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COTTON RESEARCH & DEVELOPMENT CORPORATION

FINAL REPORT

Overseas Travel: China and India June/ July 1992

CSE27C

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CSIRO

Cotton Research and Development Corporation

FINAL REPORT

Project Title: Overseas Travel, China and India 1992

Project Code: CSE27C

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Objectives of Travel.

(i) to attend the XIX International Congress of Entomology, Beijing, China.

(ii) to visit Chinese research centres in Beijing and Anyang where cotton-related research is conducted and to determine the potential for collaborative research programs involving Australian and Chinese researchers, particularly the use of IPM and plant breeding techniques in pest management.

(iii) to visit ICRISAT, Hyderabad, India to review pyrethroid resistance problems in *H. armigera* in coastal and inland cotton areas.

Summarised Itinerary

June 16	Travel to Sydney
June 17,18	Travel Sydney - Hong Kong - Beijing
June 19 - 23	Visit to Institute of Plant Protection & Institute of Zoology, Beijing
June 23 - 27	Chinese Cotton Research Institute, Anyang, Henan
June 28 - July 4	XIX International Congress of Entomology, Beijing
July 5 - 11	Post - Congress Tour in China
July 11 - 12	Travel Hong Kong - Delhi - Hyderabad
July 14 - 19	ICRISAT, Hyderabad, India
July 20 - 21	Travel - Delhi - Hong Kong - Sydney
July 21	Travel Sydney - Narrabri

Funding.

Funds were received from:

Cotton R&D Corporation	$2200
Centre for Tropical Pest Management	$840
CSIRO Cotton Research Unit	$1000
CSIRO Division of Entomology	$500
Personal Contribution	$1000

Highlights.

* Presentation of an invited paper at the International Congress entitled "Spatial population modelling of *Helicoverpa* spp: studies of adult behaviour and movement" in a symposium on Models as Links between Empiricism and Theory in Insect Ecology.

* Visit to Cotton Research Institute, Anyang, Henan Province in the centre of the main Chinese production area centred on the Yellow River valley, where details of cotton systems and pest problems and possible areas for collaborative research were thoroughly discussed.

* Identification of potential collaborative research links with Chinese cotton researchers at Anyang (Page 15).

* Presentation of various seminars on aspects Australian cotton production and *Helicoverpa* ecology at the Institute of Plant Protection, Beijing; Institute of Zoology, Beijing; Cotton Research Institute, Anyang and Andra Pradesh Agricultural University field station, Guntur, Andra Pradesh, India.

* Visit to ICRISAT and coastal cotton area near Guntur, India, where problems with pyrethroid resistance and pest management are extreme.

Attendance at International Congress of Entomology, Beijing, China. July 28-June 4, 1992.

The International Congress of Entomology is held every 4 years and this year brought together 3,500 entomologists from 78 countries around the world. The Congress included numerous Symposia, contributed papers and poster sessions covering all aspects of entomology. The volume of abstracts alone ran to 730 pages. I presented an invited paper (Attachment 1) entitled "Spatial population modelling of *Helicoverpa* spp: studies of adult behaviour and movement" in a symposium on Models as Links between Empiricism and Theory in Insect Ecology. In addition I presented a joint poster (Attachment 2) on the "Ecology and Biology of *Ichneumon promissorius*, a true pupal parasitoid of *Helicoverpa* sp. in Australia". Contacts were made with several groups involved in Geographic Information System applications in the US and Britain.

Major Symposia attended included:
Models as Links between Empiricism and Theory in Insect Ecology
Insect Migration: Physical Factors and Physiological Mechanisms
Interaction of Host Plant Resistance and Biological Control
How Plants Affect Behaviour, Fitness and Performance of Natural Enemies
Characteristics of Forest Insect Pests and Outbreaks.

Visits to Research Institutes in China.

Major Contacts Established

Institute of Plant Protection, Chinese Academy of Agricultural Sciences, Beijing, 100094, China.
Fax: 86 1 2582594

Professor Guo Yuyuan - head Cotton Insect Pests Research Group

Mr Ye Zhihua - Head of Research Management Dept.

Mr Cao Yu - Research Entomologist (mites in cotton)

Mr Wang Wugang - Research Entomologist (IPM and host plant resistance)

Mr. Zheng Chuanlin - Plant Pathologist

Institute of Zoology, Academia Sinica, 19 Zhongguancun Lu, Haitien, Beijing, China.
Fax: 86 1 2565689

Professor Li Dianmo - Head, Department of Insect Ecology

Associate Professor Ren Shi-Zen - *Mythimna separata* migration

Professor Chen-Zhu Wang, Dept. of Insect Physiology

Cotton Research Institute, Chinese Academy of Agricultural Sciences, Anyang, Henan 455112, China.

