# Pest control and sustainable smallholder cotton production: Progress and prospects

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## ABSTRACT

*Cotton provides income to millions of farmers world – wide. At present, nearly 80% of the area under cotton cultivation is in developing countries where the majority of growers are smallholders. Cotton production in developing countries is under threat. Productivity and profitability in these countries are both on the decline. For example, in China, India and Pakistan and parts of sub – Saharan Africa, pest control has become increasingly difficult and expensive due to onset of resistance in populations of* Helicoverpa armigera *(Hübner)(Lep. Noctuidae),* Pectinophora gossypiella *(Saunders)(Lep.: Gelechiidae),* Alabama argillacea *(Lep.: Noctuidae) and induction of resurgence in populations of* Bemisia tabaci *(Genn)(Hom.: Aleyrroidea) and* Aphis gossypii *(Glover)(Hom.: Aphididae) among others. In Latin America and sub – Saharan Africa, on going deregulation and macroeconomic reforms have inadvertently destabilized cotton production, in part due to the opportunity given for increased spread of some insects such as Anthonomus grandis (Boheman)(Col.: Curculionidae) and diseases such as* Fusarium *and* Xanthomonas*. In addition, reforms have been associated with increased difficulties in managing traditional pests due to input use related constraints and the collapse of some services that were previously administered by the state. In this paper, I discuss these issues and highlight some recent measures being taken to solve them taking into account the need to reconcile smallholder's requirements for food and cash.*


## Introduction

Cotton is an important commodity in the economies of many developing countries (Eisa *et al.* 1993; Gilham *et al.* 1995). It provides income to over a billion people and up to 90% or more of total export revenue in some countries (Table 1) (Fortuci, 2002). In developing countries, cotton production is largely the preoccupation of smallholders who form the bulk of the rural poor.

Low lint yields are characteristic of cotton production in most developing countries. In a survey involving 67 major cotton-growing regions countries, only 14 had average lint yields above the world average of 639 kg/ha and in the developing world only China, Mexico and Syria had national yields in excess of 1000 kg/ha (ICAC, 2002).

There are many factors limiting production in these countries (Gilham *et al*., 1995; CFC, 2001). Among them, pests constitute perhaps the most important constraint to profitability. Increased importance of major pests due to improvements in agriculture as well as induction of resistance in their populations has pushed insecticide cost to as much as 73.9% and 46.8% of growing and total production costs in some countries respectively (ICAC, 2002).

Efforts to boost yields through improved pest control have further been affected by recent economic reforms (Kabissa and Myaka, 2000). While reducing inflation, improving the efficiency of marketing systems and increasing producer prices of cotton has generally benefited smallholders, increases in input prices and cuts in some public goods and services have adversely affected smallholders' access to and uptake of seasonal inputs and productivity-enhancing technologies (Poulton *et al.* 1998; Shepard and Farolfi, 2000).

Finally, the general easing of cross border trade and unregulated movement of seed after reforms has led to increased spread of *Anthonomus grandis* (Boheman) in Latin America (Stadler, 2000) and *Fusarium oxysporum* f.sp *vasinfectum* in Eastern Africa (Hillocks and Kibani, 2002).

This paper discusses pest control with reference to smallholder cotton production and in particular, it highlights emerging challenges that threaten the sustainability of cotton farming and the steps being taken to alleviate them. The paper has an obvious entomological bias; a " pest " in IPM subsumes weeds, pathogens and non – arthropod animals as well. Such bias is necessary to limit the scope of this paper; the paper also has a clear sub – Saharan Africa slant.

## Pest problems under smallholder cotton farming

In local smallholder farming systems, cotton plays several vital roles. First, it acts as the nucleus around which, extension, input supply and marketing are built (World Bank, 1997). Second, because of its relatively long flowering period compared to food crops, cotton has considerable influence on the spatial and temporal dynamics of polyphagous pests for which it serves as a sink. An understanding of the spatial and temporal dynamics of arthropod movements between cotton and other host plants is thus essential for effective pest control (Kennedy and Margolies, 1985).

