Status of Heliothines Resistance to Bt cotton in the world

Dr. G.M.V. Prasada Rao
Principal Scientist (Entomology)
ANGR Agri. University
Andhra Pradesh, INDIA

Table 1. *Heliothines* of major agricultural importance, their distribution and principal cultivated host plants

Species	Distribution	Principal host crops
Heliothis virescence	North and south America	Tobacco, cotton, tomato, sunflower, soybean
Helicoverpa armigera	Africa, southeren Europe, Asia, Southeast Asia, Australia, eastern pacific	Maize, sorghum, sunflower, cotton, tobacco, soybean, pulses, safflower, rapeseed, groundnut
Helicoverpa punctigera	Australia	Cotton, sunflower, lucerne, soybean, chickpea, safflower
Helicoverpa zea	North and South America	Maize, sorghum, cotton, tomato, sunflower, soybean

Source: Gary P. Fitt, 1989

Advantages of *Bt* cotton

More yields and less no of sprays

Increased farmers income - during 20 years period 1995 to 2015 was estimated US $ 52 b and US $ 3.4 b during 2015 (ISAAA 2016).

Major concerns

- ✓ **Evolution of resistance by target pests**
- ➢ **Impact on non-target organisms**

Why insect pests develop resistance to *Bt* crops?

1. Wide spread prevalence of insecticide resistance
2. Laboratory selected resistance to *Bt* toxins
3. Field evolved resistance to *Bt* sprays in DBM