Fax: 86 372 424952

Professor Wang Ruohai - General Director

Associate Professor Xiang Shikang - Deputy Director

Professor Guo Jincheng - Directors Assistant

Mr Xia Jingyuan - Chairman Plant Protection Dept

Mr Song Xiao Yuan - Vice-Chairman Plant Protection Dept

Visit to the Institute of Plant Protection, Chinese Academy of Agricultural Sciences, Beijing - 19th June, 1992

The Institute of Plant Protection conducts research phytopathology, entomology, microbiology and crop pests management. Associated with the Institute is a new State Key Laboratory for Biology of Plant Diseases and Insect Pests, one of 50 established throughout China to act as a focus for high quality research and engage in collaborative research with other countries.

The Institute conducts program in cotton breeding and pest management from its main laboratory in Beijing and field stations in Henan and Hebei provinces. Prof. Guo Yuyuan is head of the Cotton Insect Pests Department and is meant to co-ordinate all *Heliothis* related research in China. However, I saw little evidence of co-ordination. Most Institutes operate largely independently and seem unaware of other *Heliothis* research. Briefings were received on major pests and cotton management, host plant resistance research, pyrethroid resistance situation and mites problems in cotton.

1. Cotton Research Overview.

The main northern cotton belt, includes the Yellow River valley and spans 4 provinces; Henan, Hebei, Shanxi and Shandong and accounts for approximately 60% of Chinese production. Cotton is sown in April and harvested in October. The cropping pattern is mainly wheat / cotton interplant or double cropping. Cotton is sown when the wheat is maturing in configurations of 6 rows wheat, 2 rows cotton. This system maintains beneficials on the wheat which then transfer to cotton after wheat harvest. There is also some interplanting of vegetables and cotton, or sorghum and cotton.

The primary pest is *H.armigera*. This species is always abundant in North China, whereas in South China it may be a major pest only 1 or 2 years in 10. The 1992 season had very high densities during the 2nd generation (the first on cotton). *H.armigera* has 4 generations; the first on wheat, 2nd, 3rd and 4th on cotton in June, July and August. Populations enter diapause in September/October. Life table studies have shown very high mortality from egg to 3rd instar, but high survival of 4th to 6th instars.

The second main pest is the cotton aphids (*Aphis gossypii)*, which occurs in two peaks, one on seedlings (mid-May) and a second peak in mid July.

Beneficial insects are a major area of research in China. To date 56 parasites and 132 predators of H.*armigera* have been identified. These all attack eggs or early instars (mainly *Campoletis* and Ichneumonids). There are apparently no parasites of late instar larvae, and the researchers had no records of tachinids. For aphids 26 parasites and 186 predators have been described. Researchers are hoping to encourage the maintenance of beneficials by expanding use of Bt sprays.

2. Host Plant Resistance Research

HPR work is focussed on *H. armigera* and aphids and began in early 1980's. A number of potential resistance characteristics are being assessed; hairiness, high gossypol, okra leaves, yellow leaves. The project aims to screen 1000 cultivars for a total of 76 different attributes. Of 200 screened to date, 33 are resistant to *H. armigera,* 63 resistant to early season aphids and 28 resistant to summer aphids. The most resistant lines are glabrous and have high gossypol gland density. Significant relationships have been detected between insect resistance and phenolic or tannic content. Now have many resistant lines in demonstrations and plan to introduce them into commercial production.

Evaluations involve both field cage and laboratory bioassays. In field cages the most resistant lines were glabrous, nectariless and suffered very low levels of square damage (0.41%), while the least resistant - hairy, nectaried suffered 56.5% square damage. Laboratory bioassays involving excised terminals in nutrient solution show significant variation in antibiosis among races of cotton. Uncultivated or semicultivated Asian and African types have been shown to be significantly more resistant than Upland types and are being used in crossing programs.

3. Pyrethroid Resistance

Ms. Tang (assistant entomologist) gave an account of the current pyrethroid resistance problem in *H. armigera* and the effects of host plants on resistance and metabolism of pesticides. Pyrethroids were only used on demonstration blocks of cotton from 1980 - 1984. Thereafter they were used extensively and resistance appeared almost immediately in the northern China cotton region in 1986, reaching high levels the following season..

History of Pesticide Resistance

Year	Resistance Ratio
1980	1
1981	1
1984	1.7
1985	1.7
1986	25.7
1987	83.7
1990	108.6

Studies of the effects of different host plants (tomato, bean, cotton bolls, capsicum fruit and artificial diet) showed a 60 fold range in pyrethroid sensitivity due to diet. There was a 5 fold range in activity of carboxylesterases and glutathion-S-transferase. Larval growth was fastest on cotton bolls (14 days) and slowest on capsicum fruit (21 days). Investigations of the physiological basis of these differences showed that MFO activity was highest in 3rd instar larvae and also varied widely with diet, being lowest in cottonfed larvae and highest in capsicum fed larvae.