Major pests of cotton in Africa, Asia and Latin America are listed in Table 2. The importance of *Helicoverpa armigera* (Hübner) has been increasing, an aspect which is associated with changes in cropping practices, e.g. changes in the relative area under cotton and sorghum in Sudan Gezira (Balla, 1982) and increases in area under wheat and sunflower in China. Similarly, there has been more Fusarium and Verticillium wilt in parts of China where there is inadequate crop rotation (Gilham *et al.,* 1995). In general, increased ravages from bollworms and some sucking pests has been an outcome of increased use and abuse of some inputs particularly pesticides (Reed and Pawar, 1982; Deguine *et al*., 2000).

## *Overview of pest control interventions*

For smallholders, the primary motivation for growing cotton is to produce marketable seed cotton, profitably. However, because seed cotton is sold on a differential grade price basis, smallholders often strive to optimize yield and quality by adopting sound agronomic practices and effective pest control measures (Fitt, 2000; Russell, 2001).

### *Host plant resistance*

Conventional plant breeding has helped make cultivation of cotton possible in areas infected by *Fusarium*, *Verticillium* and *Xanthomonas campestris* pv. *malvaceurm*. Similarly, *Jacobiasca lybica* (De Berg), which was previously a major impediment to expansion of cotton in Africa, has now been relegated to a minor pest merely through selection and use of pubescent cultivars (Parnel *et al*., 1949).

However, recent upheavals in the structure of cotton industries in SSA as well as diminishing role of the state in overall agricultural development are likely to disrupt existing breeding and seed multiplication programs (CFC, 2001). Increased spread of Fusarium wilt in eastern Africa is testimony to this fact (Hillocks and Kibani, 2000). But the major concern over conventional plant breeding programs is that mere modification of the plant habit or its biochemistry has so far not been good enough to provide a significant measure of control of against bollworms, which continue to be major economic pests (Russell, 2001).

Use of genetically engineered cotton offers considerable hope for smallholders. Its greatest potential lays with its "packaged technology in the seed" an aspect that makes it highly compatible with a low input, low output approach to production. In Argentina, China, India, Mexico and South Africa, Bt. cotton has helped to lower production costs through savings on equipment, personnel and additional pesticides necessary (May, 2002; Shelton *et al*., 2000).

Nevertheless, prospects for Bt cotton in SSA remain mixed. Introduction of Bt cotton faces enormous institutional constraints. Biotechnology, unlike the green revolution, is being developed mainly by the private sector in wealthy countries with the explicit aim of earning a profit. Such companies are unlikely to invest especially in the modification of locally adapted cotton varieties where potential sales are small, patents are not well protected and risks are high (Traxler, 1999).

### *Cultural methods*

Manipulation of sowing dates, intercropping and the destruction of crop residues have often been advocated for suppression of some pests and diseases (Risch, 1980; Coker, 1987; Risch *et al.,* 1993). These practices though, have great socio-economic implications under smallholder conditions. Thus, early sowing of cotton to mitigate bollworms and late pests is not feasible in practice because food security necessitates food crops being sown first (Reed, 1965; Norman *et al.,* 1974).

Cotton is often intercropped or relay intercropped with either legumes or cereals such as maize and wheat mainly to optimize food security and income (Myaka & Kabissa, 1996; Gilham *et al.,* 1995). In Uganda, populations of spiders and the black ant (*Lepisiota* spp.) on cotton tend to be higher on intercropped cotton where they prey on bollworms and other pests (Serunjogi, personal communication). Elsewhere, maize, sunflower or even pigeon peas serve as trap crops or reservoirs of predators for *H. armigera* and *H. virescens* (Eisa *et al.,* 1993). However, intercropping may also serve to exacerbate attacks by *Helicoverpa* spp. and *Heliothis* spp. on cotton vide the nursery crop effect (Reed, 1965; Kennedy and Margolies, 1985).

