12,290	45,148	910	1,851
Rice	45,921	91,000	1,310	2,126
Pulses	11,700	12,620	487	539
Groundnuts	4,022	6,900	560	952
Soybean	—*	800	—	941

* In 1965 soybean production was of such insignificance that it was not recorded.

Much of the seed that was distributed to farmers was dressed with insecticides and fungicides to give the seedlings a better chance of establishment and some initial protection. Other than this, pesticides appeared to play a relatively minor role in the early stages of this revolution. Wheat has relatively few pest problems. The insect and disease problems on rice have become more apparent in recent years, particularly in the case of the brown planthopper (*Nilaparvata lugens*), so by 1979 over 17% of the agricultural pesticides used in India were applied to this crop (Kapadia and Mohla, 1979). Thus, rice is the second largest consumer of pesticides, after cotton which accounts for more than 50% of the national total.

The next green revolution in India

The data in Table 1 show that pulses did not share in the last green revolution. Most of India's population is vegetarian so pulses are an important component of the staple diet. They add both taste and protein to most people's daily fare. Between 1965 and 1984 the availability of pulses dropped from 66 to 46 g per person per day. Over that same period the availability of cereals increased from 450 to 620 g per person per day (calculated from FAO, 1966 and 1984). India's major pulses are chickpea (*Cicer arietinum*) and pigeonpea (*Cajanus cajan*). The production of both these crops has shown little increase over recent years.

India has the largest area of groundnuts of any nation in the World, and this crop is the major source of edible oil in this country. However, the production of groundnut has also failed to keep pace with demand. In each of the last 3 years, India has had to import well over a million tonnes of edible oil, at a cost of up to a billion US dollars.

The Indian Government is now pressing for a green revolution in pulses and oilseeds. Demand has forced up prices of these crops to levels that should be attractive to farmers. The wholesale price index of pulses in India in mid-1986 has reached 402 (from a base of 100 in 1970) while the index for oilseeds is 305, both having outstripped the index for cereals, which now stands at 267. The higher prices offered for pulses and oilseeds have not yet resulted in large production increases, and we have to examine the reasons for this.

Pulses and groundnuts are relatively high-risk crops, particularly when compared with wheat. Pests and diseases can, and often do, devastate these crops in India. These losses, when added to the hazards of droughts and floods, make the production of these crops a very poor gamble in several areas of India. The farmers have long since realised that cereals and cotton give a more assured return and so have given their prime land and major attention to these crops. Pulses in particular have been relegated to poorer fields or have been sown as low density intercrops within the cereals. Many farmers expect little more from their pulses than enough to satisfy their family requirements. A large and rapid increase in the production of these crops will only come if farmers are confident that the risks can be minimized.

Major pest problems on groundnuts, chickpeas and pigeonpeas in India

These crops are attacked by very many insects and diseases in India. They are also particularly susceptible to competition from weeds. The full list of pest problems cannot be detailed here for they are so numerous. For example, we have recorded well over 100 insect species that attack pigeonpea. There is no doubt that insects are the greatest yield reducers on that crop. Of the many pests, *Heliothis armigera* is the most widespread and devastating. This insect is the major pest of both pigeonpea and chickpea and can also cause substantial losses to groundnut and several other crops. Calculations have shown that this insect robs Indian farmers of about US $300 million dollars worth of pigeonpea and chickpea in each year (Reed and Pawar, 1982). Many other insects also attack groundnuts. The most damaging of these is *Aproaerema modicella*, the groundnut leaf miner which can destroy large areas of this crop. Soil pests including white grubs (*Holotrichia* spp and others), termites and nematodes also severely damage groundnuts in some areas.

Birds, particularly parakeets, can seriously reduce yields by pecking the seeds from ripening pigeonpea pods, but surveys by ICRISAT have shown this to be a localized problem. Rats can also reduce yields both by digging up seed after planting and eating the seeds from chickpea before harvest.

Although insects are the major yield reducers on pigeonpea, the losses caused by insects on chickpea and groundnuts are generally less than those caused by diseases. On groundnuts, late leaf spot (*Cercosporidium personatum*), rust (*Puccinia arachidis*) and bud necrosis disease (BND, caused by Tomato Spotted Wilt Virus) destroy large areas of the crop. On chickpea, wilt (*Fusarium oxysporum* F. sp *ciceri*), stunt disease (Bean Leaf Roll Virus), and blight (*Ascochyta rabiei*) can be devastating. On pigeonpea, wilt (*Fusarium udum*) and sterility mosaic disease (SMD) cause major losses. Of these diseases, bud necrosis on groundnut and chickpea stunt are transmitted by insects and the pigeonpea SMD pathogen is transmitted by an eriophyid mite.