4. Mites on Cotton in China

Cotton in northern China is attacked by 4 major mite pests; *T.urticae* & *T.turkestani, T.truncatus, T .cinnabarrinus*. Mites first appear in the crop in mid - late May, peak in mid July - mid August, but then decline. In most years *T. cinnabarrinus* is the dominant species. This species causes distinctive leaf reddening, whereas *T.truncatus* causes a yellow leaf spotting. Managers modify their thresholds according to these different types of damage. The major natural enemies are thrips, mainly *Thrips sexmaculatus*. Management is with chemicals, normally 3-5 applications are required.

Pesticide Resistance in mites is a major problem, particularly in *T.truncatus*. Resistance to dicofol and monocrotophos is widespread, though they remain susceptible to omethoate.

Visit to the Institute of Zoology, Academia Sinica, Beijing, June 20, 1992

The Institute of Zoology conducts wide ranging studies on vertebrates and invertebrates. The Departments of Insect Ecology and Insect Physiology have a well established reputation for research on insect migration and population dynamics. Simulation modelling and decision support systems form a large part of their current work.

1.Insect Migration: Associate Prof. Ren Shi-Zen

The Institute of Zoology has developed an international reputation for research on insect migration largely through extensive, well co-ordinated field studies aimed at testing hypotheses about population dynamics and movements of pest insects.

Research on migration and overwintering of the Oriental armyworm, *Mythimna separata.* commenced during the 1950's. The aim was to develop forecasting systems for this severe pest of cereals in northern China based on trapping systems and the use of meteorological and climatic information. The Oriental armyworm had assumed mythical status in China, being known as the "terrorist" insect - it would appear suddenly, cause severe damage to rice, wheat, corn and millet crops, then disappear. When most abundant, temples were built to ward off the plague.

A nationwide study during the 1950's showed that armyworm could not overwinter in northern China; all pupae were killed by extreme northern winters where -20°C is not uncommon. Work then expanded to south China where overwintering pupae and larvae were located in winter crops grown south of 33°C Nth.

A nation wide mark-recapture study was then initiated to unravel the pattern of movements. The study used a vinegar/sugar/water lure to attract moths which were then sprayed and marked with a red dye as they flew around the lures. This work commenced in 1963 and over several years documented the typical migratory pattern which involved migration each generation from southern China into the Yangste River Valley further to the north to the Yellow River area during May/ June, thence into NE and western China in August, culminating in a return migration in Sept/ Oct back to the south. The longest individual flight recorded during these studies was 1100 km.

From the late 1970's research moved into the area of IPM programs based on biocontrol and cultural control techniques. In the mid 1980's the emphasis again swung to migration, but with an most effort on understanding the behaviour and physiology underlying migratory movements. The combination of IPM and migration research has resulted after 30 years work in an expert system for forecasting of oriental armyworm abundance and management on wheat and other cereals. This work on Oriental armyworm is one of the best documented and comprehensive studies of population dynamics anywhere in the world.

As a result of this research, attempts are being made to change the cropping system in southern China by reducing the area of winter cereals to reduce the initial source population of oriental armyworm. To date a 30% reduction has been achieved. However, these changes have also removed spring corn as a major crop and host of the asian corn borer. ACB has now become a significant pest of cotton in the south after removal of its preferred graminaceous host. ACB causes much damage to cotton by boring in the stems.

2. Cotton Pest Management - Professor Li Dianmo.

Prof. Dianmo's group are developing IPM systems based on simulation models and computer based decision support systems. They have developed simple, but workable models for the cotton plant, *Heliothis* development and phenology, and cotton aphids. These are being validated on field station sites SW of Beijing. Dr. Dianmo has also accumulated long data sets of insect density data on cotton in Henan province which he proposes to analyse for spatial patterns.

Visit to Chinese Cotton Research Institute, Chinese Academy of Agricultural Sciences, Anyang, Henan. 23rd-27th June, 1992

The Cotton Research Institute is the only National Institute for cotton research and employs 640 staff. It is situated in the heart of the Yellow River Valley of northern China, where 60% of Chinese cotton is produced. The Institutes role is to research key problems, and to co-ordinate all cotton research in areas of breeding, IPM, regional testing of new varieties, fertilisers and chemical pesticides. It is the headquarters for the Chinese Society of Cotton Scientists, and the Fibre & Seed Quality Control Centre of Ministry of Agriculture.

