A Brief History of *Helicoverpa* and *Pectinophora*

Derek Russell

Faculty of Veterinary and Agricultural Sciences

University of Melbourne

Where did Pink bollworm come from?

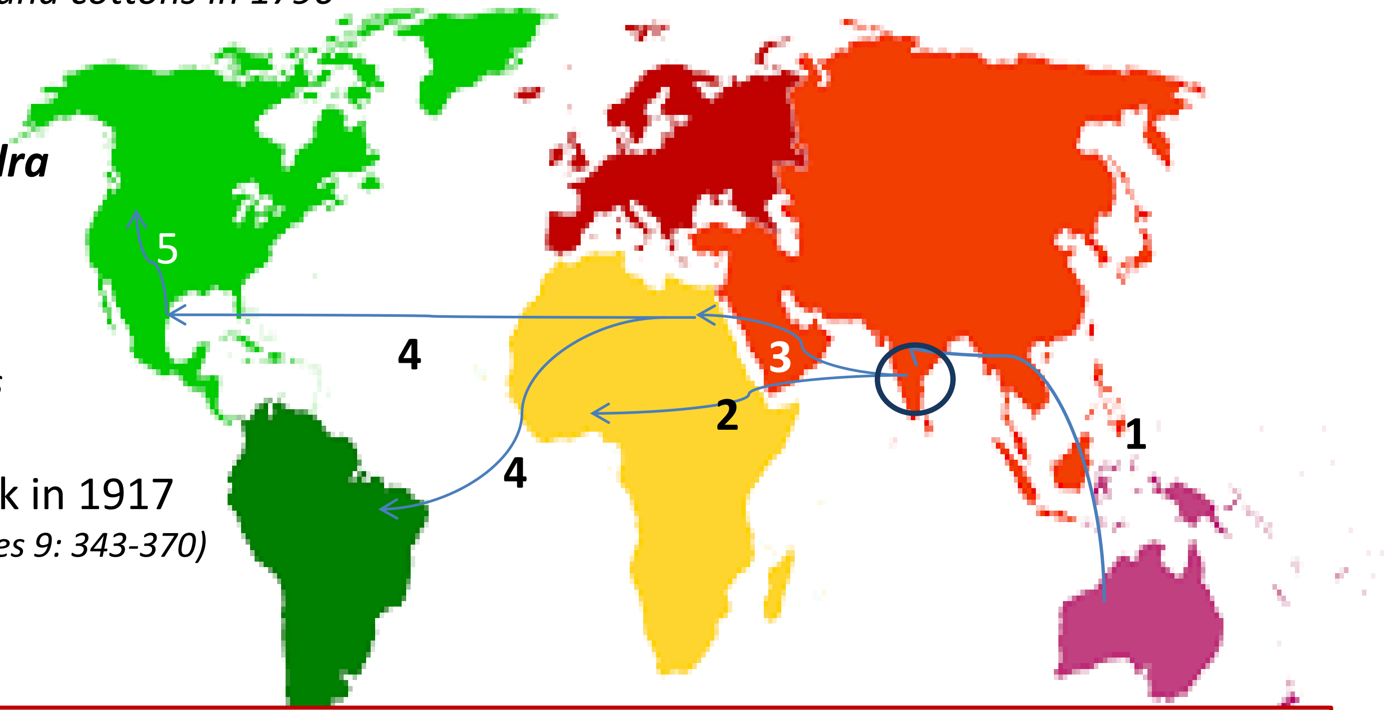
Azana (=Thespesia) lampas and populnea

Early recorded distrib. closely related to perennial *G. arboreum*

- Family: Gelechidae c. 3,000 sps
- Other *Pectinophora* species in Australia e.g. pink spotted bollworm *P. scutigera* (pests of cotton but primary hosts *Hibiscus tiliaceus* and *Thespesia polulnea*
- Possible origin ex Australia via *G.hirsutum* through Philippines to India where *Thepesia lampas* was a major wild host

Pink bollworm dispersal in cotton seed

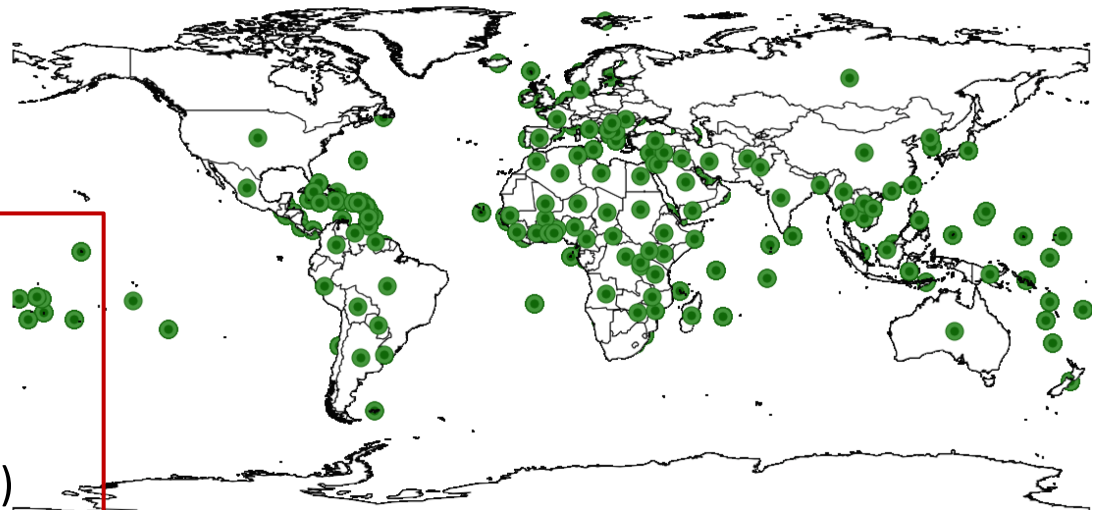
- Pest (in India) only after 1840
  -intro. of American Upland cottons in 1790
- Ist description 1843
  from India as ***Platyedra***
  by Saunders
  - other sps in Europe,
  Turkestan, Iran,
  Morocco as cotton pests
- ***Pectinophora*** – Busck in 1917
  (The pink bollworm J.Ag. Res 9: 343-370)



