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SUSTAINABLE CONTROL OF THE COTTON BOLLWORM
HELICOVERPA ARMIGERA
IN SMALL SCALE COTTON PRODUCTION SYSTEMS
(CFC/ICAC/14)

to be financed under the

SECOND ACCOUNT

Appraisal Report

Date: 21 February 2000

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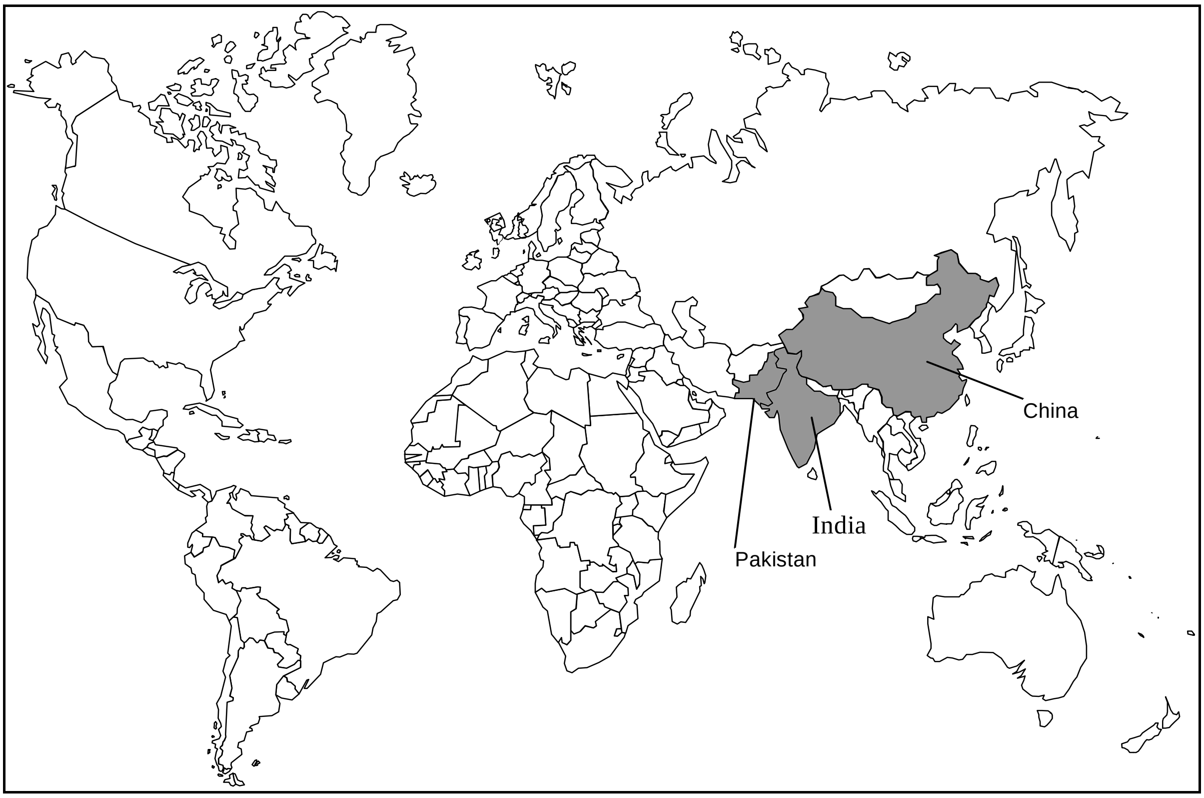

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Glossary:

ADB	Asian Development Bank
CFC	Common Fund for Commodities
CCRI	Central Cotton Research Institute, Multan, Pakistan
CICR	Central Institute for Cotton Research, Nagpur, India
FFS	Farmer field school
GOI	Government of India
IACR	Institute of Arable Crops Research, Rothamsted
ICAC	International Cotton Advisory Committee, Washington, USA
ICAR	Indian Council of Agricultural Research
IRAC	Insecticide Resistance Action Committee
IPM	Integrated pest management
IRM	Insecticide resistance management
LD_{90}	Dose of insecticide killing 90% of the given population
NATESC	National Agricultural Technology Extension Service Centre, Bejing, China
NATP	National Agricultural Technology Project (India - WB/ICAR)
NAU	Nanjing Agricultural University, Nanjing, China
NGO	Non Governmental Organization
NRI	Natural Resources Institute, Chatham, United Kingdom
NRI Ltd	Natural Resources International Limited, United Kingdom
PAU	Punjab Agricultural University, Ludhiana, India
PCC	Project Co-ordinating Committee
PEA	Project Executing Agency, in this project NRI Ltd
TNAU	Tamil Nadu Agricultural University, Coimbatore, India

SUSTAINABLE CONTROL OF THE COTTON BOLLWORM
HELICOVERPA ARMIGERA
IN SMALL SCALE COTTON PRODUCTION SYSTEMS
(CFC/ICAC/14)

Project Summary

Submitting Institution: International Cotton Advisory Committee (ICAC)

Recipient of the Grant: International Cotton Advisory Committee (ICAC)

Project Executing Agency: Natural Resources International Ltd, UK

Supervisory Body: International Cotton Advisory Committee (ICAC)

Location: China, India, Pakistan, United Kingdom and dissemination in Asia and Africa

Duration: 4 years

Objective and scope: The overall objective of the project is to develop, apply and disseminate cropping systems and pest management practices for a cost-effective and sustainable control of the cotton bollworm. The project will build on existing knowledge and experiences, or further development into efficient methods, resulting in substantially reduced uses of hazardous pesticides and increased profitability for cotton producers. Although direct project activities are focussed on the resource-poor Asian producers/production systems, throughout the project due emphasis will be given to ensure that the ultimate outcome of the project will also be relevant and applicable to the small African producers who are facing higher production costs and crop losses due to the cotton bollworm. The project will have the following main components: (a) activities to aim at filling the knowledge gaps in relation to long-term sustainable use of pesticides and their mixtures; (b) activities that address the problem of insecticide resistance management; and (c) activities that present and demonstrate the conclusions in a form directly, easily and reliably applicable by the small farmer with a minimum of training**.** The knowledge and insight gained by the project will result in tools and documentation primarily for use by producer supporting entities as well as in easily accessible documentation for direct beneficiary use.

Estimated total cost: USD 4,493,445
CFC-financing: USD 2,258,503
Co-financing: USD 1,087,594
Counterpart Contributions: USD 1,147,348

Previous Assistance to the ICB

Title of Project:	Study of Cotton Production Prospects for the Nineties
Amount of Assistance:	SDR 378,264 (Grant)
Board Approval Date:	13 October 1992 [Completed]

Title of Project:	Integrated Pest Management for Non-sticky Cotton
Amount of Assistance:	SDR 2,192,274 (Grant)
Board Approval Date:	29 March 1994
Date of Effectiveness:	21 September 1994
Closing Date:	30 September 1999

Title of Project:	Integrated Pest Management of the Cotton Boll Weevil in Argentina, Brazil and Paraguay
Amount of Assistance:	SDR 1,360,329 (Grant)
Board Approval Date:	7 September 1994
Date of Effectiveness:	25 January 1995
Closing Date:	30 June 2001

Title of Project:	Genome Characterization of Whitefly-Transmitted Geminiviruses of Cotton and Development of Virus-resistant Plants through Genetic Engineering and Conventional Breeding
Amount of Assistance:	SDR 996,111 (Grant)
Board Approval Date:	3 April 1995
Date of Effectiveness:	19 September 1995
Closing Date:	31 December 2000

Title of Project:	Improvement of the Marketability of the Cotton Produced in Zones Affected by Stickiness
Amount of Assistance:	SDR 766,639 (Grant)
Board Approval Date:	22 October 1996
Date of Effectiveness:	26 February 1997
Closing Date:	31 December 2000

Title of Project:	Improvement of Cotton Marketing and Trade System in Eastern and Southern Africa
Amount of assistance:	SDR 2,595,947 (Grant)
	SDR 4,111,739 (Loan)
Board approval date:	15 July 1997
Date of effectiveness:	to be determined
Closing date:	to be determined

PART I. INTRODUCTION

A. Project Background

A project profile for this project was reviewed at the 23rd meeting of the Consultative Committee in January 1999. In its review, the Committee recommended in particular that, given the impact of cotton bollworm in China and their available expertise, China should be included in the project; the costs of activities of UK-based institutions should be funded as far as possible via UK-based co-financing and the dissemination component of the project needed to be improved to include potential beneficiaries in African countries. In its review of the resubmitted project proposal in July 1999, and in light of consultations held with representatives from the proposing organizations, the Committee recommended that the proposal be submitted to the Executive Board for approval, subject to the confirmed acceptance of the three lead institutes in China, India and Pakistan of the proposed implementation arrangements and with the inclusion of a representative of the Supervisory Body in the Project Co-ordinating Committee.

The Executive Board of the Common Fund approved the project as designed, in its meeting on 11 October 1999. In its deliberations on the project and the magnitude of the problem it is addressing, it was noted that African countries were specifically interested in being more involved in the proposed project activities than was presently envisaged. The option of adding activities located in selected African countries was endorsed by the Executive Board, with the notion that the development and subsequent formulation of such "add-on activities" would not delay the factual start of project operations in the three Asian countries in the original project design. Upon completion of the design and subsequent approval thereof by the Executive Board (envisaged in the course of the year 2000) of the add-on activities these will be integrated in the overall project. The actual modality of such integration will depend on the substance and design of the new activities and will be subject of later consultations between the parties involved.

B. Overview of Cotton Production and Consumption.[1]

Production patterns

In 1997-8, the three countries involved in the project produced between them 45% of the world's cotton on 48 % of the cotton acreage. China's share in production was 23%, while India produced 13% and Pakistan 9%. World cotton production in 1998/99 is projected to fall by 7.3% (1.5 million tons) from 1997/98 level, and is estimated at 18.6 million tons. The most significant decline in production this season has occurred in the USA where cotton output fell by 1.1 million tons to below 3 million tons as a result of losses in harvested area and poor yields caused by adverse weather. Cotton production also suffered cumulative losses of almost 500,000 tons during 1998/99 in China (Mainland), Uzbekistan and Pakistan.

China is by far the largest producer with 4 millions tonnes produced annually on some 4.5 million hectares, mainly distributed in the Yellow River Valley, Yangtze River Valley and

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[1] **Information provided by the International Cotton Advisory Committee (as at August 1999).**

lately the Xinjiang Uygur Autonomous Region. In China (Mainland), production fell by 270,000 tons to 4.33 million tons because of poor weather and flooding in Central China. However, production in the Xinjiang region rose by 20% compared with 1997/98 and now accounts for 32% of overall production. Chinese cotton production continues to be affected by resistance to insecticides particularly in the Yellow River Valley. However, cotton yields have shown an increasing trend. The reasons for the current increase in yields in China are:

- elimination of worst insecticide resistance affected cotton area in the Yellow River Valley;
- replacement of this area with high yielding area in the Northwest region particularly Xinjiang province;
- implementation of an integrated pest management programme.

Since 1991, the cotton area in the Northwest Region has increased by almost 300%. In the late 1980s, cotton yields in the three regions Yellow River Valley, Yangtze River Valley and Northwest region, were comparable. But now yields in the Northwest Region are over 300 kg/ha higher compared to the other two regions. Higher yield and lower need for insecticide use encouraged expansion in the Northwest. The plans are to grow 1.5 million hectares in the Northwest Region in 2000.

According to Sheng (1999), during the 1980s less than 50,000 hectares in the Xinjiang were affected by the cotton bollworm. During the 1990's, the incidence of bollworm increased significantly. Following a mild winter in 1996, the 1997 bollworm density was a new record for the province. 38% of China's use of 210,000 tonnes of insecticide is on cotton (Liu et al. 1997). Rates of increase vary widely across China, many areas have seen a doubling of insecticide use in the last 7 years. There is a clear indication that resistance in the Xinjiang province is following the path of the Yellow River Valley. Despite pest control efforts, damage by the pest is generally estimated at 10-15% of cotton output, equivalent to 0.4 million tonnes or c.$470 million annually. The 1992 outbreaks were particularly severe resulting in yield losses of 50-60% in some areas. Insecticide resistance is clearly a major constraint on economic cotton production in China.

The projected cotton crop for Pakistan in 1998/99 is estimated at 1.5 million tons, down 60,000 tons compared with 1997/98 and significantly below the peak of 2.18 million tons in 1991/92. Pakistan has the technology and conditions favourable to produce over 2 million tons of cotton. However, since 1992/93, the leaf curl disease, caused by gemini viruses, transmitted by the whitefly *Bemisia tabaci* has seriously affected cotton production. The normal threshold below which insecticide application is not justified in terms of yield losses due to the whitefly, is 5-6 whiteflies per leaf. But, on average, one whitefly per leaf is enough to carry the virus and cause leaf curl disease. In an effort to keep the whitefly population as low as possible, insecticide applications increased significantly. 80% of Pakistan's 43,200 tonnes of insecticide is used on cotton and continues to rise in Pakistan growing at a rate of 20% per annum (ICAC 1998b). Because of excessive spraying, not only whitefly but also bollworms, particularly the cotton bollworm *Helicoverpa armigera,* developed resistance to insecticides. Introduction of generic insecticides in the late 1980s has also played an important role in the development of resistance with very similar materials being sprayed sequentially. *H.armigera* damage, and cotton leaf curl damage exacerbated by high whitefly numbers provoked by spraying against *H.armigera,* was responsible for a drastic decline in cotton production in Pakistan with a resultant 3% decline in GDP in 1996/97. During 1998/99 the leaf curl virus had less impact and at the beginning of the season it was estimated that Pakistan would produce about 1.9 million tons of cotton. But, farmers failed to control the cotton bollworm and consequently production was reduced to only 1.5 million tons. Insecticide resistance then, is a significant and growing problem in Pakistan.

The decline in world cotton production during 1998/99 has been lessened by increased production in India, Turkey and Australia. Production in India and Turkey is projected to increase by a cumulative 70,000 tons. Cotton yields in India, the largest cotton growing country of the world by area, are amongst the lowest in the world. Dryland conditions are mainly responsible for the lower yields. Insecticide resistance is now endemic throughout India (Armes *et al*. 1992, 1995, 1996). Despite the use of high yielding commercial cotton hybrids, resistance to insecticides has resulted in lower yields and higher production costs. Yields are already low and India cannot afford any further reduction. 50% of India's consumption of insecticide active ingredient is on cotton which occupies only some 5% of the cropped area and its use continues to rise steeply at a rate of 7% per annum. Since the early 1980's *Helicoverpa armigera* has become increasingly important on cotton and played a significant role in the crop reduction of 14.6% in India in the 1998/99 season. The insecticide resistance problem affects millions of hectares of cotton in India and is a major constraint on economic production.

Table 1: Cotton production and insecticide use statistics 1997-98 season (ICAC 1998a).

	China	India	Pakistan	Total
Cotton area 1997 (mill ha)	4.5	8.8	3.0	16.3
Area as % of World area	13.3%	26.0%	8.9%	48.2%
Production in 1997 (mill tonnes)	4.6	2.6	1.6	8.8
% of World production	23.1	13.1	8.9	45.1%
Average yield/ha (Kg lint)	1,016	294	582	-
				Mean
Insecticide as a % of growing costs	46%	44%	42%	44%
Insecticides as % of total production costs	17%	15%	18%	16.3%
% of total insecticide use which is dedicated to cotton	38%	50%	80%	47.3%
Insecticide active ingredient used on cotton annually (tonnes)	80,000	36,826	43,200	160,026

Consumption Patterns

In 1997, strong expansion of world textile demand was fostered by world economic performance, which was in its fourth year of above-average growth. In fact, world textile consumption at the end-use level increased 5.6% in 1997, the fastest increase since 1986. As world economic conditions deteriorated in 1998, the prospects for continued strong growth of textile consumption greatly diminished. Current estimates suggest that world textile consumption expanded 0.9% in 1998 and will expand 0.2% in 1999. Demand for cotton continues to perform below demand for other fibres and it is estimated that the market share of cotton in 1998 was 42.6%.

As a result of lower economic growth associated with the current financial crisis, world mill consumption of cotton is expected to decline to 19 million tons in 1998/99, 300,000 tons less than in 1997/98 and 400,000 tons less than in 1996/97. Such a level of consumption is in line with the declines that have occurred in the countries in crisis and the declines in textile activity that are being registered in other countries as a result of the increased exports of cotton textile manufactures from East Asia. Mill consumption of cotton in East

Asia declined by 140,000 tons in 1997/98, but the level of consumption during the second half of 1998 was maintained, suggesting that economic activity in the textile industry has stabilised, as is the case for the overall economy of the region. In Russia, another country affected by the financial crisis, mill consumption is expected to decline by 18% to 183,000 tons in 1998/99. Finally, in Brazil, the latest casualty of the financial crisis, mill consumption is expected to decline to 700,000 tons in 1998/99, 50,000 tons less than in 1997/98 and 130,000 tons less than in 1996/97.