One major project co-ordinated at Anyang is the so-called Le Pung project (named for the visionary Premier). It is focussed on the irrigated cotton/ wheat double cropping system introduced in north China in the 1980's and aims to obtain cotton yields of 1125-1275 kg/ha and wheat yields of 3780 -4500 kg/ha. Present yields are 900 kg/ha cotton and 3000 kg/ha for wheat. Study is being conducted in 4 experiment areas covering 1,300 ha in total. The double cropping system involves sowing of wheat in October/November with harvest in June and sowing of cotton in April for harvest in October. The crops are interplanted and since the system involves no fallow or rotations problems with insect pests and diseases are increasing. IPM strategies are not always compatible with farmers management priorities.

The Institute has 6 Departments - Germplasm, Plant Breeding, Agronomy, Plant Protection, Wheat/Corn Research, Information Systems, and is well equipped with modern analytical equipment courtesy of World Bank funds. The experiment farm covers 212 ha. A noticeable feature of the Anyang Institute is a very strict demarcation of responsibilities which extends from research projects to individual pieces of equipment. Many of the researchers are unwilling to collaborate or think beyond the bounds of their specific projects. Consequently, some staff were unaware of projects elsewhere particularly in other Institutes where cotton research is done (Institute of Zoology and Institute of Plant Protection).

Breeding.

The Institute is a major centre for breeding and has released 18 varieties - 8 in the last 5 years because of "open policy and reforms" . Zhoumian 12 is the most popular variety accounting for 1/3 of the national area (about 2 million hectares). Zhoumian 12 as Fusarium wilt resistance and is tolerant of Verticillium, the two major diseases in north China. The economic benefit of the variety has been estimated at $4,000 million.
Zhoumian 18, a glandless variety is also widely grown accounting for about 10% of national area. The seed is used for human consumption and as a medium for antibiotic production.

The breeding group has a genetic bank of 5,300 accessions for all over world and maintains a winter nursery on Hainan island in southern China. 2000 accessions have been assessed for over 60 characteristics, with all information available on database.

Biotechnology is a major area focussed on tissue culture, anther culture, protoplast culture and transformation systems.

Agronomy

This department concentrates on nutrition, cultivation techniques & modelling with the aim of optimising decision making. Soil chemical studies include a range of macro and (N, K, P) and micro elements (Boron) and growth regulators.

Plant Protection Department.

This department has an energetic Chairman, Mr.Xia and a total staff of 34 in 5 research groups:

1. Cotton Insect IPM - work on Heliothis, aphids, mites.
2. Disease IPM - work on Verticillium and Fusarium wilt, seedling disease and boll rot.
3. Host plant resistance to insects
4. Host plant resistance to diseases
5. Pesticides group - evaluation of new pesticides, toxicology - effects on insects & natural enemies, and monitoring of pesticide resistance.

Disease IPM and Host Plant Resistance

The advent of the wheat/ cotton double cropping system in northern China was associated with an in increase problems with *Rhizoctonia* and *Fusarium* and *Verticillium* wilt. Seedling diseases are managed with seed treatments. Before the 1930's wilt was not present, then when US varieties were introduced the disease appeared (!!!). During the 1940's and 50's these diseases were present but not serious, but area of infection expanded greatly in the 1960's, peaking in 1980's when 30% of all fields were seriously affected by Fusarium. Breeding for wilt resistance began in the 1960's and most varieties are now resistant to Fusarium, but not to Verticillium. Since 1970's major surveys and identification of pathogens have been conducted throughout China. Boll rots, mainly phytophthora, are managed with Pix and cultural measures such as manually removing outer leaves to open up canopy. Some fungicides are also used.

Host Plant Resistance for Insects

Research on Host Plant Resistance against insect pests has spanned only 7 years and strains with some resistance to aphids & pink bollworm have been developed. Most work is focussed on hairiness, glabrousness, nectariless and high gossypol. No work has been done with okra leaf. The Institute is well set up for HPR work having a collaborative team of entomologists and biochemists. Facilities include numerous large walk in field cages where cultivar screening and economic threshold work is done. Ms. Song (a biochemist) has worked intensively on gossypol and its relationship to insect resistance. She is convinced that in many cases gossypol concentration per se is not the major factor imparting resistance. The Institute is extremely well equipped for biochemical and chemical analyses. Two commercial HPR varieties released to date include:

Zhoumian 99 is pubescent and has higher concentrations of amino acids. It shows 25% less aphids and fewer *Heliothis* though mechanisms not yet known. Zu99 is now grown over 8,000 ha.

Zhoumian 1361 is a high gossypol line with reduced densities of *Heliothis* .