1. Australia to India via Phillipines (on *G. arboreum)* Date???
2. India to W.Africa 1904 (on *G.arboreum*)
3. India to Ceylon, Burma and Egypt 1906 and Hawaii 1911. Hawaii – W. Indies 1911
4. Egypt to Mexico and Brazil 1913-16
5. Mexico to USA c.1916

   India (???) to China 1918

P. gossypiella – current distribution



Hosts:

Malvacae

Wild

Gossypium and *Althaea sps.* (Hollyhocks)

Cultivated

Abelmoschus esculentus (Okra)
Abutilion sps, Hibiscus sps. and cotton sps.

Fabeacae

Cultivated

Midicago sativa (Lucerne)

Countries:

Asia -29
Africa - 35
North America – 2
Central America - 20
South America - 9
Europe - 11
Oceanea - 8

Data: *CABI PlantWise*

Destruction of cotton production by Pink bollworm

- *Sometimes with other sps – esp. Boll weevil*

Country	Dates
Peru	1950-60
Nicaragua, Guatamala	Late 1960s
Mexico	1960-70
USA *(Rio Grande TX, Imperial Valley CA)*	1960s-70s
Australia – (*Ord River Scheme*)	1970s
Egypt	1970s-80s
Sudan (*Gezira scheme*)	1970s-80s

Source: *Kuememan, ICAC Plenary 2005)*

Pink bollworm – *Pectinophora gossypiella*

Features supporting pest status

- Malvaceae specialist
- Larva can enter boll within 2hrs
- Does not feed on boll surface
- Internal feeder esp. on seeds
- Diapause allows carry-over
- Can spread through seeds and trash
- Rapid life cycle
- Low tillage is favourable

Potential weaknesses

- Practically monophagus allowing control by close seasons
- Boll susceptible only 1-3weeks old so population build up depends on the length of the flowering/fruiting season
- Cannot diapause in tropics
- Diapause cycle poorly adapted to rainfed cotton in many areas
- Pre-oviposition female generally moves to nearest downwind cotton

Pink bollworm – *control options*

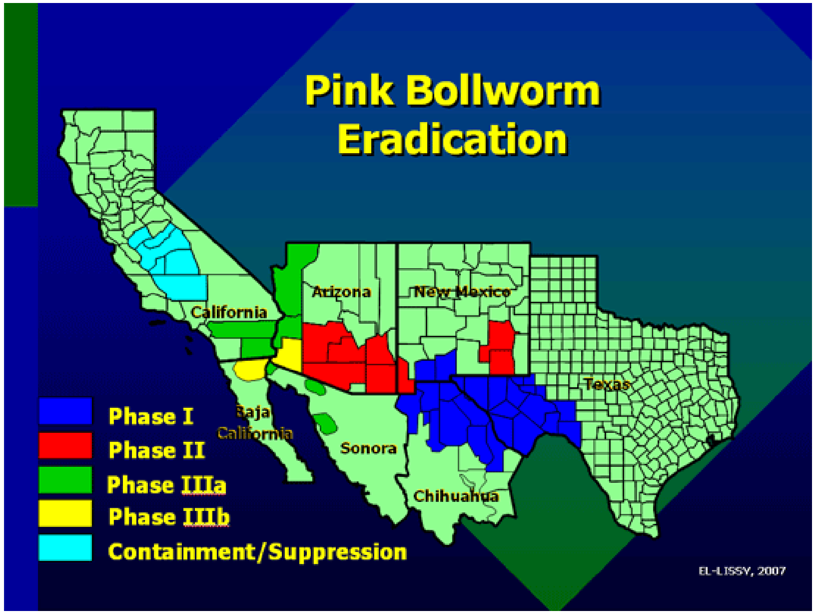
Parasitoids various sps. of *Bracon, Apantales, Chelonus, Elasmus, Goniozus, Trichogramma* etc But… no control anywhere

Insecticides Transient success. Steady resistance build-up, newer and more expensive chemistries

Pheromones Monitoring and mating disruption when used area-wide

Sterile males Successful but needs tremendous organisation and long term finance commitment

Bts Very successful But…plant bugs , sucking pests and resistance emerging



US and Northern Mexico eradication 2017??:

- 80% grower funded.
- c.5 yr process in each phase
- Last moth capture 2013?