The government of China (Mainland) has announced a policy of reducing spinning capacity and limiting cotton consumption in all sectors to a total of 4.5 million tons per year, with textile-fibre needs being met by expanded production and use of chemical fibres, mostly polyester. The policy of restricted cotton consumption is consistent with the newly announced production policy of reduced prices to farmers. A new organisation called the State Textile Industry Bureau was created last year to enforce central-government policies, and China (Mainland) has been reaching its goals for destruction of spindles. The price reductions are focussing attention on the need for production cost reduction. Crop protection costs are a prime candidate here.

Consumption in India is estimated at 2.7 million tons this season, little changed from 2.68 million tons last season. Mill use of cotton in Turkey is estimated at 1.2 million tons in 1997/98, based on the difference between production plus imports less exports, but consumption this season is estimated at 1.05 million tons based on reports of heightened competition from East Asian textile exports. Cotton use in Central Europe is falling by an estimated 15,000 tons a year to 260,000 tons in 1998/99, and cotton use in the EU, Norway and Switzerland is falling about 10,000 tons a year to an estimated 1.19 million tons.

Mill use in the USA is estimated at 2.25 million tons this season, down 9% because of surging textile imports and a shortage of quality cotton at competitive prices. The US mill consumption of cotton increased at an average annual rate of 3.1% between 1980 and 1990, and then rose at an annual rate of 4.1% between 1990 and 1995. By 1994/95, US mill use had reached 11.2 million bales. During 1995/96 and 1996/97, US mill use did not rise because of limited supplies and lower economic growth, but with greater production and lower prices. 1997/98 mill use was 11.35 million bales. The rise in cotton use during the 1980s and early 1990s was partly a result of increased textile industry investment. However, strengthening US consumer preferences for cotton were the more important factor raising domestic mill use. ICAC estimates indicate that the USA was the only country where cotton’s market share was not greatly affected by the high prices of cotton between 1994 and 1996. While cotton promotion programs in other countries were greatly reduced or discontinued after 1990, expenditures on cotton promotion in the USA more than doubled.

However, the US cotton textile industry may have entered a period of decline because of increased imports. US cotton consumption at the retail level rose by an extraordinary 8% in 1998, but imports of textiles and apparel, rose by more than 20%, resulting in lower mill use. The greatest growth in textile imports between 1995 and 1997 was in products from Mexico and Canada, but supplies from East Asia increased rapidly in 1998.

Monthly data on mill use in Pakistan confirm that there was no decline in 1997/98, and recent reports suggest a small increase is possible this season. Economic recession is leading to reduced consumption in Brazil. Consumption in Russia and other CIS countries is estimated at 430,000 tons this season, versus 450,000 last season. The Government of Egypt is disposing of excess stocks this season, with a policy similar to the one used in the USA in 1986/87, and Egyptian mill use is estimated at 240,000 tons, an increase of 30,000 tons. Mill use is also rising in Nigeria because of changes in currency values and in Syria because of government investments in the textile industry.

World cotton prices, as measured by the Cotlook A Index, have fluctuated this crop year between 68 and 55 cents per pound and have been between 55 and 56 cents per pound since the third week of November 1998, compared with the long term average of 73 cents. World cotton production is estimated at 18.6 million tons in 1998/99, about 400,000 tons less than world consumption. As a consequence, world stocks are expected to decline from 9.8 million tons in August 1998 to 9.4 million in July 1999. With a decline in production relative to consumption of the size that is being registered in 1998/99, prices would generally be expected to rise.

The stagnant behaviour of cotton demand, caused by the rapid deceleration of world economic growth in 1998 to August 1999, and the sudden change in the China (Mainland) trade position from net importer to net exporter of cotton, are two reasons that explain the downward pressures on cotton prices in 1998/99. Nonetheless, expectations about the impact of these two events on prices seem to be playing a greater-than-normal role in keeping prices below what the fundamentals of the market would suggest.

Some events might, however, bring expectations more in line with market fundamentals, creating upward pressures on cotton prices in the coming months. Such events include the recognition by the market that it has overestimated the impact of the financial crisis on cotton imports and mill consumption in several countries and exports by China (Mainland); another is the physical and psychological impact of having the United States importing cotton once again.

Yields play a role in maintaining stability in the world cotton market as they have an effect upon cost per unit of production. Average world cotton yields in recent years have not exceeded the record levels (598 kg/ha) set in 1991/92. This is the first period of more than four years since the 1940s in which a new record has not been achieved. 1994/95 was a good year for yields but average world yield was still 10 kg/ha lower than 1991/92. In 1996/97, yields remained 22 kilograms below record levels. Yields increased in 1997/98 to 592 kilograms, still 6 kilograms less than historic records. The fact that yields failed during the 1990s to maintain their long term pace of increase, made cotton production less profitable in many regions of the world and, despite relatively high prices, the planted area declined.

In the largest producing countries, resistance to pesticides and diseases has been identified as impacting badly on cotton yields during the 1990s. In addition, difficulties in providing inputs to producers persist in some countries. Given the limitations in various countries, agronomic management of the cotton plant is near optimisation. The nature of limitations to higher productivity is different in different countries but it seems that the available recoverable potential under most production conditions has been utilised. Thus, the world cotton industry has not benefited from increases in yields during 1990’s.

Cotton is a crop of global economic importance and stagnation in cotton yields and insecticide resistance problems in three of the five largest cotton production countries of the world (together accounting for 45% of world production) could further limit the availability of supply world-wide and impact negatively on cotton’s price competitiveness.

C. Relevance of the Project to the ICAC's Commodity Strategy

Within the context of stagnating yields and enhanced price competitiveness, it is the opinion of the ICAC member countries as expressed at recent plenary meetings, that reductions in the costs of production will be an important contributor to the maintenance of cotton's share of the fibre market. The member countries of ICAC have assessed their highest priorities for attention to projects that address the loss in yield, net revenue and quality of cotton associated with insect pests. Crop protection costs are increasing throughout Asia. As the majority of weed control is still undertaken mechanically, the bulk of this increase is in insecticide costs. Insecticide costs are now some 44% of growing costs and 16.5% of total production costs in the three countries covered in this proposal. In all these countries insecticide use is increasing strongly without concomitant yield increases. This is well documented to be due in large part to evolved resistance to the major chemicals available to control insect pests, and particularly the cotton bollworm (*Helicoverpa armigera*). This species is the major pest of cotton throughout the Old World and Australia. There is an enormous amount of research directed towards non-chemical control of this species but the impact of this across the region is still small, due to efficacy, reliability, availability and cost concerns in relation to the developed practices. Understanding how to minimise the impact of insecticide resistance on production costs, in a way which could be applied by farmers, would represent a very considerable and immediate contribution to the support of the commodity and the many millions of farming families which depend on it, across Asia and Africa.

PART II. PROJECT DESCRIPTION

A. Project Rationale and Objective

Member countries of the ICAC have highly prioritised projects that address losses in yield, net revenue and quality of cotton associated with insect pests. Insecticide costs continue to increase and account for some 44% of growing costs in the three project countries, mainly for control of *H. armigera* (cotton bollworm) caterpillars, which has become the regions principal agricultural pest. This single pest is responsible for at least over US$ 1000 million of crop damage per year, despite the heavy use of insecticides. Insecticide resistance in this species results in escalating pest control costs and significant environmental and human health problems across the region. Understanding the measures to minimise the impact of insecticide resistance on production costs, in ways which could be applied by farmers, would represent a very considerable and immediate contribution to support of the commodity and the many millions of farming families which depend on cotton, across Asia and Africa. Insecticide-based pest control failures are increasingly common, due to poor application technologies and equipment, poorly formulated or adulterated control compounds and resistance to insecticides by *Helicoverpa armigera*.

Environmentally 'softer' techniques are either not yet readily available in the vast majority of rural areas or they are too expensive, unreliable, or inappropriate to be viable solutions in the short term. Use of chemical insecticides is still considered to be the most reliable and economic way of protecting yields. However, with average insecticide applications rising annually (currently between 8-10 but up to 25 in some areas) and with no improvement in yields, it is apparent that a 'pesticide treadmill= situation is rapidly developing. Measures have to be found to maximise the efficacy of field practices while minimising harmful environmental impacts and slowing or reversing the development of insecticide resistance.

The overall objective is to provide a comprehensive blueprint for the cropping systems and pest management practices necessary for the successful, economic control of *H.armigera* in relatively un-regulated, unsophisticated, small farmer cotton farming systems of Asia and Africa. The project builds on the knowledge obtained and applied in large farm/high input cotton producing counties and many years of intensive work in Asia on appropriate control products and practices and will aim to;

- fill the knowledge gaps in relation to long-term sustainable use of pesticides and their mixtures
- address the problem of insecticide resistance management
- present and demonstrate the conclusions in a form directly, easily and reliably applicable by the small farmer with a minimum of training.

This will enable control to be obtained more economically, and more environmentally acceptably, with significantly reduced use of toxic chemical applications.

B. Description of Project Components

The project will be built on three main clusters of activities, including the synthesis of existing knowledge (component 1), scientific study, analysis and problem solving (components 2- 6) and development of practical tools (components 7 - 11).

Project Components comprise:

SYNTHESIS OF EXISTING KNOWLEDGE

Component 1. Summary of the effective insecticide application practices and of the impact of insecticides on beneficial organisms

Component 1a: Confirm effective insecticide application rates and persistencies at differing crop stages.

Published and unpublished trial data abound on the use of chemicals for the control of the pest complex on cotton. Nonetheless, details of the field efficacy and persistence of most materials are very poorly disseminated, making rational decision making amongst competing chemicals with the same apparent activity spectrum difficult or impossible. The project will review all the available reports and provide tabulated recommendations as to the advantages, disadvantages and field persistencies of the active ingredients in common use in small farmer situations. A further compendium will be provided of the available data for interesting newer chemistries (fipronil, spinosad, imidacloprid etc.). Where necessary field studies will be used to supplement the information available.

Component 1b: Critically assess the evidence for impacts of different chemical control practices on beneficial organisms and incorporate results directly into control recommendations.

IPM practices world-wide and on many crops assume the principle that broad spectrum insecticide use will be harmful to beneficial parasites and predators of at least some elements of the pest complex and that, consequently, delaying their use as late as possible in the growing season, will provide benefits. Some chemicals, e.g. endosulfan, are frequently regarded as ‘soft’ on beneficials. In some cases this is due to mode of action.

Stomach poisons for example are less likely to affect beneficials than materials with cuticular activity. The project will survey the world literature to extract the experimentally demonstrated evidence for these effects for existing and potentially useful new cotton insecticides and experimentally test the conclusions as to candidate 'soft' and 'hard' chemistries in the context of *H.armigera* control. Recommendations as to the most beneficial spray application sequences will directly result.

Lead Institution: Natural Resources Institute

Objective 1.1: **To ensure that by the beginning of the dissemination phase, the international experience with the main bollworm chemicals has been clearly codified.**

Output: Schedule of major chemistries and important formulations of those chemistries showing situations in which their use is appropriate and effective and the rates to be used to achieve that at different crop stages.

Activity 1: Compilation of the relevant literature, from Asia - national lead institutes, rest of world - Project Manager - mid Y1

Activity 2: Summarizing and tabulating as a report for use in the Handbook - Project Manager - mid Y2

Objective 1.2: **To ensure that by the beginning of the dissemination phase, the international experience of the impact of insecticides on beneficial organism has been clearly summarized.**

Output: Review of the literature on the impact of insecticides on beneficial organisms (mainly parasites and predators) in cotton and listing of the implications for insecticide use strategies.

Activity 1: Compilation of the relevant literature, from Asia - national lead institutes, rest of world - Project Manager - mid Y1

Activity 2: Summarizing and tabulating as a review for publication and for incorporation into the Handbook - Project Manager - mid Y2

Cost: *$ 71,502 of which CFC's contribution is $ 0*

ITEMS FOR SCIENTIFIC STUDY AND RESOLUTION

Component 2: Monitoring Insecticide Resistance

Resistance levels to different chemicals are an evolved response from the insect to the particular chemicals to which the population in the area has been exposed over the years. Different areas therefore have different levels of resistance to the various groups of chemicals. Often the resistance to a chemical in one area may be mediated by a mechanism that is different to that developed to the same chemical in another area. Fortunately the range of resistance mechanisms appears to be relatively small (four major systems) and to be reasonably consistent in any one area. However changes do occur over time as more or less insecticide is used of the various different chemical groups. Where insecticide pressure is reduced or removed, the insect population gradually returns to full susceptibility as the genes for resistance carry a 'fitness cost' and are selected again in the absence of the insecticide pressure (faster for organophosphates, slowly for pyrethroids).

It is therefore necessary to know the pattern of resistance in order to make sensible recommendations on control practices. This has been appreciated since at least the early 1980s and all three countries have laboratories set up for this purpose, sampling insects from the major cotton areas and biassaying them for resistance. The laboratories in the current proposal are the leading laboratories in the national networks for this kind of work. NATESC has 30 regional laboratories undertaking this kind of work with *H.armigera* in China; ICAR is setting up 9 laboratories in India based on the four set up under the recent NRI/ICAR project. Pakistan has one government-funded centre (CCRI) and two private laboratories. Output from the monitoring network is then fed to the extension services; directly in Pakistan via the Punjab Government. In China NAU provides funded technical support to the national extension system run from Beijing (NATESC). In India, the resistance monitoring network reports to the Indian Council of Agricultural Research, who gives national recommendations, and, in the case of the Agricultural Universities, directly to the state extension system.

This component of the project is funded from the national systems and provides the essential routine data necessary to make use of the more technical components in generating optimal advice to the farming community.

Lead institution: Tamil Nadu Agricultural University

Objective: **To map the distribution of, and trends in the levels of, resistance to major bollworm chemicals in Asia, to support decision making on the optimal pest management strategies.**

Output: Detailed information on the strength of resistance and its pattern geographically and over time, within the collaborating countries.

Activity 1: Field collection of *Helicoverpa armigera* eggs and larvae on a regular basis throughout the year by a network of laboratories across the region. India: CICR, TNAU, PAU envisaged to be supported by four new centres in other cotton growing states under World Bank/ ICAR National Agricultural Technology Project (approved to commence 1999/2000). Pakistan: CCRI China: NATESC with the support of NAU. (Y1 - Y4)

Activity 2: Bioassay of larvae derived from field collections against standard discriminating doses (LD_{99} of susceptibles) of representative chemicals of the major insecticide groups used on bollworms. CICR, TNAU, PAU envisaged to be supported by four new centres in other cotton growing states. Pakistan: CCRI China: NATESC using data from the regional centres, with the support of NAU (Y1-Y4). Local summaries collated into national figures annually by: India: TNAU, China: NATESC, Pakistan CCRI (Y1 - Y4)

Cost: *$ 599,697 of which CFC's contribution is $ 0*

Component 3: **Cross resistance - clarify the patterns and apply the underlying principles**

A huge range of insecticides is available to small farmers in India, Pakistan and China for the control of *H. armigera,* as it is in many parts of the world. Were it real, this apparently wide choice would provide the farmer with all the chemical tools needed to control these insects effectively. However, this choice is severely undermined by two critical factors. The first, and more tractable problem, is that the number of active ingredients (and therefore targets within the insect) is limited. Because of the marketing of sometimes dozens of brands of the same active ingredient, farmers are often unknowingly and sequentially applying an identical active ingredient. This markedly exacerbates any existing resistance problems and creates new ones.

Secondly, and more importantly, the effectiveness of any insecticide against *H. armigera* is governed by the nature of any resistance that the insects may have acquired previously. Within any chemical group, such as the organophosphates (OPs) or the synthetic pyrethroids (SPs), there is a general belief that cross-resistance will exist between all members of the group. In fact, this is not necessarily so. It depends on both the mechanisms of resistance in the insects and on the chemical structure of the insecticide. So there are likely to be sub-sets of the insecticides of any one chemical group within which there is strong cross-resistance, whilst between sub-sets cross resistance may be considerably less likely. The patterns of cross-resistance within a chemical group are likely to depend on the precise nature of the mechanism of resistance. Target site resistance mechanisms and metabolic resistance mechanisms almost certainly confer differing patterns of cross resistance. As a more subtle example, *H. armigera* resistance to the organophosphates monocrotophos (dimethyl phosphate) and quinalphos (diethyl phosphorothioate) is esterase mediated, but it now appears that different esterase enzymes are involved, and that the two chemicals may not form part of the same cross-resistance grouping for insect management purposes. This may allow them to be sprayed sequentially in an IPM programme.