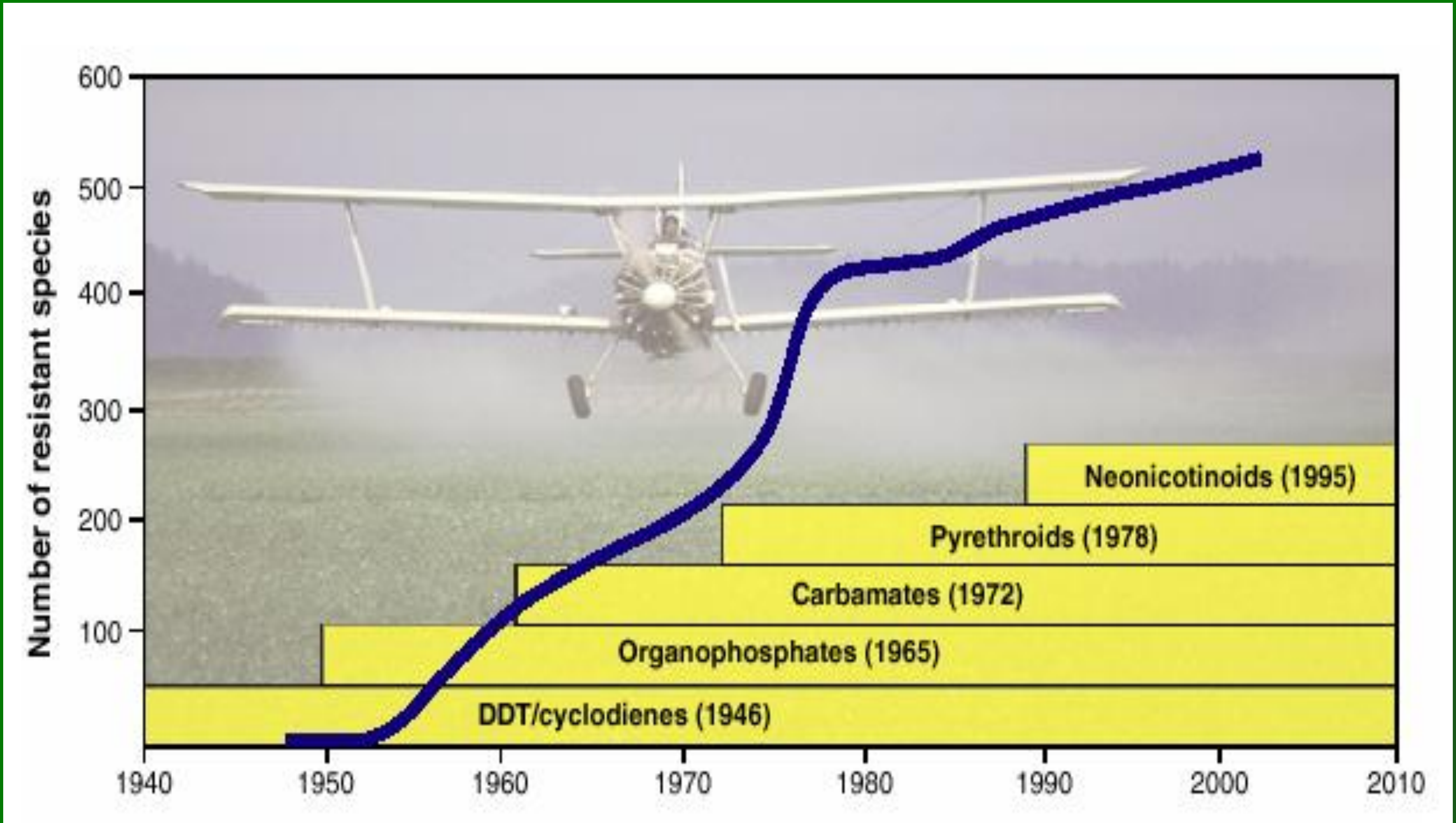
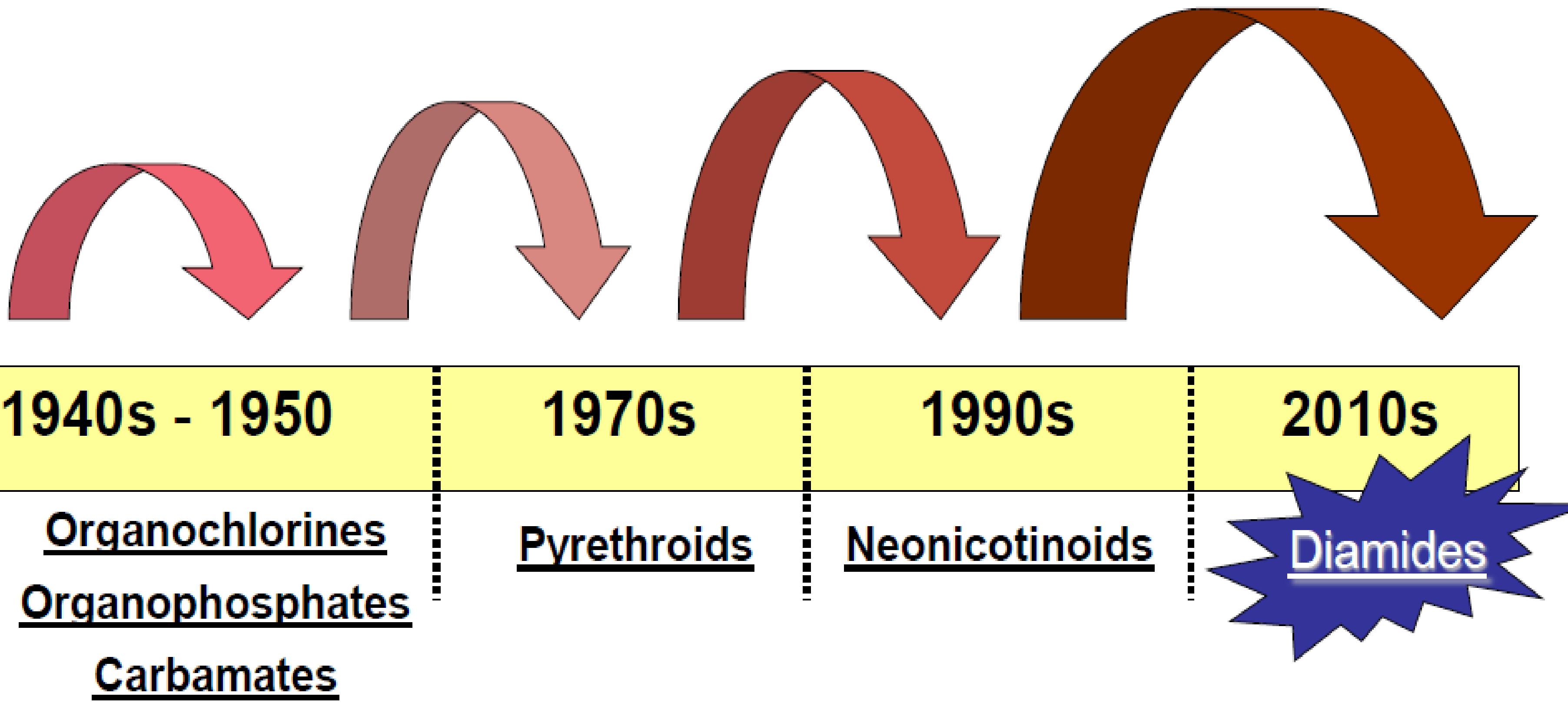