IPM and Resistance Management

Overall the two major pests are *Heliothis* and cotton aphids. Early season pests include *Heliothis* , aphids and mites. Mid-late season - *Heliothis* , plant bugs, spiny bollworm, and loopers. *Heliothis* goes through 4 generations per year in northern China. The first generation is on wheat and is rarely damaging, the 2nd, 3rd and 4th generations are concentrated on cotton. Generation 2 occurs on early squaring cotton in June and is relatively synchronous due to uniform emergence from wheat. Often this generation requires no control, the farmers being willing to sacrifice early squares. Bt is often used effectively. Generation 3 is the most damaging, while generation 4 may occur too late to severely affect yield. Early season mites are usually controlled by *Thrips sexmaculatus*.

Management relies on an integrated approach with use of beneficials where possible. Heavy use of OP's and DDT for aphid control in the 1960's lead to resistance, with the result that beneficials (particularly Coccinella - ladybirds) are now encouraged and considered in management. Research has shown a ratio of 1predator to 150 aphids will give effective control. However, predators are not reliable.

Before the introduction of the wheat/cotton system cotton aphids caused considerable damage on seedling cotton. Seed treatments and sprays were widely used. Now natural enemies which are maintained on the wheat aphid on wheat move to seedling cotton at wheat harvest with the result that there is often little need to spray aphids on seedling cotton. However, seed treatments and temic are widely used. Control of the first generation of *Heliothis* may also be unnecessary due to high predator numbers. Research has shown a 6 fold increase in numbers of predators through the cotton-wheat interplanting. Interplanting of cotton and corn are also used leading to reductions in eggs on cotton by 50%, though this must be for relatively short periods only. Around Anyang, corn is widely grown in several plantings. Single rows of corn are planted very early in the season along borders of cotton fields to act as trap plants for adults. The throat and leaves of each plant are checked each morning for moths sheltering there, which are then destroyed. Whether this really has much impact is unclear. By generation 3 in mid summer many of the beneficials leave the cotton fields, coccinella migrate to cooler areas, but return in the autumn and are often abundant enough to control the 4th generation. Despite the apparent abundance of beneficials there appear to be few parasitoids attacking late instar larvae. There were, for example, no records of tachinid flies, nor true pupal parasitoids.

Since the mid 1980's pyrethroids have been used for control of bollworm and aphids. Their introduction co-incided with a relaxation of government control over rural lands which gave farmers control over their own land and production, though markets are highly regulated. Each person in a farming family is allocated 1.5 mu (about 1/15th acre) up to a maximum of 6 mu per family (ie.half acre). This social change and the associated urge to maximise yields and so returns may well have contributed to the overuse of SP's resulting in rapid development of resistance in aphids and *Heliothis*. Since 1985 SP's have been banned for aphid control. The first widespread field failures against *Heliothis* occurred in 1990. A broad range of SP's are used with highest resistance levels to Sumicidin and Decis.

Resistance monitoring program has now been intoduced at 100 monitoring stations using assay techniques similar to those used in Australia. Only 1-2 applications of SP's are now recommended. OP's (Monocrotophos, Baythion, Parathion) and some carbamates are used instead. New and alternative insecticides such as nicotine and endosulfan are being tested. A resistance management strategy based on chemical alternation has been introduced on demonstration areas, but it is difficult to tell how widely it is applied. The strategy is as follows:

2nd generation - Bt, Bt + pyrethroid
3rd generation - OP's
4th generation - carbamates

All pesticides are applied by hand, either with knapsack sprayers or by "stem painting"- painting insecticide directly on the stem of each plant or "tip dropping"- dripping neat OP's into plant terminals.

According to the researchers most cotton crops are checked for pests by government appointed county technicians who meet regularly to jointly decide on spray decisions and advise farmers over local radio in each village. The technicians also run light traps and provide forecasts of likely egg hatching. How widespread these practices are outside the large demonstration areas was not clear. Stand densities average 4 plants per metre and treatment thresholds for *Heliothis* and aphids were:

Heliothis	2nd generation	- 200-250 eggs/100 plants or 20-25 young larvae/100 plants
	3rd generation	- 100-150 eggs/100 plants or 10-15 young larvae/100 plants
Aphids	up to 3 true leaves	- 2500-3000/ 100 plants
	then 4000 - 6000/ 100 plants provided the beneficial : pest ratio > 1: 150	

The IPM principles outlined above have now been implemented over 5 years over 210,000 ha in a single cotton growing area. Relative areas of wheat to cotton are 4:1. Claimed improvements include production losses reduced to < 10%, pyrethroid resistance remained at less than 10 fold, chemical applications were reduced by 30-50%, beneficial populations increased 5-6 fold and net economic returns were calculated at 48.5 million Yuan.