A practical example of the significance of these differences can be seen in the current work being undertaken by this research grouping. Pyrethroid resistance in the Indian sub-continent is mediated through multiple mechanisms: metabolic (cytochrome p450 and esterases), detoxification, reduced cuticular penetration and target site insensitivity. Resistance to organophosphates was found to be mediated through insensitive acetyl choline esterases and enhanced esterase activity. Cyclodiene (endosulfan) resistance may also be esterase mediated. There is therefore, the potential for cross-resistance between the pyrethroids, OPs and cyclodienes based on esterase-mediated mechanisms. Whether cross-resistance does in fact occur will depend on the particular range of esterases involved in each case and the strength of their enhancement within the field populations. Likewise a common target site modification may confer resistance to OPs and carbamates but a metabolic mechanism of resistance to one group may have little influence on efficacy of the other. Clearly, it is exceedingly difficult for the farmer to make any rational or informed judgement about which insecticides to use when faced with a control failure with one material.

To address this problem it is proposed to investigate the patterns of cross-resistance both within and between commonly used insecticide groups using strains of the insect which possess individual resistance mechanisms. These insects will be obtained from areas in India, Pakistan and China using geographic patterns which will allow comparison of the resistances in these three countries. This work will be conducted in several stages. Using field collected insects, strains of *H. armigera* will be produced which possess single, defined mechanisms of resistance using a combination of selection by insecticides and selective breeding in the laboratories of the collaborating countries lead institutions. These will be transferred to the Rothamsted laboratory which has the ability to breed under sterile conditions using single pairs of insects and to define the mechanisms of resistance in postbreeding adults, making this the logical centre for such work. Single mechanism strains would then be used to investigate the patterns of cross-resistance to a comprehensive range of the insecticide chemistries available to farmers. Scientists form India, Pakistan and China will undertake this work in Rothamsted during the non-cotton season of the first three years and a half years of the project. Part of the work on identifying the resistance mechanisms for the main cross-resistance groupings and the development of specific resistance mechanisms markers for these mechanisms will be undertaken at CICR Nagpur using facilities expanded under this project. By building up a clear picture of cross-resistance patterns it will then be possible to detail the field efficacy of materials and their logical position in a resistance management spray strategy which can be adopted directly by small holder cotton farmers.

In years 3 and 4 of the project, the information generated above will be used to demonstrate that it is possible to maintain control of *H. armigera* which are already resistant through a rational understanding of cross-resistance patterns. The development of diagnostic techniques for individual resistance mechanisms (see below) will provide a greatly added degree of precision to the quality of such advice. It should be emphasized that by solving the problems posed by the fact that farmers do not know which insecticide will be most effective, one can both reduce the absolute number of sprays applied and the incidence of resistance.

The introduction and registration of new chemical insecticides (many with apparently novel modes of action and much improved environmental profiles) provides an opportunity for small farmers to combat existing resistance. However, the degree to which new materials with novel modes of action are compromised by existing metabolic mechanisms of resistance is largely unknown. A number of carefully chosen, relevant compounds representing new areas of chemistry will be brought into the testing programmes outlined above and the results used in consideration of their suitability for introduction into cotton protection programmes.

Lead institution: Rothamsted Agricultural Experimental Station

Objective: **Clarify the patterns of cross resistance of *Helicoverpa armigera* to different insecticides and apply the underlying principles in the development of sustainable control strategies.**

Output: Schedule of insecticide use programmes which use only effective materials, avoid using materials in the same resistance group sequentially and which do not make the insecticide resistance position worse.

Activity 1 Establish cross resistance patterns in Asian *H.armigera* –Rothamsted supported by CICR Nagpur and other collaborating institutes (Y1)

- Establish a reference susceptible strain and one colony of *H.armigera* showing multi-resistance to a range of chemistries from the participating Asian countries in culture at IACR, Rothamsted (Y1).
- Bioassay response of both strains to chemicals representative of the major resistance groupings. Obtain dose-response relationships. Establish which insecticide classes are resisted (Y1).

Activity 2 Develop insect lines with single mechanisms of resistance – Rothamsted supported by collaborating institutions (Y1-2)

- If necessary cross susceptible and resistant strains to 'dilute' the resistance genes present (Y1).
- Select original or derived strain with relevant indicator compounds, e.g. endosulfan, two contrasting organophosphates and a pyrethroid. Number of generations to be determined, probably 10-15 (Y1).
- Bioassay selected strains for resistance to a range of insecticides to investigate resulting cross-resistance patterns (Y1-2).

Activity 3 Identify resistance mechanisms for each of the main cross resistance groupings. Rothamsted and CICR (Y1-2).

- S Assay selected strains for biochemical or molecular markers indicating possible resistance mechanisms (monoxygenases and hydrolases, insensitive acetylcholinesterase and knockdown resistance).

  Determine, on the basis of the above, whether selected strains appear to possess a high frequency of (a) just one mechanism or (b) more than one mechanism (Y2).

- S If (b) above, back-cross strains to susceptible insects in an attempt to uncouple coexisting mechanisms and obtain better resolved lines (Y2).

- S If (a) above, further bioassays with a wider range of insecticides to establish cross-resistance patterns in more detail (Y2-3).

Activity 4 Understanding of cross resistance patterns confirmed experimentally in the field in Asia. All collaborating laboratories in Asia (Y3-Y4)

- S Use results to date to support the design of field experiments in Asia comparing the effectiveness of control regimes based on a knowledge of cross-resistance patterns with standard control practices - Co-ordinating committee (beginning Y3).

- S Investigate the consistency of cross-resistance patterns within and between countries by comparing the genetic composition and resistance spectra of field strains. Laboratory assays of field material and biochemical assay for resistance markers for a range of national populations - Rothamsted in collaboration with participating Asian laboratories CICR (India), CCRI (Pakistan), NAU (China) (Y3-4).

Activity 5 Incorporation of the understanding of cross resistance patterns into the strategy for control - Rothamsted (Y4)

- S Condensing of findings into application sequence recommendations based on local measurement of mechanisms and resistance present (using the kits from component 8).

Cost: *$ 844,385 of which CFC's contribution is $ 310,684*

Component 4: Insecticide mixtures- demonstrate and incorporate principles of rational use

There is a common perception that mixtures of insecticides may be more effective at controlling *H. armigera* than single compounds, even when these are applied sequentially, so that the use of mixtures is popular with farmers who may perceive some benefit from their use. In fact, the evidence in support of this contention is far from clear and it is possible that, without clear guidance, resistance problems may be made worse by the use of mixtures. In theory, effective mixtures should contain compounds which themselves are not cross-resisted, which have different mechanisms of attacking the insect, which have similar half-lives in the field and in which both mixture partners are applied at full rates. Moreover, there should ideally be no existing resistance to either compound in the target population. In reality, these conditions are highly unlikely to be met in small farmer situations in India and Pakistan and hence mixtures are not recommended by the agricultural universities and the Ministries of Agriculture. The nature of existing resistance mechanisms will markedly affect the efficacy of any particular mixture. However, a range of branded mixtures has been produced by the chemical companies, largely in response to farmer demand. The effectiveness of mixtures requires critical evaluation. Limited work undertaken at PAU Ludhiana suggests that the benefits of tested mixtures are no greater than those from the best of the components of the mixture alone. However, there is good evidence in the laboratory for the synergistic effects of certain OPs in reducing the impact of metabolic resistance on the efficacy of pyrethroids. There are no doubt other situations in which the use of particular mixtures may be justified.

In order to investigate this problem laboratory studies will be undertaken at Rothamsted Agricultural Experimental Station to test whether the use of mixtures is effective at controlling resistant *H. armigera* populations and in reducing resistance levels. Field collected insects will be obtained from India and Pakistan as described above and laboratory populations established and maintained in Rothamsted. Strains with defined mechanisms of resistance, and with specific cross-resistance patterns as described above, will be challenged with optimized mixtures of insecticides which represent rational choices from locally available compounds. The levels of resistance to both mixture partners would then be assessed in subsequent generations following careful and representative breeding from survivors. In this way it will be possible to demonstrate the degree to which mixtures can be used to control *H. armigera* and thus the principles which govern the rational use of such a tactic.

Field trials will be undertaken in India (PAU, Ludhiana), China (NAU, Nanjing) and Pakistan (CCRI, Multan) in years 3 to 4 to compare the efficacy of sensible mixtures and sequential applications of single insecticides and to determine their influence on resistance levels in local populations. Effective field trials of this sort will need to be conducted using large, defined areas of cotton and monitored using efficient population census and resistance detection techniques using the project developed monitoring kits (see below).

Lead institution: Nanjing Agricultural University

Objective: **Provide a rationale for the design of effective insecticide mixtures and an understanding of the resistance implications of using mixtures.**

Output: A scientific basis for recommending certain mixtures in certain situations and for curtailing their use in others.

Activity 1: Using at least three *Helicoverpa armigera* populations showing different mixtures of resistance mechanisms, laboratory assay resistance levels to individual active ingredients of the main chemical classes (9 chemistries). Identify the mechanisms of resistance operating. Assay for mortality in all possible two -way mixtures and 6 of the more popular three-way mixtures. Work out the principles underlying cross resistance. Rothamsted, NAU, CCRI, CICR (Y1).

Activity 2: Using only the potentiating mixtures from activity one, select for resistance for 8-14 generations using the LD90 identified in activity 1. Check resistance every second generation. Select with representative non-potentiating mixtures to confirm that such mixtures have neutral impacts on resistance development. Work out the resistance development implications of the use of mixtures. Rothamsted, CCRI, NAU, CICR, TNAU (Y2-3)

Activity 3: Follow the qualitative and quantitative changes in levels of esterases, cytochrome $P_{450,}$ acetylcholinesterase and nerve insensitivity every second generation in the above experiments. Ascertain the enzyme inhibitory role of the components of potentiating mixtures. Rothamsted, NAU, CICR, CCRI (Y2-early Y4)

Activity 4: Summarize the results of activities 1-3, detailing the specific resistance mechanisms which particular potentiating mixtures can help overcome. Considering the resistance development profile of these mixtures, provide recommendations for the practical use of mixtures for incorporation into the Handbook. NAU, Rothamsted, CICR, CCRI (2nd half Y3 -early Y4).

Cost: *$ 210,867 of which CFC's contribution is $ 107,065*

Component 5: Measured resistance levels and field control: clarify the relationship, so allowing robust recommendations of effective application rates

Carefully controlled monitoring of the level of resistance to a range of plant protection chemistries has been carried out in India (by the institutions of the Indian Council of Agricultural Research '*Helicoverpa network*' including the NRI supported laboratories included in the current proposal) since 1992. Similar work, using a leaf dip bioassay method, rather than topically applied discriminating dose bioassays, has been going on at the Central Cotton Research Institute in Multan, Pakistan since 1990, and for 15 years at the NAU laboratories in Nanjing. Resistance factors (RFs), defined as the factor by which the lethal dose of insecticide necessary to kill 50% of the resistant population (LD_{50}) exceeds that of a standard susceptible laboratory strain, have traditionally been used to indicate the strength of resistance of a strain of insects to a particular compound. In the field this measurement actually reflects both the frequency of resistant individuals in the population and the absolute level of tolerance that the resistance confers to the insects.

In practice, it has often been found much more effective and efficient to use the frequency of resistant individuals surviving a discriminating dose as the important measure of resistance in the field. Such discriminating or diagnostic doses are usually obtained from the dose-response line obtained with pure-breeding susceptible insects. Our understanding of the range of mechanisms of resistance, the geographic pattern of levels of resistance and the changes in these over time, is now really rather impressive. Shifts the temporal patterns of resistance mechanisms within seasons and the additive effects of the presence of different mechanisms present in the same individual have been explored. However, the relationship between such resistance factors in laboratory studies on a standard susceptible population, and the efficacy of materials in the field is by no means clear. This severely restricts the practical usefulness of the resistance monitoring work as a guide to appropriate action.

Insecticide resistance monitoring will continue, with a network of nationally funded laboratories in India and Pakistan. This project will make use of the geographic spread of the collaborating institutions to undertake laboratory determinations and field control efficacy experiments on populations of *Helicoverpa* showing low and high levels of resistance to the most used chemistries through known mechanisms. The frequencies of resistant insects and the resistance factors to a number of commonly used insecticides representing major chemical groups will be determined both before and after spray applications with recommended doses. This will show whether existing recommendations for specific insecticides are sufficiently robust to effectively control populations of *H. armigera*. Post-spray analysis of survivors will determine whether resistant insects are surviving such doses and in what numbers. In this way it will also be possible to determine what pre-spray level of resistance is controllable by any given compound and thus indicate at what point it would be necessary for the farmer to spray an alternative insecticide.

By using different concentrations of active ingredients in controlled trials, a direct picture of the relationship of between measured resistance levels and the corresponding level of field control for a range of chemistries and resistance mechanisms will be built up. This, in turn, will allow direct recommendations to be generated from the routine monitoring work, as to which situations warrant the use of particular materials being actively discouraged and in which a change of application rate is justified. This would put such regional differences in recommendations on a scientific basis for the first time. As the range of resistance mechanisms currently appears to be strongly limited (although the strength of each may vary) this work will provide a pattern of responses which should be directly applicable in all countries in which these widespread materials are used against this pest.

Lead institution: Central Cotton Research Institute

Objective: **To identify relationships whereby the detailed laboratory bio-assay data on resistance levels can be translated into recommendations for the use of particular chemicals and at particular rates**.

Output: A robust system for calculating from laboratory tests, which materials will be effective in the field and at what rates, for local regions with specific resistance profiles.

Activity 1: Identify (from data collected in component 2) a series of research station farm sites with significantly differing resistance levels to the same chemicals and bioassay facilities. Not all centres will work with all chemicals. Project co-ordinating committee - (early Y1)

Activity 2: For at least two sites with different resistance profiles for each chemical, measure the resistance levels to the full range of test chemicals at a range of rates centering on the field application rate, by routine bioassay using standard discriminating doses.

Activity 3: At each site, spray the test chemicals at the recommended field rate in replicated randomized block layouts, undertaking very close scouting for numbers of *H.armigera* life stages both before and after spraying. Repeat three times per season, bio-assaying for resistance between applications. - CCRI, CICR, PAU, TNAU, NAG (early season Y1 - Y3)

Activity 4: Compile the data from the sites for each chemical centrally each season. Analyze the field control versus resistance data so as to predict the former from the latter. Incorporate the results into the handbook. CCRI supported by NRI (end of season Y1-Y3)

Cost: *$ 741,188 of which CFC's contribution is $ 473,256*

Component 6: Pesticide application practices: identification of the minimum effective practices necessary for satisfactory control

One aspect of the use of insecticides in the region is the poor quality of applications. Farmers mostly use very cheap lever operated knapsack sprayers. These sprayers are usually fitted with a single cone nozzle which is operated at variable pressure and held above the crop canopy. In consequence the upper canopy leaves act as an umbrella, so that only the most exposed flower buds are protected by the spray. Coverage of the lower leaf lamina is generally very minimal. Where tractors are used, nozzles are above the plant canopy, often directed outwards rather than downwards, and the applications share the same problems as that of hand applied equipment. Much of the spray liquid which is not retained on the upper foliage drips down the plant and contaminates the soil. The poor spray coverage on the plants leads to lack of control of the bollworm larvae and the farmer, seeing large larvae, tends to repeat applications, increase the dosage, or resort to insecticide mixtures, or all three, in attempt to achieve control. These tactics are considered to increase selection of resistant populations, as large larvae are better able to metabolize insecticides and survive despite exposure to increasing pesticide levels.

The project will study the effect of different application techniques on the control of key pests including bollworms, and examine the differential efficacies of differing techniques against large and small *H.armigera* larvae. Field trials will be located on research farms near Multan and at the Punjab Agricultural University farm near Ludhiana where preliminary studies have already been undertaken to assess the spray distribution on cotton. This work will provide definitive advice on what is required in the way of equipment, chemical rates and operator actions for acceptable control to be achieved using available equipment.

Lead institution: Punjab Agricultural University

Objective: Specify the minimum application equipment and practices necessary for field control of *H.armigera*.

Output: Unambiguous compilation of the minimum application equipment specifications and application practices for all major chemistries

Activity 1: Summarize the available literature on effective application technologies for bollworm control in cotton. NRI (Y1)

Activity 2: Using locations where insecticide resistance is low, test the optimal practices and set-up specifications for economically accessible spraying equipment (manual and tractor mounted) identified in activity 1 first on water sensitive papers attached to plants (three growth stages). CCRI, PAU (Y1-2). Test delivery systems performing well in droplet distribution tests against *H.armigera* populations, using before and after larval counts as the criteria of success. CCRI, PAU, NAU. (Y2-3) Compile results for recommendations, PAU (end of Y3)

Cost: *$ 244,472 of which CFC's contribution is $ 133,732*

ITEMS FOR DEVELOPMENT TO PRACTICAL TOOLS

Component 7: Immunological kits for insecticide quality determination

Insecticide quality is a major issue in the region. A large number of local formulators produce products which vary enormously in the quantity and purity of the active ingredient and appropriateness of formulation quite apart from the widespread practice of dilution or alteration of insecticides in the warehouses or at the point of sale. In addition to the severe financial loss, lack of reliability of commercial materials has greatly enhanced the use of insecticide mixtures, often inappropriately. This adds to the cost of pest control and the development of insecticide resistance.