Destruction of crop residues and observance of the closed season for control of late pests such as *P. gossypiella* and *Dysdercus* spp. has often been neglected because systematic and area – wide enforcement has been lacking or is ineffective, e.g. following budget cuts on public services.

### *Chemical control*

Cotton is renown for its huge consumption of pesticides. However, in Africa, it accounts for only 15% of total pesticides used, with coffee and cocoa accounting for 25 and 40% respectively. According to Abate and Ampofo (2000) African farmers spend only 3.0 dollars/ha per year on pesticides compared to 3.5 and 5.0 dollars/ha per year for farmers in Asia and South America respectively. The control of pesticide use on cotton expressed as percentage of growing and total production costs reflects these trends (ICAC, 2002; Table 3).

Organophosphates and synthetic pyrethroids constitute the bulk of pesticides used on cotton. In Sudan and Francophone Africa, the use of mixtures is preferred to that of single products (ICAC, 2002), for better simultaneous control of bollworms and sucking pests. The use of botanical insecticides as alternative pesticides is receiving renewed interest (Casida and Quistad, 1998; Kabissa *et al.,* 2000).

Pesticides are applied as foliar sprays by an array of sprayers (ICAC, 2002). A major challenge to pesticide application under smallholder conditions is how to improve pesticide coverage and efficacy. This drove the switch from CLV to ULV spraying in 1970s and from ULV to VLV spraying in 1990s. This has occurred in tandem with diversification of pesticide formulations, improvements in energy consumption and overall reliability of sprayers (Clayton *et al.,* 1993; Deguine *et al*., 2000). An issue for future research concerns the need for a dual-purpose sprayer for application of both insecticide and herbicides (Table 4).

In over 50% of countries surveyed by ICAC, pesticides are applied strictly on the basis of economic thresholds. Elsewhere, farmers compromise between preventive and threshold spraying (ICAC, 2002). Use of economic thresholds has resulted in over 78% of cotton in Syria and Uzbekistan not being sprayed at all. In other countries, cotton is sprayed 1 to 6 times except in Bolivia, Brazil and parts of China where more than 6 sprays are needed (ICAC, 2002). However, wider adoption of threshold spraying is in doubt given the complexities of monitoring, sampling and eventual decision-making processes in the case of illiterate smallholders.

## *Biological control*

The potential of predators, parasitoids and pathogens to suppress pest populations on cotton is widely acknowledged (Fitt, 1989; King and Coleman, 1989). In a review of natural enemies of *H. armigera* in Africa, 41 out of 176 species were predators (Van den Berg *et al.,* 1988; 1993). In the case of *Aphis gossypii* and *Bemisia tabaci*, predators tend to be more important (CFC, 2000). In most countries, there are on-going programs for either conserving indigenous natural enemies or augmentative releases of *Trichogramma* spp., *Chrysoperla* spp. and *Geocoris* spp. among others, for the suppression of *H. armigera* and *Heliothis* spp. (ICAC, 2002).

The relative effectiveness of parasitoids and predators in annually disrupted, multi–pest agro-ecosystems, such as cotton continues to be debated (Symondson *et al.,* 2002). Nevertheless, there is renewed interest in the use of resident generalists in view of their rapid colonizing ability, their temporal persistence and their opportunistic feeding habits (Limburg and Rosenheim, 2001; Symondson *et al*., 2002).

How to conserve and enhance local natural enemies under smallholder conditions is currently a major challenge in biological control. By introducing the farmer field school approach, scouting and threshold based spraying, the awareness of farmers of the role of natural enemies in pest control may improve.

## *Integrated pest management*

World - wide, IPM is increasingly becoming the official pest management paradigm. In Asia and Latin America where cotton production has been on the so-called "pesticide treadmill", promotion of IPM is geared at reducing pesticide usage. However, in Africa promotion of IPM in the aftermath of structural adjustment programs is aimed at rationalizing overall pest control costs (Kabissa *et al.,* 2000).