Techniques

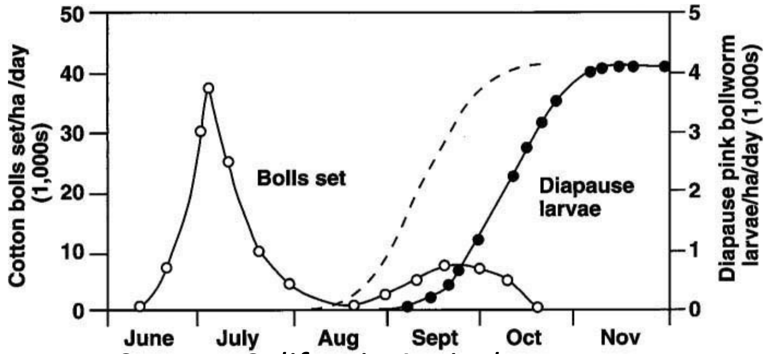
- *Intense Survey*
- *Bt cotton*
- *Mating disruption pheromones*
- *Sterile male release*

Pink bollworm eradication:

2014 Uzbekistan and Nicaragua

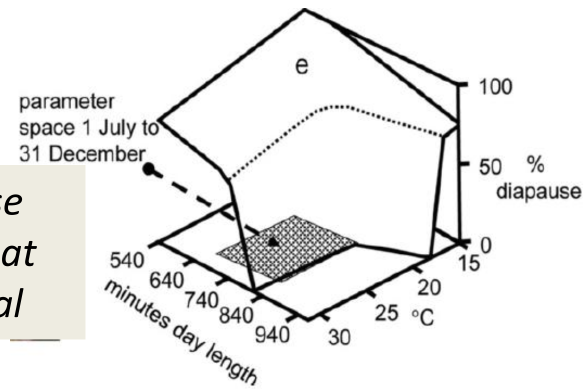
Diapause in Pink Bollworm

- Allows carry-over between seasons
- Induction – declining temps. and short, decreasing photoperiods
  Feeding in older bolls (higher lipid)
- Post diapause moths longer lived
- At 30 ° N emergence March- Aug, re-entry mid-Sept to End Oct



Source: *California Agriculture*

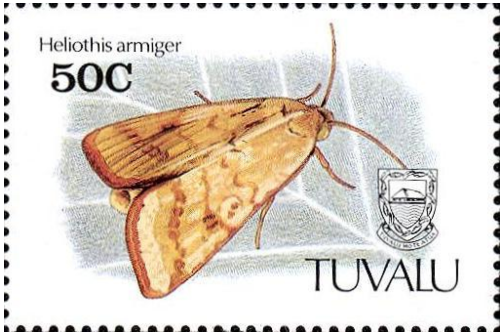
Diapause Pattern at Yavatmal



Source: *Gutierrez et al. 2015*

Strategy

- *Trash burning, burying and deep ploughing*
- *Avoid diapause carry-over by early planting and/or termination of short-season cotton*



Cotton bollworm

Helicoverpa armigera

Native to Asia, Europe, Africa and Australasia

- **Heliothis** Dennis and Schiffermüller (1775)
- **Helicoverpa** Mathews (1987) from Hardwick (1965)
- **Helicoverpa armigera** *(Hübner)*

Features supporting pest status

- Generalist feeder
- 500-1000 eggs
- Pre-oviposition female moves long distances
- Facultative winter and summer diapause

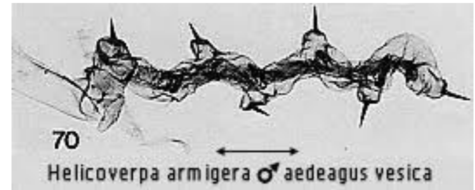
Potential weaknesses

- Exposed on leaf and boll surfaces much of the time
- Cotton not preferred host

- **India:** Only recorded as a problem on cotton in 1977 (*after the intro. of pyrethroids)*

Noctuidae: c.38,000 species

***Helicoverpa*:** defined within the Noctuidae:

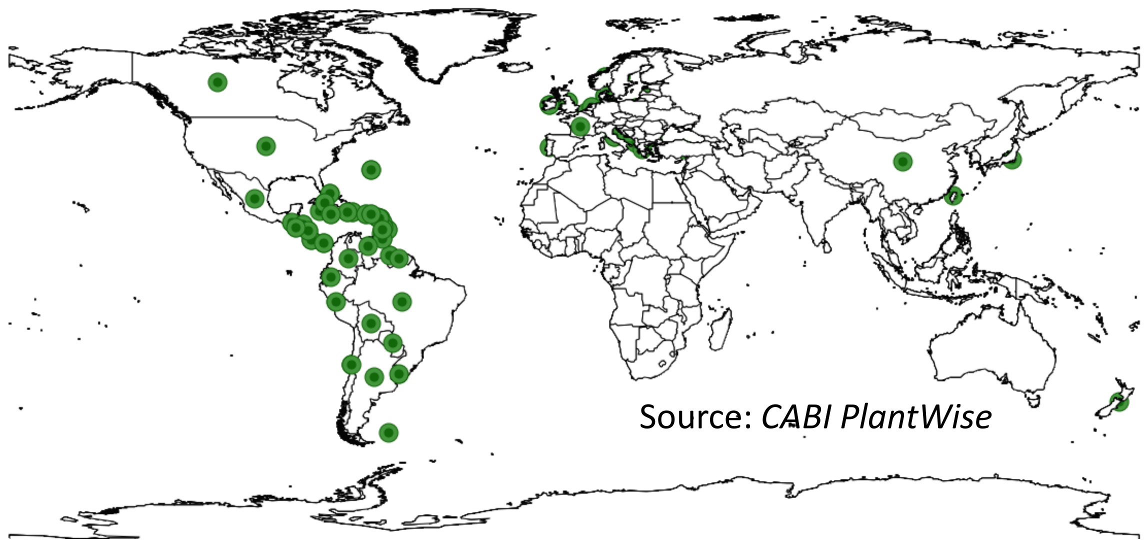


a) corkscrew/ coiled vesica of male aedeagus with strong cornutal spines
b) Row of seta-like scales along the ventral margin of the prothoracic femur