Figure 1. Wide spread resistance to synthetic insecticides

Diamide products:

✓ great opportunity for overuse and insect resistance

Insect Control Eras



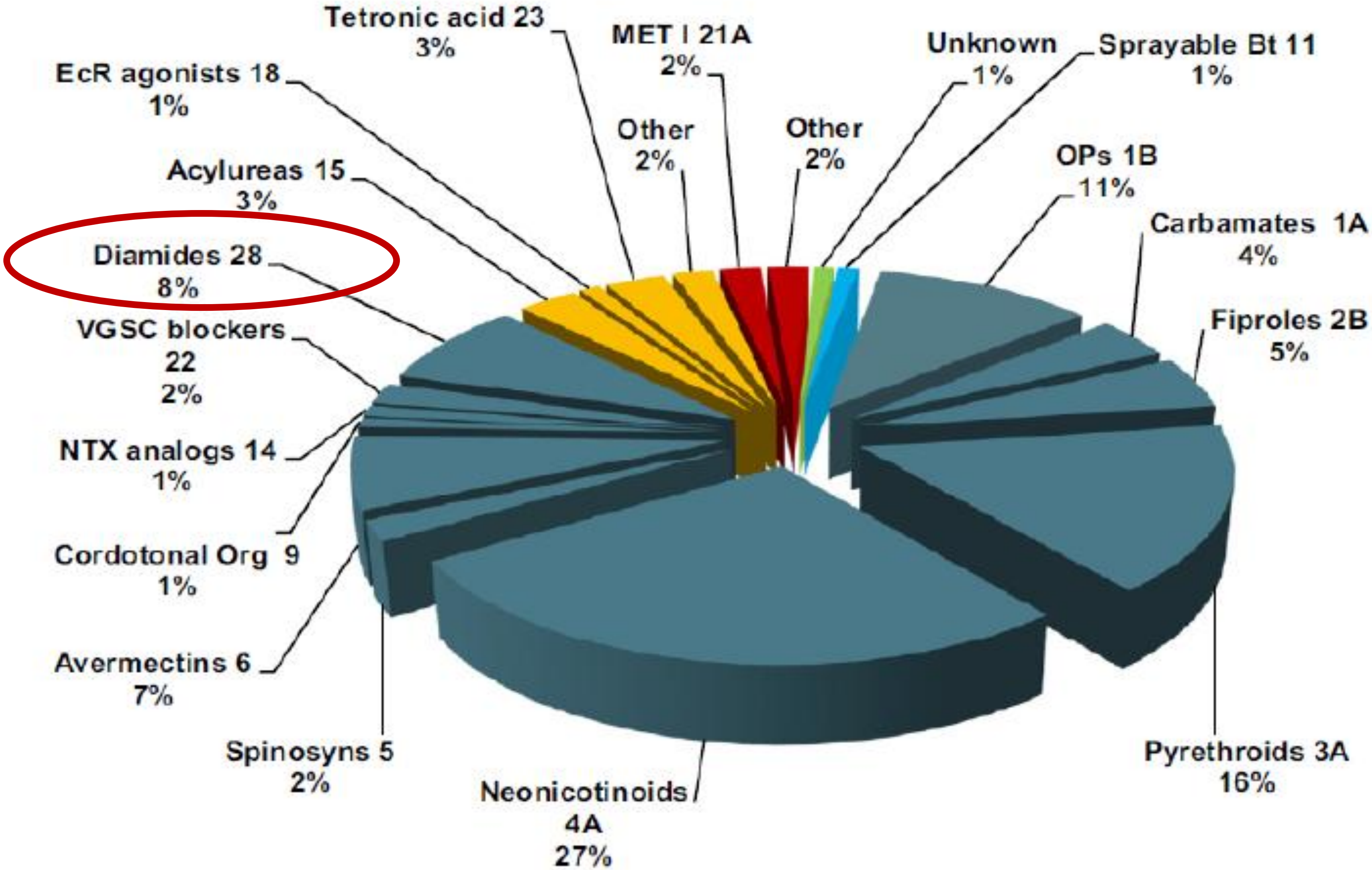
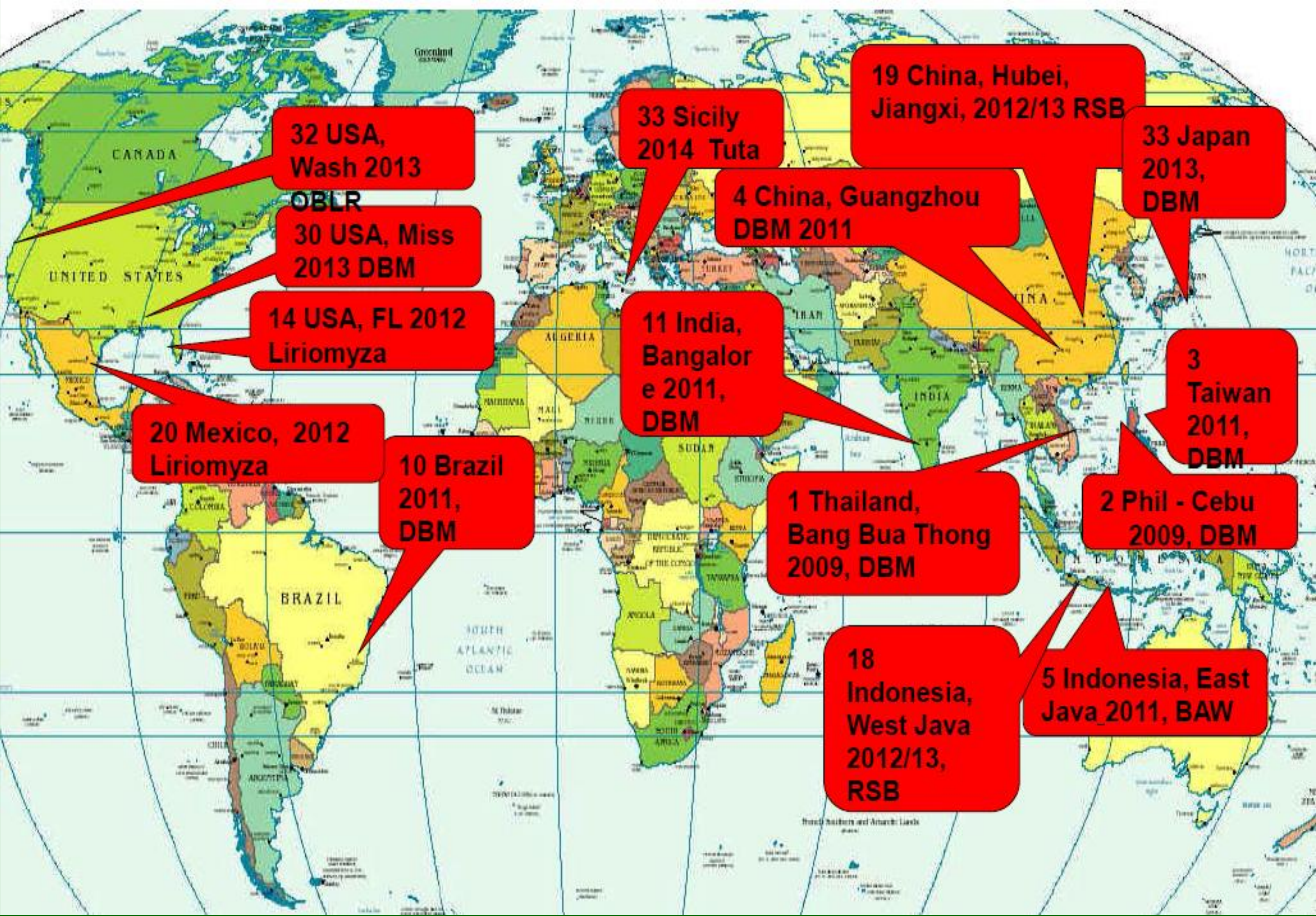