Much of the promotion of IPM in developing countries has been based on the farmer field school model, which is also emerging as a new mode of extension (Barfield and Swither, 1994; Dilts, 2001). To date, there are IPM programs targeting *H. armigera*, *P. gossypiella*, *Earias* spp., *Amrasca devastans*, *B. tabaci* and *A. gossypii* in just a few developing countries (ICAC, 2002).

In most countries, pest control is still centred on cotton and use of pesticides continues to be the principal management tactic. This derives in part from promotion by the agrochemical industry and historically from offers of pesticides as "gifts" by the donor community. Difficulties in ensuring area - wide compliance due to weak institutional support has also helped slow down adoption of IPM (Cowan and Gunby, 1996).

# *Challenges to pest control in developing countries*

Although macroeconomic and institutional reforms were designed to stimulate export crop production through price incentives to farmers, cuts in public expenditure have adversely affected the following public services:

## *Provision of seasonal inputs: The need for alternative approaches*

The ability to purchase seasonal inputs at the start of the growing season is a major requirement for smallholder participation in cotton production. An emerging challenge after the reforms has been "how to provide such resource - poor smallholders with inputs given their inability to purchase them on cash basis" under competitive market conditions.

Increasingly, use of interlocking transactions is becoming popular (Poulton *et al.,* 1998). In this system, also referred to as contract farming, seasonal inputs are provided using the borrower's expected harvest as a collateral substitute to guarantee loan repayment. This system is already in use in Zimbabwe, Zambia, Philippines and Mozambique (Burgess 2001; Gilan and Catedral 2001). There are other approaches to financing inputs e.g. Cargill's "Farmer Input Voucher Scheme" now in use in Zimbabwe and Tanzania.

## *Regulation of agricultural inputs*

Regulation of agricultural inputs by the state has often been justified on grounds that: input use implies externalities, screening of inputs will direct farmers towards the most appropriate inputs and mandating and monitoring the quality of inputs sold will ensure non-adulteration and correct labeling (Trip and Gisselquist, 1996).

However, after policy reforms, governments have often failed to cope with increased use of substandard formulations and illegal, often smuggled, pesticides. Developing countries have recently become the destination for low quality products, which are no longer under patent. This fact, fueled by inadequacies in regulations governing the distribution and use of pesticides, as well as their enforcement after macroeconomic reforms, has resulted in extensive abuse and misuse of pesticides.

## Technology development and transfer

How to increase yield has been the goal of all technology development and transfer institutions. However, ways of achieving this, namely, on pure stands and with increased use of external inputs have often not been pro smallholders. Because price, availability and lack of seasonal credit often constrain smallholders using purchased inputs, the objective should not merely be to look at how to increase yield, but also of what is cost effective over the long term, and how to reduce costs, labor, risk and environmental damage (Whiteside, 1998).

Exclusion of smallholders as collaborators and beneficiaries in the entire technology development and transfer process has often been the major cause of farmer problems with the developed technologies (Norman *et al*., 1974; Putter, 1987; Norton *et al.,* 1977; Clark, 2001). Thus, the banning of food crops being sown prior to cotton and of intercropping cotton with such crops, on grounds that both practices exacerbate pest problems on cotton, has often been rejected as it contradicts the smallholder's food security interests and the need to alleviate labor constraints (Norman *et al*., 1974; Norton *et al*., 1977; Kabissa and Myaka, 2000).

Participatory research has recently been introduced in order to address smallholders' needs by working with them on their priorities and giving them greater control over the research agenda and process. Thus, adoption of threshold spraying and the switch to plant-based insecticides in Tanzania took effect after participatory approaches were used to solve escalating pesticide costs on cotton (Kabissa *et al.,* 2000). Similarly, further spread of Fusarium wilt and *Xanthomonus campestris* in Uganda and Tanzania is being arrested by introduction of resistant varieties after participatory screening of several potential varieties (Serunjogi, personal communication; Hillocks and Kibani, 2002).