Helicoverpa groups – *Poole (1989) after Hardwick (1965)*

	Group	Species	Distribution	Economic importance
1	**punctigera**	*H.punctigera*	Australia	Major
2	**gelotopoen**	*H. bracteae*	Paraguay, Argentina, Peru	None
		H.titacacae	Peru	None
		H.gelotopoea	Chile, Argentina, Brazil, Paraguay	Minor
		H.atacamae	Chile, Peru	None
3	**hawaiiensis**	*H. hawaiiensis*	Hawaii	None
		H. pallida	Hawaii	None
4	**armigera**	***H.armigera***	**Tropical/sub tropical Old World**	**Very major**
		H. Helenae	St Helena	None
5	**zea**	***H.zea***	**Tropical/ temperate New World**	**Very major**
		H. confusa	Hawaii	None
		H. minuta	Hawaii	None
		H.asulta	Most of Old World	Minor
		H.toddi	S. Africa/ Madagascar	None
		H. tibensis	Tibet	None

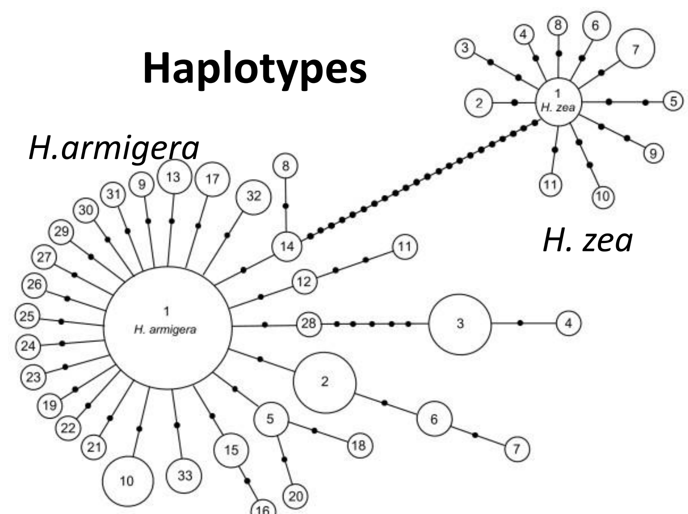
Helicoverpa zea



Source: *CABI PlantWise*

Distribution: **New World**
Hosts: **49 species in 16 families**

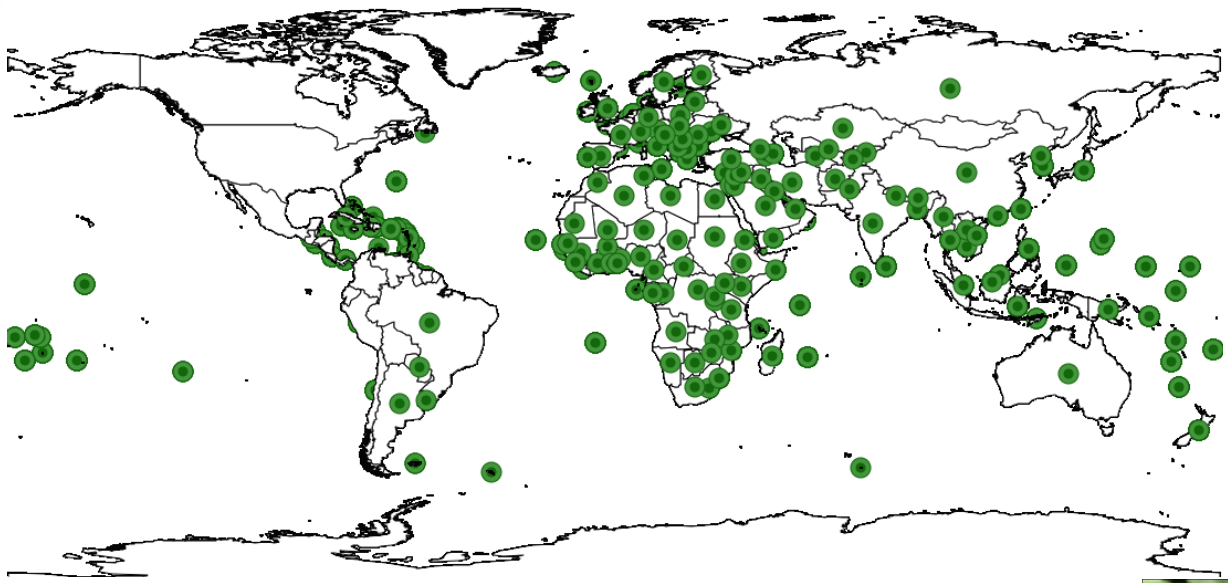
Haplotypes



- Origin from *H. armigera* incursion into the New World c. 1.5-2 mill years ago

G.Behere – PhD Thesis University of Melbourne

Helicoverpa armigera



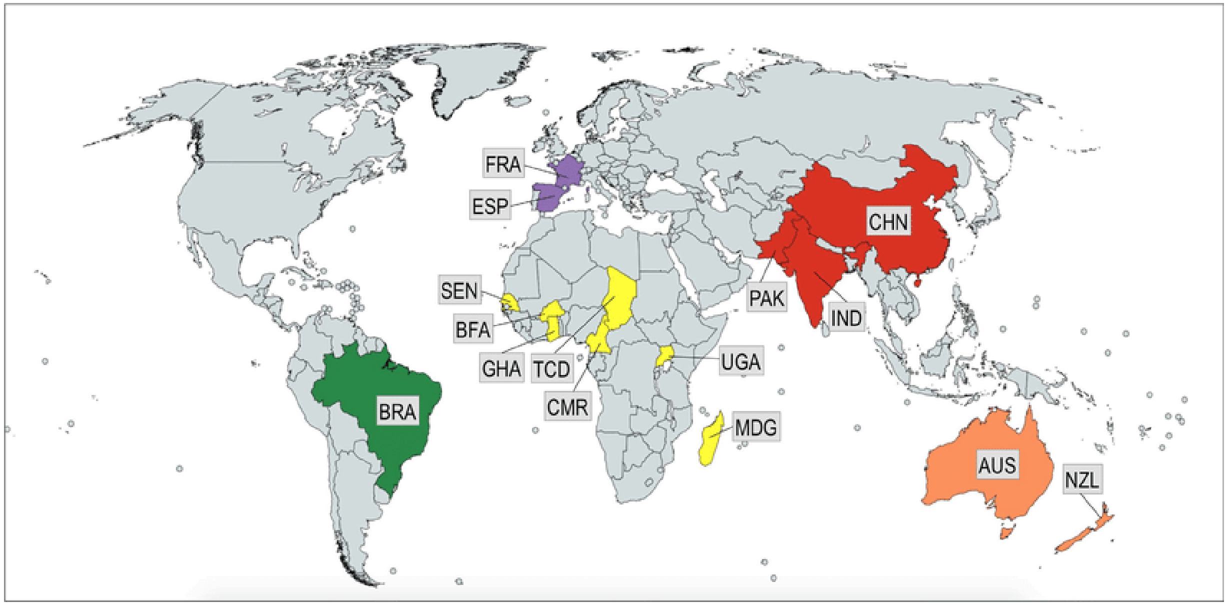
Distribution: 29 cotton producing countries
Hosts: >200 plant hosts in 68 families

Inc. chickpea, pigeonpea, peas, cowpea, ground nut, sunflower, sorghum, field beans, tomato, tobacco, maize, wheat, okra, vegetables

Source: *CABI PlantWise*

H.armigera in Brazil, Paraguay , Argentina, Bolivia, Uruguay and Puerto Rico

- Comparison of *CO1*, *CytB* and MtDNA shows Brazilian *H.armigera* to be of common and widespread Old World haplotypes with at least 4 matrilines
- **So… no smoking gun!**



Source of samples *of H.armigera* for comparison with Brazil

Tay WT, Soria MF, Walsh T, Thomazoni D, Silvie P, Behere G.T. et al. (2013) A Brave New World for an Old World Pest: Helicoverpa armigera (Lepidoptera: Noctuidae) in Brazil. PLOS ONE 8(11): e80134. http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0080134

Pupal diapause adds enormously to the geographic and climatic range