Population Dynamics Modelling of Helicoverpa armigera.

Mr. Xia Jingyuan has developed a population model for *Helicoverpa* which considers development, mortality, migration and oviposition. The model successfully predicts the timing of generation peaks in the Anyang area. Mr. Xia has conducted detailed studies of the mortality of *Helicoverpa* immatures and assembled an extensive database of information. A description of the model was obtained. Further exchanges on modelling could be beneficial.

Outbreak of H.armigera this year

This season there has been a major outbreak of *H. armigera* in northern China. Densities of eggs in late June of early squaring cotton were 20-30 eggs/ plant. Reasons for the outbreak reflect the interaction of several factors including climate, resistance frequency and population dynamics. The possible explanation outlined below highlights some gaps in research and possible areas of collaboration.

Due to high levels resistance last season larvae could not be controlled and densities were high in the 4th generation. The larvae entered diapause producing a high density overwintering population. Winters in this part of China are generally cold with snow a regular feature. Overwintering survival is assumed to be low. However, last winter was unusually warm with no snow, perhaps allowing higher survival of overwintering pupae. Coincident with this was an outbreak of wheat aphids on the wheat crop. Whereas these aphids are not normally controlled and serve to maintain beneficial populations, this season they were so abundant as to require 3 pesticide applications. These eliminated the beneficials which also normally hold *Heliothis* to low numbers in wheat. In the absence of predators first generation survival of *Heliothis* on wheat increased leading to a massive 2nd generation on cotton in June. While this scenario is plausible there is no data on the dynamics of diapause, nor the abundance or survival of overwintering pupae. Overwintering is a major gap in knowledge of *H. armigera* dynamics in northern China.

Visit to Large Scale Cotton Production Demonstration - Nei What County.

On June 26th I and Prof. Winfield Sterling (Texas A & M University) were taken to visit Nei What County, 1 hour east of Anyang to view one of the large demonstration areas of the double cropping system. The county has a total population of 630,000 people in an area of 62,000 Ha. In 1980 the cropping system was changed from single cropped cotton and maize to double cropped cotton/wheat now. In 1980 only 2,800 ha cotton was grown in the county averaging 369 kg lint /ha. By 1991 there was 35,000 ha cotton, 90% of it double cropped with average yields of 1117kg lint /ha cotton (total 39 million kg) and 3974kg/Ha wheat (total 174 million kg). For 1992 planned yield for cotton is 40 million kg. from 33,000 ha. and 95% double cropped.

Returns for Cotton Production

Chinese cotton farmers are currently paid $1.60 kg/ lint. The cost of production less labour is 43¢/kg. By contrast Australian farmers are paid $1.80 (@400/bale) with costs of production at $1.17/kg. Production cost as a proportion of return is thus much less in China - 26%, compared to Australia - 64%.

Key Techniques Involved in Transition to High Yield Double Cropping

1. Application of a uniform cropping pattern over the county - 3 rows wheat, 1 cotton, 1 metre spacing with cotton hilled up. Cotton sown in April, harvested October, Wheat sown October, harvested June. Wheat provided some protection for seedling cotton.

2. Breeding of both cotton and wheat to produce varieties suited to the double cropping system. The program is seeking cotton varieties with high yield and early maturity and wheat varieties suitable for late sowing with short straw and early maturity. Current cotton variety used is Zhoumian 12.

3. Increased inputs. Fertilizer inputs include pre-sowing applications of:
   organic manure (45-75 m^3/ha)
   cotton seed cake (450-750kg/ha).
   200-250 kg/ha N (40% pre plant, 60% later)
   90-120 kg/ha P
   75-90 kg/ha K
   15-30 kg/ah Zinc
   15kg/ha Boron

   Wheat is also heavily fertilised; 50-60 m^3 manure + 150kg/Ha N + 150 kg/Ha P - pre flowering. All inputs for the demonstration area are subsidised to varying extents.

4. Increase in plant stand to about 10 plants/metre because of shorter growing period. More early maturing bolls are produced at higher stand density. A stand of 67,000 plants/ha (compared to an older standard of 45,000) gives yields of 1500 kg lint /ha + 10 days earlier.

5. Use of growth regulators - PIX in 3 applications; 7.5-15g/ha at 1st square, 30-37.5g/ha at 1st flower and 45-52.5 g/ha at peak bloom. Experiments since 1985 have shown split applications are better than single application.