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*Table 1. The share of cotton output expressed as percentage of agricultural export revenue.*

| Country | 1980 | 2000 |
|---|---|---|
| Benin | 21. 4 | 93. 8 |
| Uzbekistan | Not available | 85. 0 |
| Tajikistan | Not available | 72. 3 |
| Togo | 10. 3 | 70. 3 |
| Burkina Faso | 49. 8 | 67. 7 |
| Mali | 41. 1 | 59. 1 |
| Syria | 61. 3 | 33. 8 |
| Egypt | 62. 5 | 26. 5 |
| Pakistan | 35. 8 | 14. 6 |
| Zimbabwe | 19. 6 | 9. 9 |
| Uganda | 1. 2 | 6. 7 |
| Tanzania | 12. 0 | 6. 2 |
| Sudan | 42. 6 | 5. 4 |

(Source: Fortuci, 2002)

*Table 2. Key arthropod pests of cotton in Africa, Asia and Latin America.*

| | Africa | Asia | Latin America |
|---|---|---|---|
| Bollworms | | | |
| Helicoverpa armigera | • | • | NP |
| Heliothis virescens | NP | NP | • |
| Pectinophora gossypiella | • | • | • |
| Earias spp | • | • | NP |
| Diparopsis castanea | • | NP | NP |
| Diparopsis watersi | • | NP | NP |
| Cryptophlebia leucotreta | • | NP | NP |
| Sacadodes pyralis | NP | NP | • |
| Sucking pests | | | |
| *Amrasca devastans* | • | • | NP |
| *Aphis gossypii* | • | • | • |
| *Bemisia tabaci* | • | • | • |
| *Thrips tabaci* | • | • | • |
| *Tetranychus* spp. | • | • | • |
| *Polyphagotarsonemus latus* | • | NP | • |
| *Dysdercus* spp. | • | • | |
| Leaf worms | | | |
| *Alabama argillacea* | NP | NP | • |
| *Spodoptera* spp | • | • | • |
| Others | | | |
| *Anthonomus grandis* | NP | NP | • |
| *Eutinobothrus brasiliensis* | NP | NP | • |

• Denotes key pest

NP Denotes not present

*Table 3. Pesticide costs expressed as a percentage of growing and total seed cotton production cost.*

| Country | % Of Growing Costs | % Of total production cotton costs |
|---|---|---|
| Brazil | | |
| • Cerrado | 73.9 | 46.8 |
| • South | 71.4 | 37.9 |
| Colombia | 54.5 | 22.2 |
| Bolivia | 72.4 | 22.1 |
| Sudan | 66.9 | 20.9 |
| Philippines – Luzon | 50.3 | 17.9 |
| India | | |
| • Central | 65.4 | 17.7 |
| • South | 60.7 | 16.1 |
| Thailand | 43.9 | 16.1 |
| Pakistan – Punjab | 35.5 | 13.3 |
| Zimbabwe – communal | 49.8 | 12.7 |
| China – Yellow River Valley | 37.6 | 12.6 |
| Mali | 39.7 | 10.8 |
| Benin | 24.3 | 7.7 |
| Cameroon | 17.2 | 7.6 |
| Egypt | 15.7 | 3.6 |
| Syria | 0.7 | 0.2 |

(Source: ICAC, 2001).

*Table 4. Smallholder's pesticide application systems: Advantages and limitations.*

| Type of sprayer | Advantages | Limitations | Remarks |
|---|---|---|---|
| Knapsack sprayers | • Simple to operate<br>• Easy to clean and store | • Need for water<br>• Manual pumping<br>• Pressure and output rate fluctuate<br>• Difficult to implement correct use | 60 – 100 liters of spray volume/ha; |
| Spinning disc sprayers | • Need for water optional<br>• Less time and labor required | • Drift hazards<br>• Coverage may not be adequate<br>• Formulations present safety hazards<br>• Difficult to implement correct use | • 1 – 3 litres/ha (ulv);<br>• 10 litres of spray volume /ha (vlv) |
| Electrodyne sprayers | • Placement sprayer<br>• No pumping<br>• Coverage more even<br>• Less drift hazards<br>• Easy to implement correct use | Useful only for application to foliage; | 0.2 – 2 l/ha; **Discontinued** |