*Facultative **COLD** diapause*:

Induced by: effect on larvae and pre-pupae of

- declining temp (19 -23° C)
- shortening day length (100% diapause at 11.5-12.5hrs)

Broken by: by temps >17°C after period below 12-13°C

- ***Critical day length***: decreases as mean temp rises - therefore goes into diapause much more easily in N and S of range
- ***Strain differences*** – eg Northern strains are more cold tolerant (to -21 ° C when soil is dry)

Facultative **aestivation**:

Induced by: effect on 3rd* larvae of

- high temp (c.37 ° C)

Broken by: >20 days at <21°C

- ***Gender difference:*** Males enter more easily than females

Helicoverpa – *control options*

Natural enemies Wide range of egg, larval and pupal parasitoids. HaNPV But… no control anywhere *(Uzbekistan? Syria?)*

Insecticides Transient success. Steady resistance build-up, newer and more expensive chemistries

Pheromones Monitor emergence in simple systems with hard winters (Texas, Uzbekistan). Not mating disruption

Plant breeding Nectariless, smooth leaf, short season
Frego bract, Okra leaf – insecticide penetration

Bts Successful But…plant bugs and sucking pests emerging. Resistance genes widespread – even to Vip3 in Bollgard 3

Helicoverpa insecticide resistance in China, Pakistan and India 2005

First pyrethroid resistance 1984 - Australia

Table 3.1: Typical resistance levels to widely used chemicals in India (I), China (C), and Pakistan (P)

Chemical	Resistance level*				
	Susceptible	Low	Medium	High	Very high
Pyrethroids					
Cypermethrin					I, C, P
Fenvalerate				I	I, C, P
Deltamethrin			P	I,C	I
Lambda cyhalothrin			P	I	I,P
Bifenthrin			P	P	
Beta Cyfluthrin				I	
Organophosphates					
Quinalphos			I		
Phoxim		P, C	C		
Chlorpyrifos		P	I		
Profenophos		I, P			
Monocrotophos		P	I		
Cyclodiene					
Endosulfan		P	I		
Carbamate					
Methomyl	C	I,P			
Thiodicarb	P		I		
Sodium channel blocker					
Indoxacarb	P				
Fungally derived					
Spinosad	I, C, P				