Although official statistics on the Indian side suggest sub-standard materials account for only some 4% of all product sold, the control system seriously underestimates the true value which, for some states, (inc. the Punjab) is probably closer to 20%. Insecticide testing laboratories use conventional GLC, HPLC or spectroscopic analysis. Such laboratories generally have a testing capacity of about 300-500 samples per year at a very high financial and manpower cost per sample. There is a keenly felt need for a testing system which is rapid and inexpensive but which can detect both the purity and quantity of the active ingredient in multiple samples.

Enzyme linked immunosorbent assay (ELISA) holds out just such a prospect. This assay takes advantage of the discriminatory power of antibodies and the extremely high catalytic power and specificity of enzymes. The specificity of antigen/antibody interactions offers the analyst many advantages, including extreme simplicity of the test itself and the ability to perform the analysis on the crude sample, by-passing the need for extensive and time consuming sample preparation, allowing a high throughput of samples. The development of a wide variety of labeling techniques has given the method a flexibility to fit many analytical needs, from rapid and moderately sensitive to extremely precise and sensitive analyses. A number of ELISA tests for insecticides have been developed since the 1980s. The project will produce a modestly priced and commercialisable ELISA based test kit for the rapid determination of the quality and quantity of the most common organophosphate, cyclodiene, pyrethroid and carbamate insecticides in use on the sub-continent (to cover >90% of all cotton insecticides in current use.) Production of the kits will possibly be commercialized through a licensing agreement and their wide availability ensured. The Indian Council of Agricultural Research may be the appropriate organization for this purpose. This will, however, depend on mutual consultations and conditions as determined by the Fund, in consultation with the Supervisory Body.

Lead institution: Central Institute for Cotton Research

Objective:	**Develop and commercialize kits for low cost measurement of the quantity and quality of insecticide ingredients in samples from retailers and farmers stores. (CICR-NRI)**
Output:	Ability of local Ministry of Agriculture staff, extension agents, dealers and farmers to rapidly and affordably detect and quantify major insecticide active ingredients in the region in field samples via a patented and commercialized, single, cheap, self contained kit.
Activity 1	Haptens synthesised for endosulfan (cyclodiene), cypermethrin, fenvalerate (synthetic pyrethroids), quinalphos and phoxim

(organophosphate), thiodicarb and carbaryl (carbamates) - Natural Resources Institute (Y1)

Activity 2 — Antisera generated for each of the haptens and tested for cross-reactivity with insecticide metabolites and other related insecticides CICR (Y1-2)

Activity 3 — Enzyme linked immunosorbent assay (ELISA), or other colorimetric or nitrocellulose membrane detection kits developed. - CIRC (Y2 - mid Y3)

Activity 4 — Kits patented world-wide through the Indian Council of Agricultural Research assisted by NRI if requested. (Y3)

Activity 5 — Kits made widely available through commercial company under licence. (Y3-Y4)

Cost: *$ 133,934 of which CFC's contribution is $ 54,467*

Component 8: Resistance detection kits

Insecticide control failures may be due to inappropriate chemical use, poor product quality, poor application, or to resistance by the insect to the insecticide. Farmers generally blame poor quality products and, increasingly, resistance. All these problems are addressed by the project. Work summarized by Armes et al. (1996) and Ahmad et al. (1998) has shown pyrethroid resistance to be ubiquitous across the sub-continent. For pyrethroids this has reached closed to 100% resistance to commonly used pyrethroids in heavily sprayed areas like coastal Andhra Pradesh, as measured by the proportion of insects surviving a discriminating dose which would have killed all of a susceptible population. However, the average level of resistance varies considerably geographically, as mentioned earlier for quinalphos and monocrotophos in Pakistan and India. There may be further differences in the form of resistance developed in the three countries, and between regions within countries, depending on the spraying history the three populations had been exposed to historically. It will be extremely useful for Ministry of Agriculture and university extension staff to be able to directly and rapidly quantify the level of resistance to particular compounds. Using this information and the project-provided list of cross-resistance patterns, extension staff can decide for themselves the most effective materials to recommend.

Development of dot blot assay kits based on the presence of specific isoenzymes present in strains of insects resistant to particular insecticides has been commenced at CICR Nagpur. Development will be completed and kits will be standardized and extended to cover the major chemical groups of current importance on the sub-continent and their production commercialized to enable rapid field assessment of resistance levels as well as identification of the associated mechanisms.

Lead institution: Central Institute for Cotton Research

Objective: **Develop and commercialize rapid test kits for resistance detection - CICR supported by Rothamsted (Y1-Y4). These inexpensive kits will greatly aid in mapping resistance mechanisms in field populations and thereby allow the**

forecasting of the probable change in resistance levels when particular materials are sprayed in the field.

Output: Ability of local agricultural universities or other extension advice providers to rapidly and cheaply assess the level of resistance in local populations of *H.armigera* to a range of insecticide active ingredients, so enabling them to determine which materials and rates to recommend. Kits based on several principles will be developed and field tested. CICR - (YI - Y2)

Output 8.1 Development of specific bioassay based kits to detect resistance at egg/ neonate stage.

Activity 1 Several bioassay approaches would be designed and tested to simplify the test procedure, to enable the end user (including farmers) to detect and quantify resistance as reliably as possible to specific groups of insecticides (pyrethroids, organophosphates, carbamates, cyclodienes and spinosad) CICR (Y1)

Activity 2 The bioassay data obtained from the practical kits will be validated through correlation with field efficacy of the test compounds. NAG, PAU, CCRI (Y2)

Output 8.2 Molecular marker kits for resistance detection - CICR (Y1-2). Several approaches will be followed to identify biochemical or molecular markers associated with insect resistance to specific groups of insecticides. These markers could be isozymes of several resistance related or unrelated enzymes or a RAPD. Once identified, the co-segregation of the marker with resistance and linkage factors would also be worked out to design a reliable detection kit.

Activity 1 Comparison of at least 10 to 15 isozyme and RAPD patterns from resistant and susceptible strains will be carried out, to identify the presence of a specific biochemical or molecular marker. The strains will be crossed and the co-segregation pattern and tightness of association of the marker with resistance will be worked out.

Activity 2 Nitrocellulose membrane kits will be designed based on the marker.

Output 8.3 Development of specific resistance mechanism based detection kits. CICR (Y1 to Y3) supported by Rothamsted. Nitrocellulose membrane-based kits, or colorimetric test kits will be developed to detect specific mechanisms of resistance, such as the enhanced production of esterases, unique esterases, acetyl choline esterases insensitive to the insecticide, enhanced production of mono-oxygenases, unique monoxygenases or insensitive sodium or chloride channels in nervous tissue.

Activity 1 Isozyme analysis (kinetics and insecticide interactions) will be worked out in susceptible and resistant strains to identify and characterise unique isozymes which are associated with resistance to specific groups of insecticides. The quantitative differences in total enzyme activity between susceptible and resistant strains will be assessed. CICR - Rothamsted (Y1-Y2)

Activity 2 Antisera will be raised against the unique isozyme and cross reactivity with other isozymes will be tested. Antisera will be raised against sodium channel mutant peptide sequences from Kdr resistant strains to enable the detection of the specific mutation in field populations. CICR (Y2)

Activity 3 Nitrocellulose membrane based or colorimetric kits will be developed based on the chemical properties of sodium channels, esterases and mono-oxygenases. CICR (Y2)

Output 8.4 Kits patented and made widely and cheaply available

Activity 4 Kits patented world-wide through the Indian Council of Agricultural Research assisted by NRI if requested. (Y3)

Activity 5 Kits made widely available through commercial company under licence. (Y3-Y4)

Cost: $ 173,174 of which CFC's contribution is $ 99,304

Component 9: Field demonstrations of the developed strategies.

To fully exploit the value of the project work it is essential that the developed recommendations and are demonstrated to have significant direct benefits to the farmer. Farmer interest centres primarily around yield, then costs and only then health and environmental concerns. Consequently the IPM/IRM practices must project yield and reduce costs. Increases in profitability without these elements is not so easily perceived as a benefit by farmers. The developed message must be simple to operate as the sheer number of farmers prevents the extension services from directly interacting with more than a small proportion of them. The project will therefore focus on simple, easy to disseminate, rule based systems to provide pest control advice that will reduce costs while meeting the other objectives.

Systems to demonstrate such benefits exist in the participating countries and will be built upon by the project. In India the ICAR has approved the setting up of a network of insecticide resistance demonstrations under its 'village adoption' programme in the main cotton producing sites. This programme commenced in the 1998-99 season and will run for a further four years under the institutes and project leaders in this proposal. Further funding is approved under the World Bank National Agricultural Technology Project for a national series of village level demonstrations, again taking advice from the project laboratories. A further major initiative is being launched in 1999 by GOI under its Cotton Technology Mission Programme, led technically by CICR. This will build up over three years to apply the identified IPM/IRM principles in 500 villages in 8 states, covering the 25 cotton districts which between them account for 82% of India's insecticide use on cotton.

The Chinese system involves the feeding of the resistance research and monitoring results through the National Agricultural Technology Services Centre (NATESC). This national centre, with over 100 regional stations, provides the pest management advice to the county level extension system. NAU is responsible for the provision of technical advice on resistance monitoring and management to NATESC, which in turn funds some of NAU's activities.

In Pakistan the resistance problem is most significant in the main cotton growing area of the Punjab. Here the Punjab Government is addressing the problems of poor yields in four of the last five years. The Punjab government supports the CCRI laboratory for resistance studies and the CCRI feeds the resulting information into the Government's recommendations for state wide extension.

With a Pakistan cotton farmers IPM field school project currently close to final approval by the Asia Development Bank, and the much larger EU funded, FAO led, cotton farmer IPM field schools project in the region (both due to commence in late 1999 or early 2000), the opportunity to feed the project results into significant regional initiatives will be actively seized. The project outputs will feed into curriculum development for these farmer field schools.

Lead institution: *All laboratories*

Objective: **To feed the project results as they become available into high-profile IPM programmes run in the collaborating countries by national and donor organizations.**

Outputs: Ramped uptake of project outputs into national and regional IPM programmes (Y1- Y4). Evidence from at least one national programme in each of the three collaborating countries of a major demonstrated benefit to farmers from incorporation of project outputs by end Y4.

Activity 1: *India:* Project to provided plan for ICAR season-long village adoption demonstrations of integrated resistance management in four states and the GOI initiative in 500 villages in the 25 highest insecticide using districts in eight states within an IPM context, based on the principles identified by the project leaders in India. CICR as leading institute, providing direct management of two of the ICAR villages and technical direction of the nation-wide programme. (Y1-4).

Activity 2: *Pakistan:* The Punjab Government is actively promoting the application of IPM/IRM principles through the direct provision of technical direction to the state extension services for implementation. The project will provide curriculum advice to the Asian Development Bank, Farmer Field School Project in Cotton (to start 2000) NRI/ Project Co-ordinating Committee (Y1 - Y4)

Activity 3 *China:* The project will collaborate closely with the National Agriculture Technology and Extension Services Centre (NATESC), Beijing in the analysis of data and provision of resistance management advice through 100 province and county stations (30 of those specifically for

H. armigera) (NATESC supports the work of the NAU lab.).

Activity 4: Project provides curriculum advice to the EU regional Farmer Field School in Cotton Project (Indian, China, Pakistan, Vietnam, Philippines). (To start 2000) Project Manager/Project Co-ordinating Committee (Y1 - Y4)

Cost: No direct cost to project, CFC's contribution is $0

Component 10: Handbook of sustainable control of *Helicoverpa armigera* in small-farmer cotton systems

Rational control of *H. armigera* using the absolute minimum of toxic chemical inputs is by no means a simple matter. Reducing the need for chemicals targeted against bollworms involves inputs at all scales, from regional decisions on cropping patterns to the use of sucking pest tolerant cotton varieties in order to retain the beneficial fauna in the crop in the early season. NRI and the collaborating partners have been working on these and related issues for many years and have experience of successfully designing and demonstrating IPM packages which take account of resistance management needs. These proven strategies and practices form the bulk of the management practices. What this project adds, is the ability to make rational decisions on chemistries and quantities when these are required. The handbook to be complied, published and disseminated by the project will encapsulate all of this information, along with the techniques required at the various levels (extension services, laboratories, farmer, national programmes) to decide what practices to use at which stages (agronomy, varietal choice, non-chemical practices and insecticide use) to optimize returns with minimum environmental risk.

The handbook must be relevant to all small-farmer cotton systems in which *H.armigera* is a problem and will therefore take a cropping systems focus. Using the handbook in conjunction with other project outputs, the local extension services could, for example, measure the resistance levels present in the local population to the main bollworm chemicals available in the area. They could then select the most appropriate chemistries, rates and application practices and determine the sequence in which they should be applied. Finally the extension service could advise farmers on the agronomic and simple pest scouting practices which will limit the need for the use of those chemistries and not exacerbate the situation for later in the season or following years. This will mark an enormous step forward from the current position, where insecticide recommendations are a mixture of empirical views on efficacy and commercial considerations of margins on particular formulations. The project will produce, publish and actively disseminate the handbook in the participating countries, thorough the national organizations, and beyond through NRI, the ICAC and the Fund.

Lead institution: Natural Resources Institute

Objective: To provide a compendium of knowledge on effective, economically acceptable, practices in the control of *H.armigera* which will act as a manual for the techniques necessary for success at all scales (from laboratory procedures to village participatory methods) in developing sustainable control practices in the light of the threat of insecticide resistance. The manual will provide for decision criteria on the situations in

which insecticide use is appropriate and specify in detail how to identify optimal materials and application practices.

Output: A comprehensive handbook for sustainable control of *H.armigera* in small farmer systems. English language version to be produced before the regional workshops in early Y4. NRI with the support of the Project Co-ordinating Committee.

Activity 1: Compilation by PEA of outputs of components 1-8, integrated with the other components of sustainable pest management practices for cotton. Publication as an English language edition (1st edn. 2,000 copies) by NRI with due acknowledgment to CFC, ICAC and the participating institutes (end Q1 Y4). Translation and publication of handbook in local languages. National lead institutes. (To commence Q2 Y4 - publication date close to or shortly after project closure)

Activity 2: Dissemination of handbook, starting with project workshop attendees, in participating countries and more widely in Africa and to other producing countries in which *H.armigera* is a production constraint. PEA to organize for Africa and supply copies to the ICAC, the Fund and the national lead institutions in participating countries for dissemination. Dissemination principles to be agreed with ICB and the Project Co-ordinating Committee. (Y4).

Cost: $ 80,884 of which CFC's contribution is $ 53,598

Component 11: Dissemination Workshops

In all cotton producing countries, there are key organizations and individuals whose influence on pest management practices is central to change. These include national farmers groups, extension services, State Agricultural Departments, directors of agriculture, pesticide manufacturer and dealer networks and the national agricultural research organizations, as well as the leaders of IPM initiatives such as the farmer-field school programmes. A single Asian workshop will be held in India early in the final year of the project, followed by national workshops in each of the three collaborating countries in Asia. These will focus on explaining the scientific rationale behind the strategy for sustainable control; demonstrating the principles, practices and new technologies developed; and then showing how these have been used to support farmer livelihoods through the various village participatory programmes in place. The emphasis will be on showing how to use the project outputs to follow a logical decision tree when setting up cotton production systems in which the impact and cost of control of pests (and particularly *H.armigera*) is minimized.

A large workshop will also be held in Africa to disseminate the project work to as many of the 29 cotton producing countries of Africa as possible. Historically resistance problems in most of Africa have been low, mostly due to limited insecticide applications. With the resources for yield enhancement becoming more widely available, resistance problems have been increasing. Countries such as Zimbabwe and Ghana are increasingly concerned about their resistance positions, others, such as Uganda, have the opportunity not to get onto the pesticide treadmill by designing appropriate IPM policies for implementation as cotton production expands. NRI is undertaking, or has undertaken, cotton work in these countries and a number of others in the region and has experience of running and organizing such workshops effectively. It is confidently expected that this workshop will help to focus Africa's producers on sustainable control of its pest complex.

Lead Institution: Natural Resources Institute

Objective: **To provide regional information to key stakeholders on the evidence for the control principles developed; to explain the implementation of the recommended practices; to demonstrate the resistance and insecticide purity test kits and to launch the Handbook as the compendium from which sustainable local level strategies can be derived**.

Output: International Asian workshop held in India (Y4). National level workshops held in India, Pakistan and China (Y4). African workshop held, in a country to be determined (Y4).

Activity 1: 10 day international Asian workshop held in Nagpur. Twenty invited national participants from each country, drawn from the national research network and the national extension system. Workshop run by the project leaders from the four collaborating countries (1st quarter of year 4).