6. IPM - *Verticillium* & *Fusarium* wilt managed with tolerant/ resistant varieties. Pest management involves cultural, biological and chemical controls with uniform monitoring, thresholds and time of application over large areas. Resistance management: pyrethroids only for 1st generation on cotton, OP's and carbamates for 2nd peak. 3rd peak often does not need control. Early season aphids are usually controlled by predators moving from wheat. Aphid thresholds - early season 20% of plants with curled leaves, mid season 5% with curled leaves.

Heliothis thresholds vary with generation and yield potential of field. All fields are classified into 3 classes on June 20:

Class 1 (best) - 50% of plants squaring
Class 2 - 30-50% of plants squaring
Class 3 (worst) - < 30% of plants squaring

Use higher thresholds on best fields

Class 1 - 30 larvae/100 plants
Class 2 - 20 larvae/100 plants
Class 3 - 10 larvae/100 plants

2nd generation thresholds (July) - 20 larve/100 plants on all fields.

Sampling. There was one technicican in each township plus 105 farm technicians, which averages out at 1 technician/ 266ha. Crops are checked every 3 days or daily if numbers are high. The technicians meet every 5 days to pool results and decide on area-wide measures. If treatment is required advice on sprays and chemicals, fertilizers, pix applications is broadcast three times a day over radio. Farmers usually wait until broadcast before spraying. Also 7 resistance monitoring regions in the county each with a technician. Township and village technicians are paid by the county, county officials are paid by the government.

Overall this was an impressive demonstration of highly productive double cropping. However, it was unclear how well these techniques applied here were being adopted by farmers elsewhere. Given the level of inputs it would seem difficult for individual Chinese farmers to afford the costs. The whole demonstration area seemed heavily dependent on subsidised inputs.

Visit to International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad, India. July 14-19, 1992.

ICRSIAT is a large International centre with staff of 4000 which conducts research on 5 mandate crops: sorghum, millets, pigeon pea, chickpea and peanuts. Considerable research on *Helicoverpa* ecology has been conducted here, largely by researchers from NRI in Great Britain. Nigel Armes a Research Scientist with NRI is based at ICRISAT working on pyrethroid resistance in *H. armigera* in India. He has some collaboration with Neil Forrester (NSW Agriculture, Narrabri).

The visit involved one day talking with various researchers, then a two day visit to the coastal cotton production area near Guntur, where pyrethroid resistance first appeared in India and where levels of resistance are high. A ressitance monitoring program is underway in this area to document seasonal changes in resistance frequency. Cotton had not yet been sown due to lack of planting rains. Discussions were held, and a seminar presented to research staff at the Andra Pradesh Agricultural University field station. From these discussions it became apparent that while the level of understanding of pest problems and possible solutions was high, the extension and implementation of IPM or resistance management remains a major difficulty. The wide availability of pesticides through numerous dealers exacerbates the problem of farmer education.

Major gain from India was Delhi belly.

Potential Collaborative Research Exchanges with Cotton Research Institute, Anyang.

The Cotton Research Institute is particularly keen to establish collaborative research program with Australian researchers. Discussion were held with Prof. Wang Ruohai (Institute Director), Prof. Xiang Shikang (Assistant Director) and Mr Xia Jingyuan (Chairman - Plant Protection Dept) about possible areas of exchange or collaboration. While no commitments were made, the following areas were seen as a high priority from their point of view. In most cases there seems minimal benefit for the Australian cotton industry, apart from broader experience for researchers and

1. Reciprocal Variety testing program. The Cotton Research Institute has a collaborative agreement with USDA under which 6 new varieties are exchanged each year for testing in China and the USA. The Directors we keen to establish a similar arrangement with Australian breeders. This would involve exchange of seed each season of up to six varieties and subsequent exchange of yield and quality information. Details about trial designs, plot sizes, amounts of seed etc were discussed but seem premature until Australian breeders and CSD determine whether they wish to be involved in such a program. This, and other issues relating to Australian breeding material or varieties, need to be determined by CRDC, ACGRA, CSD and CSIRO.

2. Biocontrol of insect pests. There is scope for Australia to assist in introducing a number of potential biocontrol agents for Heliothis management in China. Species of tachinids and the pupal parasitoid *Ichneumon promissorius* are two possibilities. In addition the Chinese would be interested in any exchange of information about parasitoids and predators in Australia. This will be provided.

3. Research on Overwintering/diapause of *Helicoverpa*. Results and techniques from Australian research on diapause and overwintering ecology of *Helicoverpa*. would be beneficial to Chinese researchers seeking to understand dynamics in the main cotton areas. There are possibilities for a research exchange program here to provide research techniques and diapause models. This might be pursued through ACIAR.