Susceptible – RF<3; Low – no field effects; Medium – some reduction of field efficiency but chemical still useful; High – chemical compromised for field use; Very High – high larval survival at the field rate, chemical not useful

Subsequent resistance reported for **Spinosyns** and **Indoxacarb** and now **Diamides**

Source: *Russell and Kranthi Handbook: cotton bollworm control in small scale systems ICAC 2006*

Relevant *Helicoverpa* biology

❖ **Cotton is not the preferred oviposition host**

Implication: Cropping systems may be able to be manipulated

❖ **Emergence – most moths move right out of the area prior to oviposition**
(long dist migration is a response to deteriorating conditions).

Implication – Local control measures will not carry over to long term population suppression.

❖ **Diapause pattern varies enormously with temperatures and day length but is locally predictable**

Implication: Management of diapausing pupae in soil may be practicable but not in more tropical areas

❖ **Some cotton countries e.g. Egypt do not have *Helicoverpa* problems**

Implication: We should actively study the factors resulting in absence.

Thumbnail history of both species

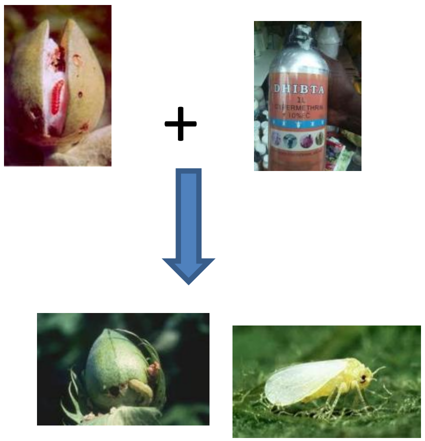
India as an example

+

- Pink bollworm became an issue with the introduction of upland cottons (c.1840 in practice) and jumped to prominence only with the introduction of pyrethroids in 1970s (*itself a response to OP resistance in Spodotera litura*)

Thumbnail history of both species

India as an example



- Pink bollworm became an issue with the introduction of upland cottons and jumped to prominence only with the introduction of pyrethroids in 1970s (*itself a response to OP resistance in Spodotera litura*)

- Arguably this increase in insecticide use promoted the very rapid increase of *Helicoverpa (unknown in cotton until 1997),* defoliators and whiteflies in the late 70s leading to severe outbreaks esp. in 1983 and 1990 and to spiralling costs

Thumbnail history of both species

India as an example

- Pink bollworm became an issue with the introduction of upland cottons and jumped to prominence only with the introduction of pyrethroids in 1970s (*itself a response to OP resistance in Spodotera litura*)

- Arguably this increase in insecticide use promoted the very rapid increase of *Helicoverpa (unknown in cotton until 1997),* defoliators and whiteflies in the late 70s leading to severe outbreaks esp. in 1983 and 1990 and to spiralling costs

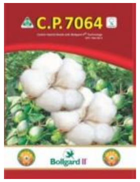
- The response to this was Bt cotton from 2000, which (*ignoring incipient resistance*) has controlled both species well but has led to upsurges in mealybugs, plantbugs and whiteflies

Thumbnail history of both species

India as an example

- Pink bollworm became an issue with the introduction of upland cottons and jumped to prominence only with the introduction of pyrethroids in 1970s (*itself a response to OP resistance in Spodotera litura*)

- Arguably this increase in insecticide use promoted the very rapid increase of *Helicoverpa (unknown in cotton until 1997)*, defoliators and whiteflies in the late 70s leading to severe outbreaks esp. in 1983 and 1990 and to spiraling costs



- The response to this was Bt cotton from 2000, which (*ignoring incipient resistance*) has controlled both species well but has led to upsurges in mealybugs, plantbugs and whiteflies

- This has led to increases in insecticide use, which in 2013 were back to the levels they had been in 2000 (pre-Bt) but the combined Bt/ insecticide cost is much higher.

What next in Asian small-farm systems?

- **Long season, multiple-picking upland cottons and their hybrids have led to high input = expensive production systems**

Lesson to be learnt?

- USA – PBW a key pest only since 1960s in S. California. Heavy insecticide use in irrigated cotton for PBW control generated bollworm, defoliator and whitefly problems. Imperial Valley production dropped from 60,000ha to 5,500 by 1989.

- Resolved by high yielding, high density short-season cottons *(from 28% of US cotton in 1978 to 68% in 1986)*

But.. Needs early termination and deep ploughing and was replaced by Bt cottons.

SO….

- We need to understand local insect/ cotton interactions better

- Consider revamping the system using shorter season, small stature (non-Bt?) cottons at higher density?