Activity 2: 3 national workshops (10 days each) in Multan, Nagpur and Nanjing. 30 invited participants per workshop drawn from the national extension system, researchers, pesticide dealers organizations, agriculture development NGOs and cotton farmer organizations. PEA to organize with national project leaders (Y4).

Activity 3: 10 day African workshop, in a location to be determined by the PCC, covering:

- *N.Africa*: Sudan, Egypt, Ethiopia
- E.Africa: Kenya, Tanzania, Uganda, Malawi
- W.Africa: Nigeria, Ghana, Senegal, Mali, Chad, Central African Republic, Cote d'Ivoire, Niger
- *S.Africa*: Zimbabwe, Mozambique, Zambia, S.Africa

Approximately 30 invited participants, drawn from the national research networks, national extension systems, pesticide companies and dealers organizations, agriculture development NGOs and cotton farmer organizations, plus CIRAD in W.Africa. PEA to organize in collaboration with the national venue host institution.

Cost: $ 240,905 of which CFC's contribution is $ 228,384

Component 12: Project management and financial administration

Lead institution: NR Institute/ NR International

Objective: **To ensure the sound management of the project across Asia and to operate the project finances so as to achieve maximal benefit for the resources available.**

Output:	Management of the project, ensuring deadlines are adhered to and milestones achieved on time. Chairing the Project Co-ordinating Committee; visiting all project sites at least annually to monitor and support technical progress; preparing project reports to ICAC and CFC as per the agreed schedule, notifying them of necessary changes in project pace or direction and seeking any necessary contractual alterations. Project Manager for NRI. Responsible organization, administration, management, auditing and reporting of project finances. Natural Resources International supported by Project Manager (Y1 - Y4).
Activity 1:	Project manager (PM) will be responsible through the PEA for all project activities and accountable for all project resources. The manager will organize the initial project co-ordination meeting; chair the Project Co-ordinating Committee at its annual meeting and produce minutes of these meetings; orchestrate financial requests and disbursements; organize and report on the mid-term review; collate and compile the interim and final reports with the component leaders. The PM will be responsible for the successful operation of the experimental work and will therefore visit each collaborating institution at least annually and normally twice per year to discuss and help support progress in addition to reviewing the financial reporting. The PM will liaise frequently with the ICAC and the Fund, reporting on progress and seeking approval to modify work or financial plans where necessary.
Activity 2:	The financial administrator in NR International operating under the supervision of the Project Manager will: organize contracts with collaborating institutions; assist in the set up of imprest accounts in the collaborating institutions and train local staff. (1st quarter of Y1). Organize contracting, procurement and invoicing (CFC and suppliers); request funds from CFC and disburse to collaborating organizations; organize and administer reporting of the quarterly financial statements from the collaborating institutions; organize annual auditing as per CFC rules - attend and give evidence. (Y1-Y4). Close accounts and produce project completion financial report (final quarter Q4).
Activity 3:	Project Co-ordinating Committee meetings. Preliminary one week planning meeting of the Project Co-ordinating Committee of the project at NRI. Project Manager (Quarter 1, Y1). Annual 3 day meeting in participating countries in turn. Project Manager/country leader (Y1 -Y3).
Activity 4:	Four day mid-term review, with ICAC, CFC and any appointed reviewers (end of cotton season Y2).
Activity 5:	CFC monitoring and ICAC supervisory visits/participation in annual PCC meetings. Mid-term evaluation and a final project evaluation.
Cost:	*Project management $ 549,234 of which CFC's contribution is $ 393,784* *Project financial administration $ 129,110 of which CFC's contribution is $ 129,110 Monitoring, Supervision and Evaluation by the CFC/ICAC: $ 116,000 financed by CFC*

C. Benefits and Beneficiaries

With pressure on cotton prices from competing artificial and man-made fibres, a major thrust in retaining farmer incomes must be through cost reductions. For small-scale cotton farmers in the region, the insecticide component of growing costs is approximately 44% and increasing. As profitability is marginal, in particular for small-scale farming families small reductions in growing costs translate into major proportional increases in profitability. The project is expected to have a positive macro-economic and environmental impact in the three countries, through increased cotton production, reduced production costs and enhanced profitability, and reduction of environmental damage. The impact within the project lifetime is expected to occur through the national programmes. In the longer term, practical benefits will also flow to cotton producing countries in Africa through the project workshops and dissemination of the handbook as well as through a possible "add-on" project which is presently being considered.

With regard to the environmental, the project has as its main target the reduction in the use of toxic materials in cotton production in Asia. Insecticide costs account for nearly 10% of the value of the cotton lint produced by the region's farmers. Toxicity problems vary from chemical to chemical. For example profenophos has a relatively low environmental persistence or other side effects when on the crop but puts the operator at risk from inhalation during the process of application. Although the environmental profile of the majority of the chemistries widely used in the region has improved greatly over the least 20 years, particularly with the decline in the use of organochlorines, the 160 thousand tonnes of toxic active ingredient of the formulations applied still represent an enormous human health and environmental problem.

The thrust of the project's work is to remove the unnecessary use of toxic materials. This involves making applications only when they are needed and no alternative control is available; using the environmentally 'softest' effective option, and using them in such a way as to maximize their efficacy against the target without exacerbating the resistance position and so creating an increased future demand. Certain of the chemistries registered for use on cotton in the region but listed as highly or moderately toxic by the WHO will not be recommended for use at all, and indeed a number are in the process of being phased out by the national governments. No materials will be recommended which make the health and environmental risk situation worse than it is at present.

Since application of the developed principles will result in recommendations for the use of more effective materials, used only when required, insecticide use by farmers adopting the recommendations will decline significantly. As mentioned earlier, in a farmer-participatory village trails run by the proposal team in 15 villages in four states in India from 1996-9, the application of the current imperfect state of knowledge on resistance resulted in an overall reduction of 46% in the human toxicity risk of the applied materials while reducing costs and enhancing yields. Similar benefits arose in effects on non-target soil and water organisms. While this level of impact could not perhaps be expected without a significant level of supervisory input, substantial benefits will certainly arise. All the new chemistries to be considered for a place in the IPM/IRM recommendations have environmental profiles which are better than those of the materials which they may replace.

The proposers are therefore confident that this project will provide significant environmental benefits to the region; in health terms for farmer, farm laborers and those involved in the pest management industry; and in overall environment in terms of the impact of pest control operations on non-target organisms.

The following table provides overall economic justification for the project. Project costs will be recovered over 10 years with a minute increase in production in the three collaborating counties of 0.000016%, or a reduction in production costs of $0.01 per ton of lint. The benefits of impact in Africa will reduce that figure further. Given that insecticide costs are currently some 16% of total production costs in the region, and are accepted as the major target for production cost reduction by all the major stakeholders in the industry in the region, this is a readily achievable target.

Gains in productivity or reduction in crop production costs needed to recover the project cost	
Project cost to CFC	= $ 2.25 million
Approximate total value of production p.a. in China, India and Pakistan	= $ 15.49 billion
% increase in production over 10 years required to regain project cost	= 0.000016%
Cost of insecticides p.a. in China, India and Pakistan (1997 base)	= $ 1.501 billion
% reduction in insecticide costs required to regain project cost in 10 years	= 0.00015%

D. INTELLECTUAL PROPERTY RIGHTS

Under the Project Agreement, CFC will hold the intellectual property rights to project outputs. The insecticide quality and quantity detection kits and the resistance mechanism detection kits may be patentable. As the majority of the intellectual and technical work which has gone and will go into their development has been carried out by scientists of institutes of the Indian Council of Agricultural Research, it is proposed that the Indian Council of Agricultural Research be assigned as the patent holder, on conditions to be mutually agreed. Preliminary, non-prejudicial discussions have been held with the Indian Council for Agricultural Research who are open to discussion on this matter. Any agreement would include assurances that the kits would be rapidly commercialized in a manner beneficial to the whole cotton producing community world-wide. NRI will play a role in obtaining world patent rights if requested. If ICAR does not pursue the patent within six months, or if the commercial prospects for the kits do not warrant patenting, the information will be placed in the public domain.

E. Project Costs and Financing

The total project cost is estimated at USD 4,493,445, as summarized in Table 1. The project would be financed by a grant from the Common Fund of USD 2,258,503; co-financing of USD 1,087,594; and counterpart contributions of USD 1,147,348 provided in kind by participating institutions.

Table 1

FINANCING TABLE BY COMPONENT
(base cost US$)

Component	CFC	Co-financing	Counterpart Contribution	Total Cost
1. Review of insecticide efficacy		60,222	11,280	71,502
2. Monitoring of insecticide resistance		408,715	190,982	599,697

3. Cross-resistance patters	310,684	216,649	317,052	844,385
4. Principles of insecticide mixtures	107,065	35,200	68,602	210,867
5. Laboratory measured resistance and field control	473,256	64,000	203,932	741,188
6. Minimum effective insecticide application practices	133,732	52,761	57,979	244,472
7. Insecticide quantity and quality kits	54,467	41,069	38,398	133,934
8. Resistance detection kits	99,304	10,000	63,870	173,174
9. Field demonstration of strategies	Finance in place in national programmes			
10. Handbook of sustainable control of *H. armigera*	53,598		27,286	80,884
11. Dissemination workshops	228,384		12,521	240,905
12 a. Project management	393,784		155,449	549,234
b. Financial administration	129,110			129,110
c. Monitoring, Supervision and Evaluation	116,000			116,000
Total Base Cost	2,099,386	888,616	1,147,349	4135,351
Contingency/Unallocated	159,117	198,977		358,094
Project Total	**2,258,503**	**1,087,593**	**1,147,349**	**4,493445**
Base cost as % of project total	51	21	28	100

Note 1: Co-financing contingency includes counterpart contingency estimates
Note 2: Totals may not add up due to rounding

A summary of the envisaged expenditure by cost category is given in Table 2. The allocations to the different cost categories are based on the present project design. In the course of project implementation, some transfers may be considered appropriate without exceeding, however, the currently proposed overall CFC contribution to the project.

Table 2

SUMMARY PROJECT COST
BY CATEGORY OF EXPENDITURE BY YEAR
(base cost US$)

Category	PY 1	PY 2	PY 3	PY 4	Total Cost
I. Vehicles, machinery and equipment	429,682	82,100	61,700	54,532	628,014
II. Civil works					
III. Material and supplies	143,277	132,947	138,047	128,677	542,948
IV. Personnel	317,092	323,759	334,600	305,037	1280,488
V. Technical assistance and consultancy					
VI. Duty Travel	114,458	83,030	91,354	102,866	391,708
VII. Dissemination and training		17,600	4,575	157,365	179,540
VIII. Operational costs	271,455	241,366	252,260	231,572	996,653

IX. Monitoring, Supervision and Evaluation	9,000	49,000	9,000	49,000	116,000
Total	**1284,964**	**929,801**	**891,536**	**1029,050**	**4135,351**
Contingency/ Unallocated					358,094
Project Total					**4493,445**

Note: PY = “Project Year”

Detailed cost tables and summary cost tables are given in Appendix III. It is to be noted that the costings are indicative and that in some cases pro-forma cost estimates have been used. During implementation, due consideration will be given to choosing lower/least-cost options where technically and economically feasible. Designation of use of CFC funds in the different countries/locations as presently identified are indicative, based on the current allocation of project activities. These may be re-allocated during the course of project implementation, such in close consultation with the Fund, the Supervisory Body and the project parties concerned.

F. Procurement, Disbursement, Accounts and Audit

Procurement will be in accordance with the Fund's Rules and Regulations for the Procurement of Goods and Services of the Second Account for all items financed by the Fund. Since no procurement is foreseen of contracts with a value exceeding an estimated value of USD 100,000, no International Competitive Bidding is foreseen. Contracts with an estimated value between USD 50,000 and USD 100,000 will be awarded on the basis of Limited Competitive Bidding, in accordance with procedures satisfactory to the Fund. For contracts with a value between USD 5,000 and USD 50,000 Local Competitive Bidding or International Shopping procedures will apply. Local Shopping procedures will apply for contracts valued at less than USD 5,000. Consultants will be selected and recruited following accepted international procedures.

Disbursement against the purchase of items with a value of USD 500 or more shall be supported by copy documentation like invoices/payment receipts. Other expenditure will be disbursed against certified Statements of Expenditures (SOE). The Fund will make an initial deposit of the equivalent of USD 250,000 equivalent to an estimated six months worth of expenditures eligible for the Fund's financing. The Project Account will be replenished in accordance with the Fund's procedures for operating a Project Account. Based on an agreed work programme and allocation of responsibilities, the PEA shall provide funds to the collaborating institutions for implementation of their part of the programme. The Supervisory Body will ensure, prior to first disbursement of the funds to the PEA, that the committed inputs of the PEA and the collaborating institutions are confirmed in writing.

Accounts and Audit The PEA and the involved collaborating institutions will maintain independent and appropriate financial records and accounts in accordance with internationally acceptable accounting practices. All financial records and statements, including those for the Project Account, will be audited annually by independent auditors acceptable to the Fund. The audited accounts and the auditor's report, including separate opinions on the Statements of Expenditure and on the utilization of the funds in the Project Account, will be submitted within three months after the end of the project's fiscal year.

G. Organization and Management

The Natural Resources International Ltd. is the Project Executing Agency. The PEA has assigned a Project Manager, the Head of the Entomology and Weed Science in the Pest Management Department of the Natural Resources Institute, University of Greenwich to be the lead agency in the implementation of the project. Natural Resources International Ltd will assume full responsibility for the substantive and financial management of the project, and ensure co-ordination between co-operating institutes. The Natural Resources Institute and IACR Rothamsted will undertake the training, research and development activities in the UK. The Plant Protection Department of the Nanjing Agricultural University will co-ordinate the project in China, the Central Cotton Research Institute will lead the project in Pakistan, and the Central Institute for Cotton Research will take the leading scientific role in India. Further technical inputs will be provided from the Punjab Agricultural University and Tamil Nadu Agricultural University in India. Appendix IV of this report presents a statement of expertise of the institutions and the key staff involved in the project.

The PEA will agree with each of the main counterpart organizations on the detailed tasks assigned, contributions pledged and on implementing/reporting arrangements for both substantive and administrative/financial matters.

To ensure adequate co-ordination and consultation, the PEA will establish a Project Co-ordinating Committee (PCC) comprising project leaders from the co-ordinating institutions in each country plus a representative of the International Cotton Advisory Committee and chaired by the Manager of the project. The Fund may wish to be represented in the meeting if deemed appropriate. The PCC will meet at least once every twelve months. The PCC will review and approve the annual work programme, evaluate the progress of the project and advise on actions necessary to ensure the achievement of the project objectives. The programmes and reports are to be prepared by the project leaders in their countries and compiled by the Project Manager. The Project Manager will provide technical /managerial comments on the proposed country programmes and reports as deemed appropriate. The PEA will likewise prepare annually a substantive project progress report, which will be submitted to the Fund and the Supervisory Body prior to its review by the Project Co-ordinating Committee, at its annual meeting. Brief half yearly reports will be prepared by the PEA for information on the status of project implementation.

The Annual Work Programmes and Budgets will be prepared by the PEA in draft for submission to the Fund and the Supervisory Body for comments, prior to their review by the Project Co-ordinating Committee at its annual meeting. No changes in the work programme and fund allocation will be made without prior approval of the Supervisory Body and the Fund.

Pre-disbursement conditions. Prior to the first disbursement of funds for activities in each of the project countries, it is required that (a) written confirmation of the co-financing and counterpart contributions be obtained from the relevant institutions, (b) memoranda of understanding be signed between the PEA and lead partner institution in each of the countries detailing the activities to be undertaken, reporting and budgetary responsibilities as agreed in the final appraisal report and the institution’s adherence to the contents and substance of the Project Agreement between the Fund, the ICAC and the PEA, and (c) annual budget and work plan for the first year be agreed by the PEA, SB and the Fund.

The PEA will prepare a project completion report in accordance with the requirements of the Fund**.**

H. Monitoring, Supervision and Evaluation

Supervision: The International Cotton Advisory Committee is the Supervisory Body for this project. In this capacity it will actively participate in the supervision of project activities including assessment of results obtained. Technical and management reports and other outputs will be analyzed and commented upon. These comments will be provided to the PEA and the Fund.

Monitoring, Evaluation: The Fund will undertake monitoring missions, as appropriate, in consultation with the PEA. Provision is made for a mid-term evaluation and for a final project evaluation, which will be organized by the Fund, in consultation with the Supervisory Body and the PEA.

I. Risks

For this multi-institutional and, for some components, highly scientific complex project certain risks cannot be avoided or excluded. The following risks have been identified as well as the actions taken or envisaged to be taken in order to reduce them as much as possible:

Institutional risks*:*

Project management: NR International and NRI have very considerable experience in management large projects of this type. NRI is familiar with the partner institutions, that those institutions are familiar with each other. All the project lead scientists are individually known to the other members of the team and all the institutions have previously carried out successful collaborative work with the UK in the area of insecticide use in crop protection.