4. Collaboration on adult trapping and mark-recapture studies in China. Mr. Xia is keen to introduce pheromone traps as monitoring tools in Chinese cotton areas. At present light traps are used. Australian experience with the use and interpretation of pheromone trap catches may be helpful. Mark-recapture studies might also be used to document local adult movements although I am not convinced this type of information is necessary.

5. Population dynamics modelling. Mr. Xia has developed his own *Helicoverpa* population dynamics model. He has an extensive data set on immature mortality on cotton and interesting ideas about how mortality should be modelled. There could be considerable benefit to Australian modelling efforts from a short term exchange to provide information on experimental and modelling techniques.

6. Exchange of germplasm. The Anyang Institute maintains an extensive germplasm bank of cultivated and wild cottons. They are willing to engage in exchanges of various germplasm with Australian breeders.

ATTACHMENTS.

ATTACHMENT 1.

SPATIAL POPULATION MODELLING OF *HELICOVERPA SPP.* : STUDIES OF ADULT BEHAVIOUR AND MOVEMENT. Gary P. Fitt and Martin L. Dillon,
CSIRO Division of Entomology, NARRABRI, NSW, AUSTRALIA, 2390

An ambitious simulation model is being developed as an aid to predicting the regional population dynamics of *Helicoverpa* spp. in multicropping systems. The model has the acronym "HEAPS" (*HElicoverpa Armigera* and *Punctigera* Simulation) and will be used to evaluate the effects of various agronomic practices on the seasonal distribution and abundance of *Helicoverpa armigera* and *H.punctigera*, and hence assist in the design and implementation of areawide management strategies.

Unlike previous models of *Helicoverpa* (MOTHZV, Helsim), HEAPS includes a spatial component. The model divides a region into a grid of square simulation units, of definable size, with population processes (oviposition, development, mortality and host phenology) simulated in each unit. Adult moths are then moved between simulation units according to a series of movement and host selection rules. The model is highly sensitive to this function and considerable research has been undertaken to quantify adult behaviours.

Phenology of adult emergence and emigration from source crops has been studied using direct observations, radar and mark-recapture. These show that low level movement is predominantly downwind and flight distance and direction are both functions of wind conditions in the model. A characteristic take-off flight occurs at dusk with low level flights between crops occuring for several hours depending on night-time temperatures. Mark-recapture studies confirm that *H. punctigera* is probably an obligate migrant and that *H. armigera* is less mobile. Flying moths alight on host crops in response to their relative attractiveness and are assumed to remain there for the remainder of their reproductive lifetime. A greater understanding of factors influencing host selection and movement is needed.

HEAPS has been designed as a flexible research tool to experiment with a diverse range of scenarios and pest management strategies. Parameter values for various modules have been derived from a range of sources and are being progressively validated. The completed model should be applicable to a variety of pests in cropping situations.

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ATTACHMENT 2

BIOLOGY AND ECOLOGY OF *ICHNEUMON PROMISSORIUS*, A TRUE PUPAL PARASITOID OF *HELICOVERPA* SPP. IN AUSTRALIA. Cheryl L. Mares and Gary P. Fitt, CSIRO Division of Entomology, Narrabri, NSW 2390, Australia.

Ichneumon promissorius (Erichson), is a true pupal parasitoid of various noctuids in Australia, including the major pest species of *Helicoverpa*, *H. armigera* (Hubner) and *H.punctigera* Wallengren. Studies of the biology, behaviour and field ecology of *I. promissorius* were initiated to assess its impact on pupal populations of *Helicoverpa* and to assess its potential as a biocontrol agent.

I. promissorius is a solitary parasitoid with typical haplo-diploid sex determination. At 25° development from oviposition to adult emergence takes 18-20 days, with males developing 1-2 days faster than females. Females mated almost immediately after emergence and virgins were highly attractive to males. During oviposition a single egg is deposited into any part of the pupa, although about two-thirds were placed in the pupal abdomen. Extensive host feeding on haemolymph exuding from the puncture often follows oviposition. On average each female produced 75 progeny over a lifetime of about 40 days.

In the laboratory there was no avoidance of superparasitism. Each host pupa will sustain the development of only one larva and studies of larval competition involving multiple ovipositions showed that survivors were exclusively female. However in the field, where pupae must be located in the soil, the possibilities for superparasitism are slight. How pupae are located is not yet known.

In the field, *I. promissorius* has been recorded from *Helicoverpa* pupae under a range of field crops during summer and winter, though notably not in maize, a crop which often supports high densities of *Helicoverpaa*. Parasitism by *I. promissorius* is most significant in overwintering populations of *Helicoverpa* under cotton stubble, where up to 20% of pupae may be parasitised. Adults are active through winter and can thus progressively parasitise overwintering host populations. Augmentation of this level of control may be possible if a suitable mass rearing system can be devised.

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