Short season cotton systems

- **Good for bollworm control (esp. Pink)**
  - avoids build up in-season
  - can utilise diapause characteristics

- **Additional characters**
  - *Inc. nectarliness, thick boll rind, red leaf, glabrous, okra leaf, frego bract*
  - *Narrow rows – less water*
  - *In less determinate varieties can control by de-topping, desicants etc*

Issues

Entomological:

- **Leafworm, thrips, plant bugs, fleahoppers, spider mite, aphid** - no +ve impact
- **Whitefly** -early termination moves attack earlier . High humidity in early closing canopy
- ***Earias*** - must be controlled in early shoots and squares

Agronomic:

- More determinate = risky
- Needs control of water and fertility esp. at boll set
- Early fruit must be protected
- Concentrates labour demand when picking

Short season cotton systems

- **Good for bollworm (esp. Pink)**
  - avoids build up in-season
  - can utilise diapause characteristics

- Inc. Nectarliness, thick boll rind, red leaf, glabrous, okra leaf, frego bract
- Narrow rows – less water
- In less determinate varieties can control by de-topping, dessicants etc

Issues

Entomological:

- **Leafworm, thrips, plant bugs, fleahoppers, spider mite, aphid** - no +ve impact
- **Whitefly** -early termination moves attack earlier. High humidity in early closing canopy
- ***Earias*** - must be controlled in early shoots and squares

Agronomic:

- More determinate
- Needs control of water and fertility esp. at boll set
- Early fruit must be protected
- Concentrates labour demand when picking

So…

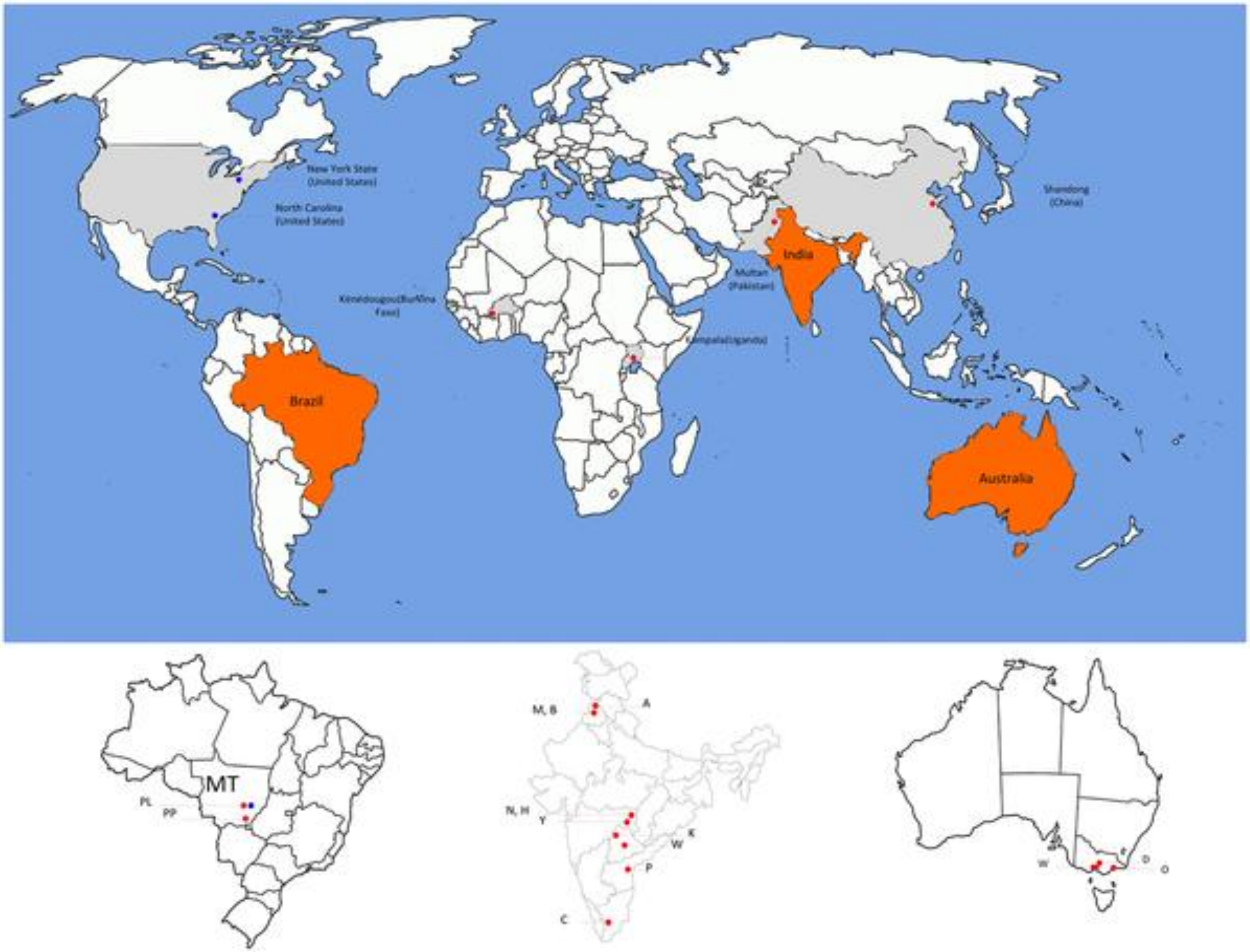
- **Worth considering for Irrigated cotton**
- **Maybe not suitable for Rainfed, low input**

THANK YOU

Acknowledgements

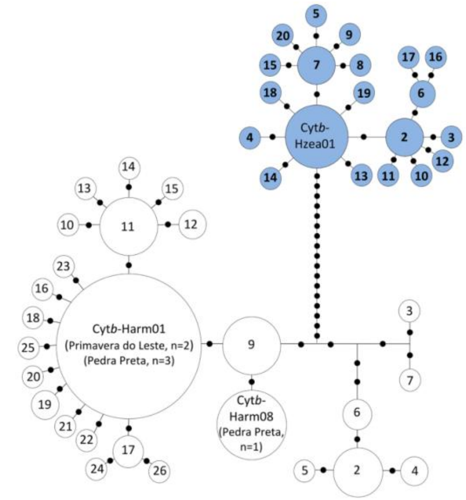
Google Images

Sampling sites and countries from which Helicoverpa armigera and H. zea were obtained for this study.