Financial management: NR International successfully administers some 90 large international projects. The current project is not exceptional in its size or complexity. Efficient, transparent and controllable financial arrangements will be set up with the counterparts to ensure a smooth handling of resources and their subsequent reporting thereon. Financial reporting and control is not expected to add any risks to the probability of achievement of the technical outcomes. Financial management of previous projects with the collaborating institutes in India and Pakistan by NRI has run smoothly. UK collaborative projects with NAU in this area (through Reading University) have also not experienced financial management problems.

Contribution of Co-financing organisations

UK:
The DFID contribution will be directly managed by the PEA as an integral component of the project.

India:
The Indian Council of Agricultural Research has approved funding for the IRM 'village adoption scheme'. Work has commenced in three of the four Indian states, managed, or

co-managed by the technical leaders on the current project (CICR for the Tamil Nadu, Maharashtra and Haryiana sites), the other will commence soon. Project results will thus feed directly into those programmes. The support for the Insecticide Resistance laboratories under the World Bank sponsored National Agricultural Technology Project (IACR) is approved. The resistance monitoring function needed in the development of appropriate strategies is therefore funded at PAU, TNAU and CICR. All these institutions have extensive experience of managing ICAR funds. This should not therefore pose a risk to outputs.

Pakistan:
The Pakistan Central Cotton Committee and the Punjab Government have indicated continuing support for the monitoring of insecticide resistance at the CCRI laboratory with further funds being made available from 1999 to 2002 which will support the current work. As the regional and national advice on insecticide management is provided by this laboratory, the funding is assured.

China:
The Entomology Department of NAU already holds the National 9th, 5 year key project in the development of field monitoring techniques for pesticide resistance of important pests and resistance risk assessment. Achievement of the objectives is well underway and problems in the achievement of outputs are not expected. Discussions have been held with NATESC management. NATESC welcomes the development of new technical knowledge which can feed into its national system of provision of advice on resistance levels and resistance management (indeed this is a function already assigned to NAU). NATESC would therefore expect to be able to disseminate practical project outputs widely across China (including the resistance and insecticide quality kits). Support for the project in terms of provision of national resistance monitoring data, provision of appropriate field sites and of insects from a range of provinces is assured.

Technical risks:

Components 1 and 2: Items for synthesis of existing knowledge.
Drawing on the expertise and familiarity with the literature of the project leaders, achievement of these components is expected to be straightforward.
Components 3 and 4: Cross resistance and Insecticide mixtures.
These components will be the most difficult to achieve technically. As a large number of insect breeding lines require to be maintained, crossed and back crossed and challenged with a range of insecticide materials, there is a risk of failure at any stage of the process delaying the achievement of part at least of the output. Previous experience with long term rearing of such lines in India and Pakistan suggests that the local prevalence of debilitating virus's, and the risk of cross infection from field collected material, mean that the most critical steps in the process should take place in an insect quarantine facility outside the region. Earlier steps will take place partly in China, Pakistan and India, because of the physical scale of the rearing required. In each case at least two laboratories will undertake the production of each iso-line to minimize the risk of losing those lines. The IACR laboratories at Rothamsted have extensive facilities and the experience to undertake the major technical portion of this work, which will however, need the scientific input from experienced national scientists from the collaborating countries. In this way, the risks of partial achievement of this output are minimized.

Component 5: Laboratory measurements and field control
This component requires a range of resistance levels to particular chemistries and

mechanisms to be present in the field. Careful laboratory measurement of resistance levels to particular chemical groups and then measurement of the field efficacies of the materials is required. There is a risk that such ranges of resistance will not be available in sites over which the project has management. It is for this reason that institutions from a geographic range of sites (across in within countries), which are known to have significantly varying average resistance levels, are involved in this component. Over five years of monitoring data for each site provide the confidence that appropriate insect material will be available. *Helicoverpa armigera* is not a sporadic pest of cotton. Nonetheless an appropriate intensity of attack in particular experimental farms cannot be guaranteed. Sites with regular, high intensity attack, have been chosen to minimize this risk.

Component 6: Pesticide application practices

Measurement and optimization of spray deposition at different crop stages can be readily undertaken using water sensitive papers attached to plant surfaces. There are not expected to be technical difficulties in achieving this information for the different plant architectures, densities and growth stages in the various countries. It should be appreciated that some spray application methods, including some of the widespread backpack spray technology used, may not be adequate for bollworm control, even when properly calibrated and used. Whether even good spray coverage will result in satisfactory control depends on the life history stage of the pest at the time of spraying (large caterpillars are hard to kill) and the efficacy of the material on susceptible and resistant insects. Successful achievement of this output therefore rests to some extent on the ability to identify effective chemicals for a given resistance situation i.e. on the outputs of several of the other components.

Component 7 and 8: Resistance and insecticide quality test kits.

The principles of development of the resistance detection kits are well known. Successful identification of appropriate biochemical or molecular markers associated with each major type of insecticide resistance (metabolic mechanism) and resistance to each major insecticide group, will be essential. The existence of such markers has been demonstrated in the Nagpur laboratory of CICR previously but there is a small risk that the range of resistance able to be assayed may be restricted and so the diagnostic power of the nitrocellulose membrane or colorimetric kits may be limited.

The basis of the insecticide purity detection kits is the raising of an immunogenic response. Since insecticides are small molecules which do not elicit such a response, these need to be conjugated to large protein molecules to be able to be antigenic. This requires the synthesis of appropriate haptens for each insecticide group. This will be carried out at the University of Greenwich, UK by chemists familiar with the production of such molecules. Difficulties are not foreseen but cannot be discounted.

The value to be obtained from these components depends on their successful dissemination through commercialization. This in turn will depend on the costs of manufacture and consequently price, as well as demand. The resistance detection kits are expected to be used at local research institute level and the active ingredient detection and quantification kit at local extension agent/Ministry of Agriculture local office level. While the thrust of the development is specifically to produce economical kits and the principles to be followed have been demonstrated with other materials previously, absolute guarantees of the commercial attractiveness of the products cannot be given. By patenting the inventions through the Indian Council of Agricultural Research, which has extensive experience in this area of the provision of affordable products for commodity development, availability at an affordable price should be assured.

Component 9: Field Demonstrations in Asia

The notes on co-financing above are relevant here. All three countries are looking for solutions to the insecticide control failures problems and all three have field oriented activities involving the collaborating institutions, which provide appropriate uptake pathways. Provided that the outputs are presented in a practically useful manner, uptake at the field demonstration level seems assured. In addition to these pathways, the Asia Development Bank is progressing a $500,000 project for the development of farmer field schools for cotton IPM in Pakistan. This will focus on non-chemical control but it is expected that the results of the current project will feed directly into curriculum development for insecticide use when economic thresholds are exceeded. A much larger, regional farmer field school project in cotton IPM funded by the EU and implemented by the FAO is in the final stages of approval. This will be active in several other countries in Asia in addition to India, Pakistan and China, with the aim of undertaking 90,000 field schools by the end of the five year project. Again input to curriculum development for the insecticide use component of the field schools is actively welcomed. This is expected to be a major uptake pathway for the results. Both projects are in the final stages of approval but as yet their commencement cannot be absolutely guaranteed. The more ambitious multi-institution initiative, covering 500 villages in 8 states was launched by the Union Ministry of Agriculture in April 1999. This is technically led by CICR Nagpur with funding from GOI ($265,000 over three years from 2000-2003).This programme involves agricultural universities, parastatal organizations such as the Cotton Corporation of India and fertilizer and insecticide companies in addition to ICAR research institutes. This has a major potential for impacting widely and provides an excellent vehicle for uptake of the current project outputs. However, the organization is complex and maintaining a firm technical lead through CICR will be a challenge.

Pesticide dealers and credit agents are by far the single most important sources of pest management advice to farmers (Overfield et al. 1999). The majority of pesticide inputs are bought on credit and virtually every village in the cotton growing regions has its network or credit agents and dealers. Although there will be reductions in the volumes of pesticides sold, this will not necessarily impact on the incomes of dealer networks across the region. The great majority of pesticide is supplied to farmers on credit by dealers who are also the credit providers for all financial needs. The experience in India is that such dealers have a strong vested interest in the overall profitability of cotton, as it provides the ability to repay loans, and that reductions in pesticide credits are matched by increasing sales of other products. Dealer hostility, and hence a possible restriction on the uptake of project outputs can be avoided by dissemination of the outputs in a genuinely village participatory way.

Component 10: Handbook of sustainable control

This work will subsume the results of the previous sections and is therefore subject to successful outcomes in the other components. The Natural Resources Institute is a major publisher of development science literature, production and publication of the handbook does not pose problems. Appropriate production and dissemination pathways for local language versions of the handbook in Pakistan and China will need to be sourced. ICRISAT is the most appropriate organization in India.

Component 11: Dissemination workshops

These will be organized by the PEA. Within the three main target countries, the collaborating institutions have the skills and experience to target an appropriate audience and to successfully run these. For Africa, the laboratories of the National Agricultural Research Organization in Uganda, provide a venue and staff used to collaborative work with NRI and involved in the active extension of IPM in cotton. NRI is currently working with NARO at Serere. The Commercial Cotton Growers Association of Zimbabwe may also provide an appropriate venue of Kadoma. Bringing key players from countries in each of the regions to the workshops will, of course, depend on national government permissions being received. Past experience suggests that this is not likely to be a significant constraint.

APPENDIX I

PROJECT LOGICAL FRAMEWORK

Title: Sustainable control of the cotton bollworm *Helicoverpa armigera* in small scale cotton production systems

Narrative Summary	Objective Verifiable Indicators	Means of Verification	Assumptions
GOAL Sustainable control of the cotton bollworm *Helicoverpa armigera* in small scale cotton production systems			
PURPOSE To develop the tools necessary to enable rational , economically and environmentally acceptable control of the insecticide resistant cotton bollworm *Helicoverpa armigera* in small scale cotton production systems			
OUTPUTS 1. A detailed understanding of minimum effective insecticide application practices and of the impact of the insecticides on beneficial organisms	Relevant Asian literature summarized and tabulated	Report for use in project handbook/ Mid PY2	None
2. Understanding of the pattern of resistance to major bollworm chemicals in Asia	Detailed information available on the strength of resistance and its geographic pattern over time within the collaborating countries	Field collection and bioassays carried out under national programmes. Local summaries collated annually	National programmes continue to monitor resistance and make data available
3. Bollworm control strategies based on the patterns of cross-resistance of *H. armigera* to different insecticides	Schedule of insecticide use programmes incorporating cross-resistance principles developed and confirmed experimentally in the field in Asia	Understanding of cross-resistance patterns incorporated into the strategy for control PY4	Single resistance mechanisms insect lines can be developed and maintained. Biochemical or molecular markers for resistance can be ascertained and used to design back crosses to uncouple co-existing mechanisms
4. Clear guidelines on the principles of rational use of insecticide mixtures	Rationale for the design of effective insecticide mixtures provided	Laboratory tests confirm developed principles- second half PY3. Recommendations incorporating resistance development implications in handbook- PY4	*H. armigera* populations showing different mixtures of resistance mechanisms available. Resistance selection using potentiating mixtures is practicable.
5. Developed ability to use laboratory measured resistance levels in designing field control strategies for *H. armigera*	A robust system for calculating from laboratory tests which materials will be effective in the field and at what rates for local regions with specific resistance profiles	Field tests in areas showing different resistance levels validate predictions- PY3. Results incorporated in handbook- PY4	Insect populations sufficiently high for effective experimentation in areas with different resistance levels to each insecticide
6. Clear advice on the minimum insecticide application practices which will be effective for control of *H. armigera*	Minimum application equipment and practices identified and confirmed in field trials- PY3	Reports on application equipment experiments -PY2 & 3. Recommendations compiled for handbook- end PY3	None

7. Simple and accessible kits for measuring the quantity and quality of insecticides from field collected samples	Kits for low cost measurement of the quantity and quality of insecticide ingredients in samples from retailers and farmer stores developed and commercialized	Haptens synthesised for major chemicals- PY1. Anti-sera generated -PY 1-2. ELISA or other tests developed -Mid PY3. Kits patented- PY3	Hapten synthesis and anti-sera generation possible
8. Provision of simple to use insecticide resistance detection kits	Rapid test kits for resistance detection developed and commercialized.	Bioassay, molecular marker and resistance mechanism- based detection kits developed	Resistance mechanism-specific isozymes can be determined. Anti-sera can be raised against unique isozymes
9. Field demonstration of economically and environmentally acceptable control of *H. armigera* in India, Pakistan and China	Evidence form at least one national programme in each of the three collaborating countries over major demonstrated benefits to farmers of incorporation of projects by end- PY4	Reports of national programmes	National programmes continue and are susceptible to modification on the basis of advice
10. Handbook of sustainable control of *H. armigera* in small scale cotton farming systems	Provision of a comprehensive handbook for *H. armigera* in small farmer systems	English version handbook produced early PY4. Local languages handbook produced end- PY4	None
11. Output dissemination workshops	International Asian workshop held in China. International African workshop held in Uganda	Workshops held-PY4	None
12. Management of Project insuring timely achievement of milestones. PCC organized and technical reports to ICAC and CFC as per the agreed schedule. Project finances organized, administered, audited and reported on.	Project-centre visits undertaken. Technical and financial reports provided as per schedule. PCC meetings and mid-term review undertaken	Project and committee technical and financial reports as per schedule	None
ACTIVITIES			
Review of insecticide efficacy and effect on beneficial insects			
1.1 Compilation of relevant literature on effective insecticide application practices	Literature summarized and tabulated- Mid PY2	Included in handbook -end PY3	None
1.2 Compilation of relevant literature on the impact of insecticides on beneficial organisms and its implications for insecticide use strategies	Literature summarized and tabulated- Mid PY2	Included in handbook -end PY3	None
Monitoring of insecticide resistance across the region			
2.1 Field collection of H. armigera on a regular basis on a network of laboratories across the region	National resistance monitoring reports provided	Annual summary reports for the region produced	National systems continue to monitor resistance and provide data
2.2 Larval bioassay of field collections against standard discriminating doses of representative insecticides undertaken	National resistance monitoring reports provided	Annual summary reports for the region produced	National systems continue to monitor resistance and provide data
Cross-resistance patterns			
3.1 Establish cross resistance patterns in Asian H. armigera by establishment of reference susceptible and	Susceptible and multi-resistant strains established.	Project Report PY1	A range of multi-resistant strains is available

multi-resistant lines. Bioassay to obtain dose response relationships			
3.2 Develop insect lines with single resistance mechanisms by crossing and selection with indicator compounds. Bioassay selected single mechanism strains for cross-resistance patterns	Single mechanism strains developed and bioassayed for cross resistance	Project Report PY1 & 2	Single mechanism strains can be separated
3.3 Identify mechanism for each cross-resistance grouping by assay for biochemical or molecular markers. Use back-crosses to uncouple co-existing mechanisms and improve line resolution	Resistance mechanism strains assayed for mechanism markers	Project Report PY2 & 3	Uncoupling mechanisms is technically feasible
3.4 Understanding cross-resistance patterns confirmed experimentally in the field by comparison with standard control practices. Underpin this with direct measurement of the genetic composition and genetic spectra of field strains	Consistency of cross-resistance patterns within and between countries ascertained by comparing the genetic composition and resistance spectra of field strains. Results confirmed by field experiments n Asia. PY3 & 4.	Project reports PY2 to PY4	Genetic and biochemical markers identifiable
3.5 Incorporate the understanding of cross-resistance patterns into the strategy for control	Application sequence recommendations produced.	Project Report and handbook PY4	None
Principles of insecticide mixtures 4.1 Assay resistance levels to individual active ingredients and mechanisms identified enabling cross resistance principles to be identified	Resistance levels to the nine major chemistries identified for three populations and assayed for cross-resistance.	Project reports PY1 and PY2	Rearing programme is logistically feasible.
4.2 The value of potentiating mixtures identified and their resistance implications clarified	Resistance selected for 8/14 generations using potentiating mixtures. Neutral impacts on resistance development identified.	Project reports PY2 and PY3	Mixtures with neutral impacts on resistance development exist
4.3 Enzyme inhibitory role of components of potentiating mixtures identified	Quantitative changes in biochemical markers of resistance monitored	Project reports PY2, 3 and first quarter PY4	Nerve insensitivity marker can be found
4.4 Production of specific recommendations concerning the use of mixtures	Recommendations prepared for handbook	Handbook second half PY3 and Early PY4	None
Lab measured resistance and consequent field control 5.1 Field sites showing a range of resistance levels to the same chemicals identified	Identification undertaken by the Project Co-ordinating Committee	Report of Project Co-ordinating Committee first quarter PY1	Such sites exist
5.2 Resistance profiles for each chemistry identified	Profiles for all chemicals at a range of rates undertaken using discriminating doses	Project reports PY2 and PY3	Appropriate sites available
5.3 Experimentally measure the relationship between laboratory measured resistance and field control	Test chemicals sprayed at recommended field rates in randomized block layouts. Three times	Project reports PY1-3	Sufficient H. armigera available at all sites

	per season bioassaying for resistance before and between application		
5.4 Prediction of field control from lab resistance data	Data compiled from each site and chemical each season control regressed on resistance measurement	Project reports PY1 –3. Results incorporated in handbook PY4	Clear relationship emerges for each chemical
Minimum effective insecticide application practices			
6.1 Summary of literature on effective application technologies for bollworm control in cotton	Literature summarized	Project report end PY1	None
6.2 Optimal equipment specification and practices field tested	Recommendations perform well in droplet distribution tests using larval counts as success criteria	Project report PY2-3 summarized for handbook end PY3	Appropriate equipment available
Insecticide quantity and quality kits			
7.1 Haptens synthesised for major bollworm chemicals	Haptens available end PY1	Haptens provided to CICR	Sufficient specificity can be achieved
7.2 Antisera generated for each hapten and tested for cross-reactivity	Antisera available	Project report PY1 and 2	Antisera titres adequate
7.3 Development of ELISA, colorimetric or nitro-cellulose membrane detection kits	Kits produced end PY2, mid PY3	Kits available	Developed kits adequately sensitive
7.4 World-wide patents applied for	Patent application submitted PY3	Patent application	Indian Council for Agricultural Research (or other) actively pursues patents
7.5 Commercialization of kits	Kits offered for sale by commercial companies PY3 and 4	Kits available	Developed kit sufficiently commercially attractive
Resistance detection kits			
8.1 Bioassay kits to detect egg/ neonate resistance developed and validated in the field.	Kits developed PY1 and PY2	Kits available	Kits can be simplified for farmer use
8.2 Molecular marker kits for resistance developed	Resistance markers identified and nitro-cellulose membrane kit developed	Developed kit	Appropriately linked markers can be found
8.3 Development of resistance mechanism based kits	Mechanism specific isozymes identified and antisera raised and tested against these and sodium channel mutant peptide sequences from Kdr strains, and appropriate kits developed	Kits available	Stains sufficiently distinct for antisera specificity
8.4 World-wide patents applied for	Patent application submitted PY3	Patent application	Indian Council for Agricultural Research (or other) actively pursues patents
			Developed kit sufficiently commercially attractive