Fig. 5. Distribution of total insecticide sales (percent of total value) by IRAC MoA Group or Subgroup. Total value = $17,016 million; excludes fumigants. Based on 2013 End-user sales data from Agranova [24], July 2014.

(T.C. Sparks & R. Nauen (2015) Pesticide Biochemistry and Physiology; http://dx.doi.org/ 10.1016/j.pestbp.2014.11.014)



Diamide Resistance, March 2015

Table 2. Selection for resistance to *Bt*

S. No.	Name of the insect	Product	RR	Remarks
1	*Plodia interpunctella*	Dipel (Btk) Cry 1A	100	Mcgaughey -1985 15 generations
			250	36 generations
2	*Plutella xylostella*	Cry 1 A	1500	2nd generation
3	*P. xylostella*	*Btk* and *Bta*	330 and 160	Malasia
4	*Heliothis virescens*	Cry 1 Ac protoxin	10000	YHD2 strain
5	*S. exigua*	Cry 1 Ca	850	Cross resistant to Cry1 Ab, Cry 2Aa and Cry9 Ca
6	*S. littoralis*	Cry 1 Ca	500	Susceptible to Cry 1Fa

Source: Juan Ferre and Jeroen Van Rie , 2002.

Helicoverpa armigera was capable of developing resistance to Cry 1Ac under laboratory conditions by the end of 10th generation resistance levels increased by 76 fold

LC_{50} values; from 0.185 µg/ml diet in F1 to 11.50 µg / ml diet in 10th generation.

Source: Kranthi *et al.*, 2000

What is the Status of resistance?

I. Helicoverpa zea

The United States of America

First report on

Resistance to Cry 1 Ac in some field populations of *H. zea*

from Arkansas and Mississippi than in North Carolina

Reference	Particulars
Luttrell and Ali 2007	
2003-2004	**RR for Cry 1 Ac > 50 -six field strains** **> 100 -two field strains** **> 500 -two strains**
2005-2006	**>100 -seven additional strains** **> 1000-two strains**
	Cry 2 Ab **The percentage of population, RR >10 increased from Zero in 2002 to 50% 2005**
Jackson *et al*., 2011	**Increased no. of sprays against *H. zea***
Williams 2012	**1999-2011: two toxin *Bt* cotton area increased to 90% and insecticidal sprays tripled.**
Luttrell and Jackson, 2012	**No strong evidence on sustained loss due to field control.**

Luttrell and Jackson, 2012

Supplemental insecticides are required for effective management of *H. zea* even on dual gene *Bt* cottons.