The losses caused by most of these insects and diseases can be reduced by the use of chemical pesticides. In many cases, pesticide use on well grown crops will be profitable, provided the appropriate chemical is applied at the correct time. However, chemicals should not be considered as the only remedy for pest problems. Disasters caused by the overuse and misuse of pesticides have been widely publicized. The development of insects that are resistant to insecticides, and the resurgence of insect pests and diseases, have caused major problems in several areas (Huffaker and Smith, 1980). Pesticides will not eliminate all pest caused losses. It has been estimated that preharvest losses to pests in the USA are about 37%, even after use of modern pest control technology (Pimentel, 1981)! Host plant resistance, biocontrol and appropriate cultural practices should be the primary means of pest management and chemical pesticides should be used to supplement these methods, when needed.

Host plant resistance

Breeding for host plant resistance has been particularly successful in the management of many crop diseases, but there have been fewer examples of success against insect pests. Screening and breeding for host plant resistance require persistent, interdisciplinary, long term research. Lukefahr (1982) has pointed out that such research has not been afforded top priority because new insecticides, particularly the synthetic pyrethroids, appear to offer easy solutions to our insect pest problems. However, the rapid development of resistance in *Heliothis* spp to the synthetic pyrethroids in Australia (Queensland Department of Primary Industries, 1983), and recent massive infestations of whitefly on cotton and other crops in areas where these insecticides have been used intensively in parts of India, may give fresh impetus to host plant resistance research.

Breeding for host plant resistance on groundnuts, pigeonpea and chickpea has been in progress for several years, both in the Indian national program and at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). The World's germplasm of these crops, which is held at ICRISAT, has been screened for resistance to the major insect pests and diseases. Sources of resistance to almost all of the important diseases and to many of the insect pests have already been found. Our breeders are now making crosses, and selecting from progenies to intensify these resistances and to combine these with each other and with other required characteristics. Their objective is to produce cultivars that are resistant to the major insects and diseases and give high yields of good quality grain.

Chickpea and pigeonpea cultivars with resistance to one or more of the major diseases have already been released to farmers. Resistant groundnuts are in the late stage of multilocation testing. Care is being taken to ensure that all new cultivars are no more susceptible to the common pests than are the currently available cultivars. Within the next few years we expect to release chickpea cultivars that have sufficient resistance to the major insect pest and diseases to allow farmers to obtain good stable yields without pesticide use. Although we are also making good progress in combining resistance to insect pests and diseases with other required characteristics in pigeonpea and groundnuts, we do not expect to produce high yielding varieties of these crops that will require no pesticide protection in the near future.

We expect to produce cultivars for two basic situations. High yielding cultivars will be intended for farmers and areas where inputs including irrigation and pesticide are likely to be used extensively. Cultivars that combine the maximum of resistances to biotic and abiotic stresses will be released to areas and farmers where inputs are unlikely to be used. In this way, we hope to increase and stabilize production of these crops.

Biocontrol and cultural practices

Most of the insect pests on these three crops have many natural enemies. For example *H. armigera* has been found to have 26 parasites and several predators

in India (Bhatnagar *et al.*, 1982). We must try to retain the benefits from these natural enemies and if possible augment their effects. Many scientists are working on the possibilities of augmenting the biocontrol elements. The introduction of exotic parasites and predators, the breeding and field release of these and of the native beneficial insects, and the multiplication and field application of native pathogens that kill the pests, all show promise. However, such research has yet to result in benefits in many farmers' fields mainly because the mass production and distribution of the biocontrol elements is difficult and expensive.

Cultural practices, particularly crop rotation and synchronous sowing, can play a very important role in the management of several diseases and insect pests. The problems of ensuring group action should not be underestimated, but we must not abandon these very profitable methods of pest management by substituting them with chemical pesticides.

Insecticides

In several tests, at many locations in India, it has been shown that insecticides can be profitably used to control *H. armigera* on pigeonpea and *A. modicella* on groundnuts. However, insecticide use is only profitable when the crop is well grown, and so worth protecting, and when the pest populations threaten to exceed the economic threshold. Threshold levels for the major pests of these crops have been calculated for some areas but much more research into this aspect is required. Cost benefit ratios of greater than 1:6 have been obtained in a series of trials where carbaryl was applied for the control of *A. modicella* on groundnuts (Reddy, 1982). Such benefits are obvious to farmers and a large proportion of the groundnut crops grown in India is treated with insecticide. The 1979 survey of the National Council of Applied Economics Research revealed that more than 29% of the groundnut crop was pesticide treated, a greater proportion than on any other major crop.

Government agencies are encouraging farmers to protect their crops with insecticide use through a variety of credit and subsidy schemes that give help in the purchase of both sprayers and chemicals. Insecticide use in India is rising rapidly, having increased from 39,000 tonnes in 1973/74 to 62,000 tonnes in 1983/84. This increase is greater than these tonnage figures indicate, for insecticides such as DDT, which are applied at a kg or more per hectare, are being replaced by more effective insecticides such as the pyrethroids that are applied at much lower dosages. Over 95% of the insecticide used in India is manufactured indigenously. It has been predicted that insecticide use in India will increase by 2.3% per year, with much of the increase being applied to pulses and oilseeds (David, 1986). The recent fall in the price of petrochemicals, which provide the basic materials for most insecticides, is likely to make insecticide use even more attractive, if this results in cheaper prices at the farm level.