8.5 Commercialization of kits	Kits offered for sale by commercial companies PY 4	Kits available	
Field demonstration of strategies in India, Pakistan and China			
9.1 India: Ramped input into ICAR multiple village adoption insecticides resistance demonstrations	Village adoption programme undertaken by ICAR	ICAR reports PY1-4	ICAR actively pursues programme
9.2 Pakistan: Project provided advice to Punjab Chief Ministers task force on cotton implemented	Minutes and reports of task force	Task force reports PY1-4	Task force remains receptive to Project advice
9.3 China: Project provided advice implemented by NATESC	NATESC instructions to the extension service centres reflects project advice	NATESC reports PY1-4	NAU remains key provider of advice to NATESC
9.4 Curriculum advice provided to EU regional farmer field schools in cotton	Advice provided	Project and EU reports PY1- 4	EU project commences and is open to advice.
Handbook of sustainable control			
10.1 Handbook compilation by PEA of outputs from components 1-8 with other IPM practices in English and local languages	Handbook produced English end of Q1PY4, National languages PY 4	Handbooks produced	None
10.2 Handbook disseminated at workshops and more widely by PEA and PCC and ICB	Dissemination undertaken at workshops and by collaborating bodies	Handbooks disseminated	None
Dissemination workshop			
11.1 International Asian workshop, Nagpur, India	Workshop undertaken Q1PY4	Project reports	None
11.2 National Asian workshops held in Multan, Nagpur and Nanjing	Workshops undertaken PY 4	Project reports	None
11.3 International African workshop	20-country workshop held	Project reports	Relevance to Africa demonstrated
Project management and financial administration			
12.1 Project manager organizes successful operation of experimental work, Project co-ordinating meetings and Project reports and reviews, reporting through ICAC to CFC	PCC meetings held; project laboratories visited at least once a year. Technical and financial reporting on schedule to PEA	Project reports through PEA to ICAC and CFC	None
12.2 PEA undertakes financial administration	Contracts organized, accounts set-up, contracting procurement, invoicing and disbursement undertaken. Financial reporting and auditing undertaken.	Quarterly, annual and final financial reports	None
12.3 Project Co-ordinating Committee facilitates the undertaking of the project	Initial and annual meetings in participating countries	Minutes of meeting	Visa problems overcome
12.4 Mid-term review	Mid-term review undertaken end of PY 2	Report of review	None

APPENDIX II

Implementation Schedule

(Excel file)

APPENDIX III Financing Contributions and Detailed Cost Tables

Financing Contributions - Co-financing

Department for International Development (DFID)	(UK)	$ 422,899
Indian Council of Agricultural Research (ICAR)		$ 171,721
Pakistan Central Cotton Committee		$ 52,322
Ministry for Science and Technology, China		$ 148,843
Insecticide Resistance Action Committee (IRAC)		$ 92,832
Total (excl. contingency allocations)		$ 888,617

Mode of co-financing

UK	DFID - grant support for UK technical staff costs and provision of part of the equipment to the Indian laboratories
India	ICAR - Funding of national field IPM/insecticide resistance management programmes for this pest at the same institutes and led by the same staff, into which the results of this project will flow.
Pakistan	Funding of national resistance monitoring laboratory
China	Grant to NAU from Ministry of Science and Technology for the development of field monitoring techniques and risk assessment and from National Science Foundation for resistance gene frequency monitoring. NATESC provision of national data and insects. Support for the uptake of the developed technologies
Insecticide Resistance Action Committee	Provision of equipment and technical ingredients for study

Counterpart contributions

UK	NRI	$ 212,364
	Rothamsted	$ 311,592
		$ 523,956
India	CICR	$ 146,061
	PAU	$ 92,759
	TNAU	$ 62,238
		$ 301,057
Pakistan	CCRI	$ 212,317
China	NAU	$ 100,643
ICAC		$ 9,375
Total		**$ 1,147,348**

Detailed Cost Tables (Excel files)

Table 1	Summary Base Cost by Component by Year
Table 1a	CFC Base Contribution by Component by Year
Table 2	Detailed Cost Table by Component and Item of Expenditure
Table 3	Summary Project Base Cost by Component by Year
Table 4	Summary Project Base Cost by Category by Year
Table 4a	CFC Base Rate Contribution by Category by Year
Table 5	Summary Financing Plan by Component
Table 6	Breakdown of CFC Base Cost by Country/Location by Component
Table 6a	Breakdown of Total Base Cost by Country/Location by Component
Table 7	Summary of Funding Organisations by Country/Location
Table 8	Financing Contribution by Contributor by Year by Country/Location

APPENDIX IV Statements on Main Institutions Involved

ICB

The project will be supervised by the International Cotton Advisory committee, the cotton ICB.

International Cotton Advisory Committee
1629 K Street, Suite 702
Washington DC 20006
United States of America

Tel: 20 2 463 6660
Fax: 20 2 463 6950

Head of the Technical Information Section - *Dr Rafiq Chaudhry*

ICAC has the capacity and resources to assume the project supervisory role. The ICAC is an association of governments having an interest in the production, export, import and consumption of cotton. It is an organization designed to promote co-operation in the solution of cotton related problems, particularly those of international scope and significance. Its members account for more than 80% of the world's cotton exports and for more than half of the imports.

The CFC has approved five earlier projects, sponsored by the ICAC, with a total SDR grant value of US$ 9,314,818 and loan value of US$ 5,717,250.

- Study of Cotton Production Prospects for the Nineties 1992-1995
- Integrated Pest Management for Cotton 1994-1998
- IPM of Cotton Boll Weevil in Argentina, Brazil and Paraguay 1995-2000
- Genome Characterization of Whitefly-transmitted Geminiviruses of Cotton and Development of Virus-resistant Plants through Genetic Engineering and Conventional Breeding 1996-2000
- Improvement of the Marketability of Cotton Produced in Zones Affected by Stickiness 1996-2000

PEA

The executing agency is Natural Resources International Limited.

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Natural Resources International Limited (NRI Ltd) is owned by four UK institutions (the Universities of Edinburgh & Greenwich, Imperial College of Science, Technology and Medicine, and Wye College of the University of London). NRI Ltd is experienced in tendering for and managing large consultancy projects funded by bilateral and multilateral donors. It currently manages over 90 consultancy projects in 29 countries, bringing together specialist, multi-disciplinary and multi-institutional teams for such projects and provide full co-ordination of their inputs and work outputs on behalf of its clients. NRI Ltd acts as the agent for the Natural Resources Institute (of the University of Greenwich) in marketing and business winning.

Project Manager, *Dr Derek Russell*, Pest Management Department of Natural Resources Institute.

The Natural Resources Institute (NRI) is a not-for-profit institute of the University of Greenwich, having been privatized into the university sector in 1996 from its previous position as the major natural resources research provider within the UK Department for International Development (DFID). DFID remains a major funder of NRI's work. The Natural Resources Institute has a professional scientific staff of 270 in 5 departments involved in research, consultancy and post-graduate training. Its mission is to provide support to the development process through science. The 60 scientific staff of the Pest Management Department undertake a wide range of research and consultancy projects in the integrated management of pests and diseases of crops and livestock. The Department has had extensive experience in cotton pest control over many years, running recent IPM projects in Peru, Tanzania and Egypt in addition to Pakistan and India. NRI staff, (including the proposal programme manager), have worked with all the principal and secondary collaborating institutes of this proposal.

C.2 Implementing Agencies

India

Central Institute for Cotton Research (CICR)
Wardha Road
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Nagpur, Maharashtra,
India

Tel: +91 7103 75536
Fax: +91 7103 75529

Dr Keshav Kranthi, Department of Biotechnology

The Central Institute for Cotton Research is an Indian Government Institute falling under the Indian Council of Agricultural Research. It is the leading cotton institute in India. Its mission is to develop and promote cotton and to provide the underpinning research necessary to achieve this goal. Through on-station work at its headquarters in Nagpur and its Regional stations at Coimbatore, Tamil Nadu and Sirsa, Haryana, CICR undertakes a range of varietal improvement, agronomy, and crop protection work.

Recent and commencing insecticide resistance projects at CICR include:

1. Resistance studies in *Helicoverpa armigera* In: 'Basic studies on Cotton Integrated pest management" ($105,000) (1993-1996), funded by the World Bank under the NATP programme.
2. Insecticide resistance management of *Helicoverpa armigera* -an international project ($95,300) in collaboration with The Natural Resources Institute, and funded by DFID, United Kingdom, at CICR, Nagpur. Project duration 1993-1996 (Phase-1), 1996-1999 (Phase-II).

3. Development of resistance to Bt toxins in *Helicoverpa armigera* and *Spodoptera litura* ($100,000)(1998-2001), proposal under active consideration, funded by the Department of Biotechnology. Government of India.
4. Laboratory studies on ovicidal effect and *Helicoverpa* resistance development with Spinosad, Chlorpyriphos, Spinosad + Chlorpyriphos combination (Rs $12,000) (1998-2000) Funded by De-Nocil Crop Protection ltd.

Approved for commencement:

5. Development of *Bt* transgenic cotton varieties and resistance management strategies ($476,000)(1999-2004), funded by the World Bank under National Agricultural Technology Programme.
6 National Research Network on Integrated Management of *Helicoverpa armigera* ($833,333) (1999-2004) Funded by the World Bank under National Agricultural Technology Programme
7 Technical backstopping for the Union Ministry of Agriculture's IPM/IRM village (500) adoption project ($265,000) (1999-2002). Funded by the government of India under the Cotton Technology Mission Programme.

Pakistan

Central Cotton Research Institute (CCRI)
Pakistan Central Cotton Committee
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Multan, Punjab
Pakistan

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Fax: +92 61 75153

Dr Mustaq Ahmad, Entomology Section

The Central Cotton Research Institute, Multan is the Pakistan government body charged with developing cotton though research on agronomy, genetics, physiology, fibre technology and crop protection. It has 41 scientific staff and its own laboratories and an experimental farm.

CCIR, Multan has undertaken the following research projects:

1. IPM in cotton, funded by ADB ($40,000) (1993-97),
2. Studies on CLCuV through integrated, interdisciplinary approach for research and extension, funded by ADB ($4,000 for resistance studies and $11,000 for training) (1995-97).
3. Upgrading cotton research facilities in the Punjab, sanctioned by the Government of the Punjab ($40,000) (1999-2001).

China

Nanjing Agricultural University (NAU)
Nanjing 210095, Jiangsu Province

Tel: 0086 25 4431150

Fax: 0086 25 443 1492

Dr Wu Yidong of Department of Plant Protection

Nanjing Agricultural University, which is a national 'key' agricultural university, falls under the administration of the Ministry of Agriculture. It is one the earliest higher education establishments for agriculture. NAU is dedicated to teaching and research in support of Agriculture in China. NAU has 10 colleges and 1800 teachers including 500 senior scientists. NAU has 600 ha of farmland on teaching and experimental stations. It has international collaborations and exchanges with over 30 institutions in 10 countries.

The department of Plant Protection belongs to the College of Agriculture and Life Sciences. It consists two sections, entomology and plant pathology. Within the entomology section there are 25 staff members, 5 assistants, 15 PhD and 24 MSc students. The Entomology Research Section is a 'key' scientific group sponsored by the Jiangsu Province and the laboratory is a 'key' open laboratory nominated by the Ministry of Agriculture. Since 1982 the Entomology Section has been involved in the study of insecticide resistance of important agricultural insect pests, including monitoring and management, mechanisms and genetics. The Entomology Section has organized and been in charge of national 'key' projects funded by the Ministry of Agriculture since 1985.

Nanjing Agricultural University has undertaken the following research projects on insecticide resistance within the Entomology Section

1. Field monitoring techniques for pesticide resistance of important pests and resistance risk assessment. Funded by Ministry of Science and technology National 9th Five Year Key Project(total 35,000 US$) (1996-2000).
2 Purification of cytochrome P450 isoenzymes and resistance gene frequency monitoring in *H.armigera.*(Natural Science Foundation, 13,000 US$,(1998-2000).
3. Resistance risk assessment of *H.armigera* to transgenic Bt cotton, funded by Natural Science Foundation (11,000 US$) (1997-1999))
4. Control measurements for *H.armigera* in Jiangsu Province, Jiangsu 9th Five Year Key project (24,000 US$) (1996-2000).
5. Ecological genetics of pyrethroid resistance in cotton bollworm, *Helicoverpa armigera*, funded by the Natural Science Foundation (7,500 US$) (1993-1995).
   Monitoring and control of pesticide resistance in agricultural pests, funded by Ministry of Science and Technology, National 7th Five Year Key Project (total 47,600 US$) (1986-1990).
6. Resistance forecasting technique for *H.armigera*.(National 8th Five Year Key Project, funded by Ministry of Science and technology (total 30,000 US$) (1991-1995).
7. Resistance forecasting technique of Chlio spp. National 8th Five Year Key Project, funded by Ministry of Science and technology (total 17,800 US$) (1991-1995)
8. Data processing and management system for insecticide resistance monitoring, funded by Ministry of Science and Technology, National 8th Five Year Key Project (1991-1995) (total 17,800 US$)
9. Mechanisms of pyrethroid resistance in the cotton bollworm, *Helicoverpa armigera,* funded by Natural Science Foundation (7,100 US$) (1991-1993)

In 1988 a National Training Centre for Pesticide Resistance Monitoring was established in the entomology research section. This continues to operate as a training and technical advice provider to the Chinese National insecticide "resistance monitoring" network run from the National Agro-Technical Extension and Service Centre (NATESC) in Beijing. This role puts the Centre in a unique position of access to all Chinese national pesticide and resistance data. The centre provides dedicated, rearing facilities for *Helicoverpa armigera,* a fully equipped insecticide resistance laboratory including equipment necessary for the quantification of metabolic mechanisms of resistance and a staff with world class experience in the study of the mechanisms and monitoring of insecticide resistance.

C.3 Supporting Laboratories

United Kingdom

IACR Rothamsted Agricultural Experimental Station
Harpenden, Herts AL5 2JQ
United Kingdom

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Fax: +44 1582 760981

Dr Ian Denholm - Department of Entomology and Nematology

The Institute of Arable Crops Research (IACR) Rothamsted, Experimental Station is an international centre for agricultural research that acts to advance and disseminate new technologies upon which future agricultural sustainability will depend, through research, training and consultancy activities. It is the largest agricultural research institute in the UK, employing over 800 scientists. Research links have been nurtured with more than 40 countries worldwide and over 150 visiting researchers work in IACR each year. During the past 5 years IACR has been a major partner in more than 90 projects with the developing world, more than 50 of which have been in integrated pest management (IPM). To facilitate collaborative work in China, India and Pakistan scientists from IACR have made over 100 visits to the region. Current projects in partnership with these countries have a value of almost $5 million. The following are examples of IACR research project.