Tay WT, Soria MF, Walsh T, Thomazoni D, Silvie P, et al. (2013) A Brave New World for an Old World Pest: Helicoverpa armigera (Lepidoptera: Noctuidae) in Brazil. PLOS ONE 8(11): e80134. https://doi.org/10.1371/journal.pone.0080134
http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0080134


Brazil
India
Australia
MT

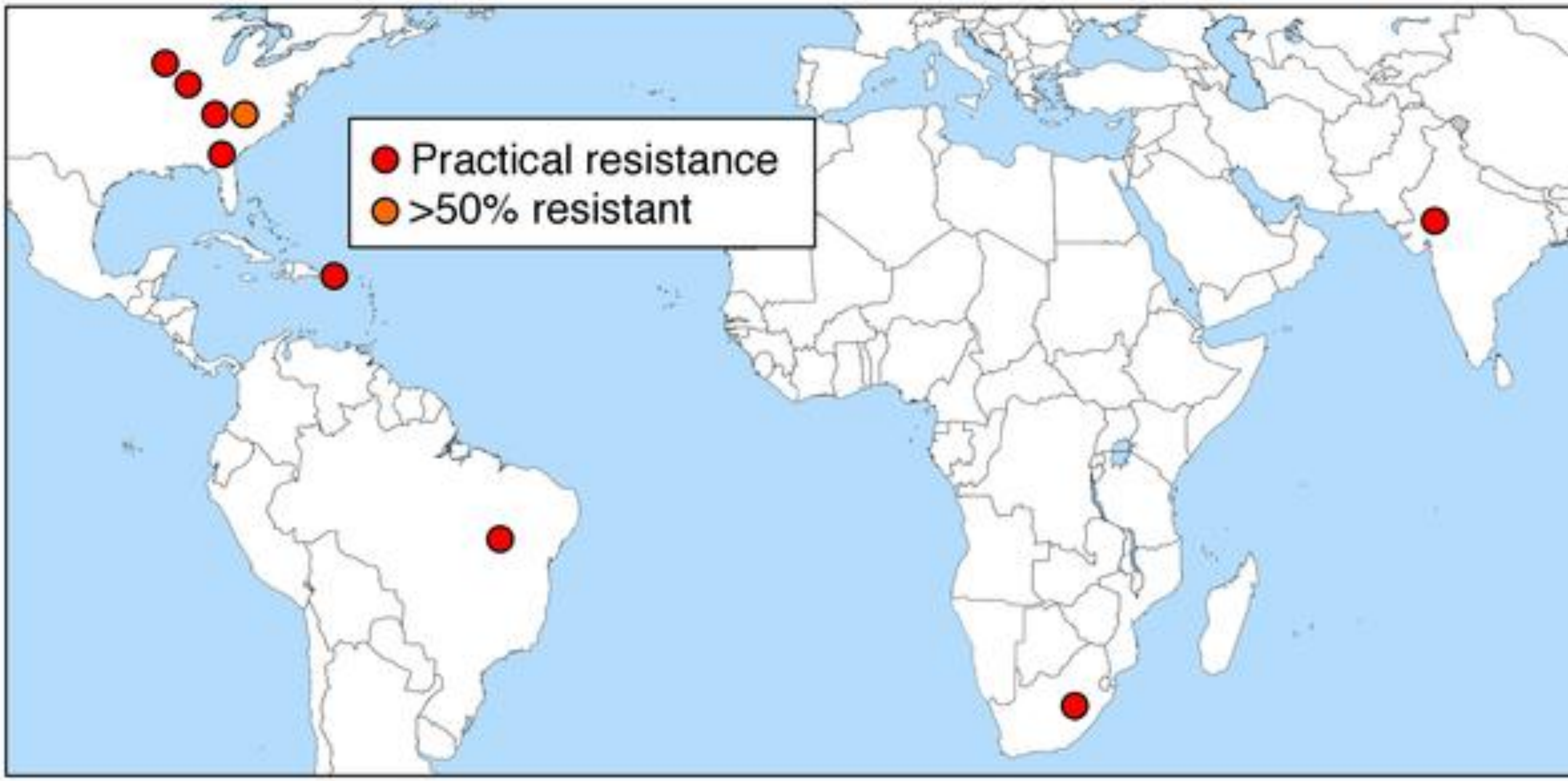

Cytb-Hzea01
Cytb-Harm01
(Primavera do Leste, n=2)
(Pedra Preta, n=3)
Cytb-Harm08
(Pedra Preta, n=1)

Moths – 60-70 mya (late Cretaceous to early Eocene)

- Pink
- Glechidae – 3000 sps

- Helicoverpa
- Noctuidae – 38,000 sps (prob . not monophyletic)
- No fossils before Pliocene

- Recent pest of cotton – eg. India reported only post-1977 (not in 1976 1st edition of Ag pests of South Australia and their management)


Practical resistance
>50% resistant