Fungicides

With very few exceptions, the disease problems of pigeonpea and chickpea can be solved by the use of resistant cultivars, seed dressings and cultural practices, including crop rotation. Thus, farmers are unlikely to use fungicide sprays on these crops, or in the soils on which they are grown. However, fungicide sprays may be used profitably on groundnuts to control late leaf spot and rust in areas and seasons where these diseases are devastating, but some form of early warning of such hazards will be required. The prophylactic use of fungicides will be wasteful, but if the farmer waits until he sees the diseases in his crop before he obtains and applies fungicides it will usually be too late to obtain good disease control.

Herbicides

The yields of pigeonpea, chickpea and groundnut are greatly reduced if weeds are allowed to compete with the young crop, so timely weeding is essential. In most farmers' fields the weeding is done by inter-row cultivation using bullock drawn implements. However, there is also a considerable amount of hand weeding, which is a labor intensive operation. Herbicides are used successfully on these crops on ICRISAT.

There is concern that new technological developments should not create unemployment in India so the use of herbicides in areas where adequate labor is available for timely weeding will not be encouraged. However, there are labor shortages in some areas and herbicides may already compete economically with other means of weed control, particularly in groundnuts. Herbicides sales in India have increased rapidly in recent years to about 2,500 tonnes in 1984/85 (David, 1986). This quantity is very small in relation to the insecticide consumption, but demand is expected to grow at an even faster rate in the future particularly for use in irrigated areas. Sales of herbicide in India may eventually overtake those of insecticides and fungicides, for they have already done so in the developed world.

Post-harvest losses

Long term storage for large quantities of wheat and rice has been rapidly expanded in India to cope with the large surpluses in recent years. Pest problems in these stores are controlled by fumigation. Insecticides are not admixed with grains that are intended for human or animal consumption. However, almost all grain that is intended for use as seed is dressed with insecticide/fungicide dusts or slurries soon after harvest and drying.

There has been no need to store pulses and groundnuts for more than a few months so there is little experience with long term storage of these crops. However, pulses can become heavily infested with *Callosobruchus* spp, and groundnuts

with *Caryedon serratus*, within a few months in store in India. If medium-term storage of these crops is to be undertaken then the dried grain must be kept in insect and rodent proof stores. The demand for rodenticides and fumigants is expected to increase from the present 1,000 tonnes to 1,800 tonnes by 1989/90 (David, 1986).

Discussion

The stage is now set for the next green revolution in India. This will involve both pulses and oilseeds. Pesticides are expected to play a greater role in this revolution than they did in the wheat and rice success, for they will be required to reduce the risks, particularly from insects, on these crops. However, it is intended that pesticides will only be used according to need, to supplement host plant resistance, biocontrol and cultural practices, rather than as the sole means of pest control. Over 90% of the pesticides that are required will be indigenously produced but some of the newer pesticides will have to be imported until production facilities for these are developed locally. Crop insurance schemes are being introduced that are intended to further reduce the risks faced by individual farmers, however Walker *et al.* (1986) have argued that such schemes will not contribute substantially to income stability.

New, high-yielding varieties of these crops are being made available to farmers through the public sector and private enterprise seed corporations. A recent example is of a short duration pigeonpea that produces high yields when grown in high plant populations and protected by insecticide use. This is being taken up by many farmers in southern India. It is expected that traditional tastes will limit the acceptance of any radically new pulses. Chickpea and pigeonpea and the other traditionally grown pulses have a variety of uses in the Indian kitchen and a very large increase in production of all these can be absorbed by the local market. There will be a ready market for new oilseed crops. Soybean production has already expanded from virtually zero production in 1965 to 800,000 tonnes in 1984 (FAO, 1966 and 1984) and considerable areas of oil palms have already been planted. However, groundnut is expected to be the dominant oilseed for the forseeable future and the demand for increased production of this crop will lead to the increased use of inputs by the farmer.

We must also ask what lessons can be learned from the Indian experience that will be of benefit for countries where green revolutions are even more urgently required, such as those in the African Sahel? The primary factor in the Indian success story was the profit incentive at the farmer level. Farmers were confident that they could profit from inputs such as high-yielding varieties and fertilizer use because there was an assured and remunerative market for their produce. Such markets require well organized purchase, collection and distribution systems, right down to the village level. Also the inputs — seed, fertilizer, pesticides and reliable agronomic advice, have to be readily available and accessible to the

farmers. For some farmers there may have to be credit, to purchase the inputs, at reasonable interest rates. These are the ingredients for a green revolution and we cannot expect farmers to raise their production much above the subsistence level unless all the ingredients are available.

Even if all of the inputs necessary for a green revolution are made available, we must not forget that most of the Developing World's agriculture is rainfed. Unless we can greatly increase irrigation availability, most of the farmers will continue to be at the mercy of the raingods!

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