1. Antipest agents for pest control especially against resistant organisms. Chile, Egypt, Germany, Ghana, India, Trinidad, South Africa, Sri Lanka, Zimbabwe. Donor: BTG
2. A systems approach to sustainable insect pest management in irrigated cotton in India. DFID
3. Integrated management of *Bemisia tabaci* with emphasis on insecticide resistance. Pakistan. DFID
4. Resistance of legumes and cereals to *Striga* species. Nigeria, Netherlands, Mexico, France, European Commission
5. Study pathogens and their control in oilseed crops in India and the UK. India ODA; DFID
6. Strategies for integrated control of *Sclerotinia* stem rot in rapeseed. China. European Commission
7. Higher Education Link with BCKV Kalyani, West Bengal, India. British Council
8. Introduction of stable resistance to soil borne mosaic viruses to improve Chinese wheat. European Commission - INCO
9. Combating fungicide resistance in China. European Commission
10. Characterization and diagnosis of barley yellow mosaic virus and *Polymyxa graminis*. China.

INDIA

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India
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Prof. Joginder Singh, Entomology Department

Punjab Agricultural University (PAU) is one of India's premier agricultural universities. Like other Agricultural Universities it operates as the major provider of scientific research and advice for the state. Dr Singh's team in the Entomology Department, are responsible for cotton research and recommendations. Since 1996, this team has been working collaboratively with NRI on Cotton Leaf Curl Virus epidemiology and the understanding and management of insecticide resistance in the irrigated cotton of northern India. The Punjab provides a high resistance site for a number of the field experiments.

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Madurai campus - Dean, *Prof. A.Regupathy*

Tamil Nadu Agricultural University plays the same role in southern India as PAU in the north. Prof. Regupathy is a respected ecotoxicologist who has headed up a number of major national initiatives in cotton entomology and insecticide resistance. His team has led the development of novel component technologies for control of *Helicoverpa armigera* in the DFID funded resistance laboratory network. Tamil Nadu provides a relatively low resistance site for a number of the field experiments.

Appendix V References

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Components	Outputs	Project Year I				Project Year II				Project Year III				Project Year IV			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Component 10	**Handbook of sustainable control of *H.armigera* for small farmers**																
Activity 1	Compilation of outputs, publication.										■	■	■	■			
Activity 2	Dissemination of Handbook													■	■	■	■
Component 11	**Dissemination workshops**																
Activity 1	Workshops in India, China and Pakistan													■			
Activity 2	Workshops in Africa (four)														■		
Component 12	**Project managment and financial administration**																
Activity 1	Project monitoring, management and reporting	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Activity 2	Start-up, financial adminsitration, close-down and reporting	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Activity 3	Project supervisory committee meetings	■				■				■				■			
Activity 4	Mid-term review									■							
	Reporting schedule																
	Inception report	●															
	Bi-annual reports		●		●		●		●		●		●		●		
	Draft project completion report																●
	Final project completion report																●

Table 1 - SUMMARY BASE COST BY COMPONENT BY YEAR (US$)		
COMPONENT	**TOTAL**	**% of total**
1. Review of Insecticide efficacy	71,502	1.73%
2. Monitoring of insecticide resistance	599,697	14.50%
3. Cross-resistance patterns	844,385	20.42%
4. Principles of insecticide mixtures	210,867	5.10%
5. Lab. measured resistance and field control	741,188	17.92%
6. Minimum effective insecticide application practices	244,472	5.91%
7. Insecticide quantity and quality kits	133,934	3.24%
8. Resistance detection kits	173,174	4.19%
9. Field demonstration strategies		
10. Handbook of sustainable control of *H. armigera*	80,884	1.96%
11. Dissemination workshops	240,905	5.83%
12a. Project management	549,234	13.28%
12b. Financial Administration	129,110	3.12%
12c. Monitoring/Supervision/Evaluation	116,000	2.81%
TOTAL	**4,135,351**	**100.00%**

TABLE 1a - CFC BASE CONTRIBUTION BY COMPONENT BY YEAR (US$)						
COMPONENT	**YR1**	**YR2**	**YR3**	**YR4**	**TOTAL**	**% of total**
1. Review of Insecticide efficacy						
2. Monitoring of insecticide resistance						
3. Cross-resistance patterns	112,680	56,972	82,972	58,060	**310,684**	14.80%
4. Principles of insecticide mixtures	60,671	15,338	15,888	15,168	**107,065**	5.10%
5. Lab. measured resistance and field control	179,122	112,822	90,656	90,656	**473,256**	22.54%
6. Minimum effective insecticide application practices	34,363	25,358	37,114	36,896	**133,732**	6.37%
7. Insecticide quantity and quality kits	29,319	10,619	8,356	6,174	**54,467**	2.59%
8. Resistance detection kits	53,464	24,820	19,620	1,400	**99,304**	4.73%
9. Field demonstration strategies	Finance in place with national programmes					
10. Handbook of sustainable control of *H. armigera*		16,000	17,506	20,093	**53,598**	2.55%
11. Dissemination workshops			12,706	215,679	**228,384**	10.88%
12a. Project management	98,134	99,484	98,434	97,734	**393,784**	18.76%
12b. Financial Administration	40,800	28,775	28,775	30,760	**129,110**	6.15%
12c. Monitoring/Supervision/Evaluation	9,000	49,000	9,000	49,000	**116,000**	5.53%
TOTAL	**617,553**	**439,188**	**421,025**	**621,619**	**2,099,386**	**100.00%**

Table 3 - SUMMARY PROJECT BASE COST BY COMPONENT BY YEAR (US$)

COMPONENT	YR1	YR2	YR3	YR4	TOTAL
1. Review of Insecticide efficacy	35,751	35,751			**71,502**
2. Monitoring of insecticide resistance	249,361	116,779	116,779	116,779	**599,697**
3. Cross-resistance patterns	238,064	210,176	234,956	161,190	**844,385**
4. Principles of insecticide mixtures	89,021	40,488	41,038	40,318	**210,867**
5. Lab. measured resistance and field control	246,105	179,805	157,639	157,639	**741,188**
6. Minimum effective insecticide application practices	74,862	46,918	65,107	57,586	**244,472**
7. Insecticide quantity and quality kits	87,988	14,218	16,955	14,773	**133,934**
8. Resistance detection kits	76,634	50,852	39,288	6,400	**173,174**
9. Field demonstration strategies	Finance in place with national programmes				
10. Handbook of sustainable control of *H. armigera*		18,499	32,155	30,230	**80,884**
11. Dissemination workshops			12,706	228,200	**240,905**
12a. Project management	137,379	138,540	137,140	136,175	**549,234**
12b. Financial Administration	40,800	28,775	28,775	30,760	**129,110**
12c. Monitoring/Supervision/Evaluation	9,000	49,000	9,000	49,000	**116,000**
TOTAL	**1,284,964**	**929,801**	**891,536**	**1,029,050**	**4,135,351**

Table 4 - SUMMARY PROJECT BASE COST BY CATEGORY OF EXPENDITURE BY YEAR (US$)

CATEGORY	YR1	YR2	YR3	YR4	TOTAL
I. Vehicles, machinery and equipment	429,682	82,100	61,700	54,532	**628,014**
II. Civil Works					
III. Materials and Supplies	143,277	132,947	138,047	128,677	**542,948**
IV. Personnel	317,092	323,759	334,600	305,037	**1,280,488**
V. Technical assistance and consultancy					
VI. Duty Travel	114,458	83,030	91,354	102,866	**391,708**
VII. Dissemination and training		17,600	4,575	157,365	**179,540**
VIII. Operational Costs	271,455	241,366	252,260	231,572	**996,653**
IX. Monitoring, Supervision, Evaluation	9,000	49,000	9,000	49,000	**116,000**
BASE TOTAL	**1,284,964**	**929,801**	**891,536**	**1,029,050**	**4,135,351**
X. Contingency/Unallocated	87,053	76,351	75,262	119,428	358,094
PROJECT TOTAL	**1,372,017**	**1,006,153**	**966,798**	**1,148,478**	**4,493,445**

Note:Total contingency/Unallocated for co-financing and counterpart contribution is US$ 198977.
This amount has been indicatively allocated over the four years, in adddition to the CFC provision.

Table 4a - CFC BASE RATE CONTRIBUTION BY CATEGORY BY YEAR (US$)

CATEGORY	YR1	YR2	YR3	YR4	TOTAL
I. Vehicles, machinery and equipment	276,953	24,400	1,800	1,800	**304,953**
II. Civil Works					
III. Materials and Supplies	84,494	80,714	86,264	78,344	**329,816**
IV. Personnel	110,576	137,157	154,747	127,557	**530,036**
V. Technical assistance and consultancy					
VI. Duty Travel	66,653	58,378	76,903	116,815	**318,749**
VII. Dissemination and training		16,000	4,500	154,290	**174,790**
VIII. Operational Costs	69,877	73,539	87,811	93,813	**325,041**
IX. Monitoring, Supervision, Evaluation	9,000	49,000	9,000	49,000	**116,000**
TOTAL	**617,553**	**439,188**	**421,025**	**621,619**	**2,099,386**
X. Contingency/Unallocated	37,053	26,351	25,262	70,451	159,117
PROJECT TOTAL	**654,606**	**465,539**	**446,287**	**692,070**	**2,258,503**

Table 5 - SUMMARY FINANCING PLAN BY COMPONENT (US$) - Base Cost

COMPONENT	CFC	DFID	IRAC	ICAR	NATESC	PCCC	CC	TOTAL
1. Review of Insecticide efficacy		60,222					11,280	**71,502**
2. Monitoring of insecticide resistance		102,229		151,721	102,443	52,322	190,982	**599,697**
3. Cross-resistance patterns	310,684	216,649					317,052	**844,385**
4. Principles of insecticide mixtures	107,065	3,200	20,000		12,000		68,602	**210,867**
5. Lab. measured resistance and field control	473,256		40,000		24,000		203,932	**741,188**
6. Minimum effective insecticide application practices	133,732	9,529	32,832		10,400		57,979	**244,472**
7. Insecticide quantity and quality kits	54,467	31,070		10,000			38,398	**133,934**
8. Resistance detection kits	99,304			10,000			63,870	**173,174**
9. Field demonstration strategies	Finance in place with national programmes							
10. Handbook of sustainable control of *H. armigera*	53,598						27,285	**80,884**
11. Dissemination workshops	228,384						12,521	**240,905**
12a. Project management	393,784						155,449	**549,234**
12b. Financial Administration	129,110							**129,110**
12c. Monitoring/Supervision/Evaluation	116,000							**116,000**
TOTAL	**2,099,386**	**422,899**	**92,832**	**171,721**	**148,843**	**52,322**	**1,147,349**	**4,135,351**
TOTAL AS %	**51%**	**10%**	**2%**	**4%**	**4%**	**1%**	**28%**	**100%**

Table 6 - BREAKDOWN OF CFC BASE COST BY COUNTRY/LOCATION BY COMPONENT (US$)

COMPONENT	UK	CHINA	INDIA	PAKISTAN	AFRICA	ICAC/CFC	TOTAL
1. Review of Insecticide efficacy							
2. Monitoring of insecticide resistance							
3. Cross-resistance patterns		88,548	140,036	82,100			**310,684**
4. Principles of insecticide mixtures		52,568	54,497				**107,065**
5. Lab. measured resistance and field control		93,388	235,140	144,728			**473,256**
6. Minimum effective insecticide application practices		20,998	63,840	48,894			**133,732**
7. Insecticide quantity and quality kits			54,467				**54,467**
8. Resistance detection kits		6,546	85,912	6,846			**99,304**
9. Field demonstration strategies	Finance in place with national programmes						
10. Handbook of sustainable control of *H. armigera*	29,148	450	16,000	8,000			**53,598**
11. Dissemination workshops	62,822	28,400	20,950	18,750	89,000	8,462	**228,384**
12a. Project management	374,634	5,900	6,550	6,700			**393,784**
12b. Financial Administration	129,110						**129,110**
12c. Monitoring/Supervision/Evaluation						116,000	**116,000**
TOTAL	**595,715**	**296,798**	**677,392**	**316,018**	**89,000**	**124,462**	**2,099,386**

Table 6a - BREAKDOWN OF TOTAL BASE COST BY COUNTRY/LOCATION BY COMPONENT (US$)

COMPONENT	UK	CHINA	INDIA	PAKISTAN	AFRICA	ICAC/CFC	TOTAL
1. Review of Insecticide efficacy	71,502						**71,502**
2. Monitoring of insecticide resistance		135,883	321,411	142,403			**599,697**
3. Cross-resistance patterns	485,271	106,378	152,276	100,460			**844,385**
4. Principles of insecticide mixtures		89,083	121,783				**210,867**
5. Lab. measured resistance and field control		149,723	373,406	218,058			**741,188**
6. Minimum effective insecticide application practices	19,058	43,507	91,449	90,458			**244,472**
7. Insecticide quantity and quality kits	55,070		78,865				**133,934**
8. Resistance detection kits	39,000	8,485	116,764	8,924			**173,174**
9. Field demonstration strategies	Finance in place with national programmes						
10. Handbook of sustainable control of *H. armigera*	48,207	1,830	18,499	12,348			**80,884**
11. Dissemination workshops	62,822	28,610	23,347	19,289	89,000	17,837	**240,905**
12a. Project management	527,102	6,950	7,300	7,882			**549,234**
12b. Financial Administration	129,110						**129,110**
12c. Monitoring/Supervision/Evaluation						116,000	**116,000**
TOTAL	**1,437,141**	**570,450**	**1,305,099**	**599,823**	**89,000**	**133,837**	**4,135,351**

Table 7 - SUMMARY OF FINANCING BY FUNDING ORGANISATIONS BY COUNTRY/LOCATION (US$) - Base Cost

Funding Body	UK	India	China	Pakistan	Africa	ICAC/CFC	TOTAL
GRANT							
CFC	595,715	677,392	296,798	316,018	89,000	124,462	**2,099,386**
CO-FINANCING							
DFID	317,470	105,429					**422,899**
IRAC		49,500	24,166	19,166			**92,832**
ICAR		171,721					**171,721**
NATESC			148,843				**148,843**
PCCC				52,322			**52,322**
CO-FUNDING							
UK - NRI, Rothamsted	523,956						**523,956**
India - CICR, PAU,TNAU		301,057					**301,057**
China - NAU			100,643				**100,643**
Pakistan - CCRI				212,317			**212,317**
ICAC						9,375	**9,375**
TOTAL	**1,437,141**	**1,305,099**	**570,450**	**599,823**	**89,000**	**133,837**	**4,135,351**

Table 8 - Financing Contribution by Contributor by Year by Country/Location (US$)

	UK				INDIA				CHINA				PAKISTAN				AFRICA				CFC/ICAC				TOTAL
Funding Body	**YR 1**	**YR 2**	**YR 3**	**YR 4**	**YR 1**	**YR 2**	**YR 3**	**YR 4**	**YR 1**	**YR 2**	**YR 3**	**YR 4**	**YR 1**	**YR 2**	**YR 3**	**YR 4**	**YR 1**	**YR 2**	**YR 3**	**YR 4**	**YR 1**	**YR 2**	**YR 3**	**YR 4**	
GRANT																									
CFC	131,084	124,559	153,670	186,403	284,802	141,272	123,941	127,378	111,300	44,650	62,948	77,900	81,368	79,708	71,466	83,476	0	0	0	89,000	9,000	49,000	9,000	57,462	**2,099,386**
CO-FINANCING																									
DFID	123,584	105,706	64,944	23,236	105,429	0	0	0																	**422,899**
IRAC					13,500	13,500	13,500	9,000	6,375	6,375	6,375	5,041	5,125	5,125	5,125	3,791									**92,832**
ICAR					50,573	33,716	43,716	43,716																	**171,721**
NATESC									36,211	36,211	38,211	38,211													**148,843**
PCCC													16,829	11,831	11,831	11,831									**52,322**
CO-FUNDING																									
UK - NRI, Rothamsted	160,295	126,766	125,017	111,879																					**523,956**
India - CICR, PAU,TNAU					79,989	78,474	73,628	68,966																	**301,057**
China - NAU									18,548	19,352	33,607	29,137													**100,643**
Pakistan - CCRI													50,953	53,558	54,557	53,248									**212,317**
ICAC																					0	0	0	9,375	**9,375**
TOTAL	**414,963**	**357,030**	**343,631**	**321,517**	**534,293**	**266,961**	**254,785**	**249,060**	**172,433**	**106,588**	**141,141**	**150,289**	**154,275**	**150,222**	**142,979**	**152,346**	**0**	**0**	**0**	**89,000**	**9,000**	**49,000**	**9,000**	**66,837**	**4,135,351**