II. Helicoverpa armigera

1. India

2. China

3. Australia

Table 3. LC_{50} vales recorded in different populations of *H. armigera* against Cry 1 Ac toxin in India

Year	No. of locations	Highest LC_{50}	Resistance Ratio
1999-00	10	0.67	7
2002-03	45	0.54	5
2003-04	20	0.38	4
2004-05	21	0.74	7
2005-06	39	0.72	7
2006-07	27	0.79	8
2007-08	49	1.15	12
2008-09	26	3.12	31
2009-10	31	3.14	31
2010-11	27	3.26	33
2011-12	**17**	**5.10**	**51**

Kranthi KR, 2012.

Kranthi KR, 2012

Indian *H. armigera* populations are susceptible to *Bt* cotton (Cry 1 Ac) even populations showed 51 fold decrease in susceptibility are also being controlled by *Bt* cotton under field conditions.

2.China

Reference	Particulars
He *et al.*,2000	Cry 1 Ac allel frequency is 0.0058 during 1999
Xu *et al.*, 2009	Frequency (0.0146) increased by 2.5 times during 2003-2005
Liu *et al.*, 2007	Frequency is 0.075 during 2007
Tabashnik *et al.*, 2009	Ambiguous evidence-change in screening methods
Haonan Zhang *et al.*, 2011	Survival was significant for 13 populations at high diagnostic concentration of 1000 ng /cm2 (LC99 is 100 ng / cm2.)
Lin Gin *et al.*, 2015	Tested "Natural Refuge Strategy". Resistance individuals increased from 0.93% in 2010 to 5.5% in 2013.

Reference	Particulars
Yiyun Wei et al., 2017	**Baseline susceptibility of *H. armigera* to Vip3 Aa in 12 field populations**
	LC50 values: 0.05 to 1.311 µg / cm2 25 fold natural variation among populations
	No cross resistance to Cry 1Ac and Cry 2 Ab.

Haonan zhang *et al*., 2011

Resistance monitoring in *H. armigera* against *Bt* cotton in China has provided an Early warning that urgently needed to implement the proactive resistant management strategies to restrict the consequences of resistance development to Cry 1Ac.

3. Australia

Frequency of alleles conferring Cry 1 Ac and Cry 2 Ab in *H. armigera* and *H. punctigera* Increased over eight years but maximum is <1%.

Maximum allelel frequency detected is 0.048 (2008-2009)

Downes et al., 2012 – Incipient Resistance

Downes and Mahon 2012- resistance to Cry 2 Ab did not increase from 2008-09 to 2010-2011.

Tabashnik 2013

Incipient Resistance

Further increase in resistance are remote

Why Australian *Bt* cotton is still Resistant to bollworms?

Strict compliance of refuges

Table 4. Scale of field assessment and commercial development of Ingard cotton in Australia

Year	Area (Ha)	% of Cotton Area	Main Activity
1992/93	200 plants	-	Assessment of outcrossing risk and field efficacy.
1993/94	0	-	Field efficacy and assessment of outcrossing risk.
1994/95	10	-	Field efficacy and environmental impacts (non-targets, pest dynamics).
1995/96	40 (4 sites)	-	Environmental impacts and IPM performance.
1996/97	30,000	8.0	Five year registration granted and annual review. Limited commercial release by area and region
1997/98	60,000	15.0	Limited commercial release by area and region.
1998/99	85,000	20.0	Limited commercial release by area and region.
1999/00	125,000	25.0	Limited commercial release by area and region.
2000/01	165,000	30.0	Limited commercial release by area and region.
2001/02	184,000	30.0	Capped at 30% until two gene Bt varieties become available (2003/2004).

Source: Gary P. Fitt, 2003

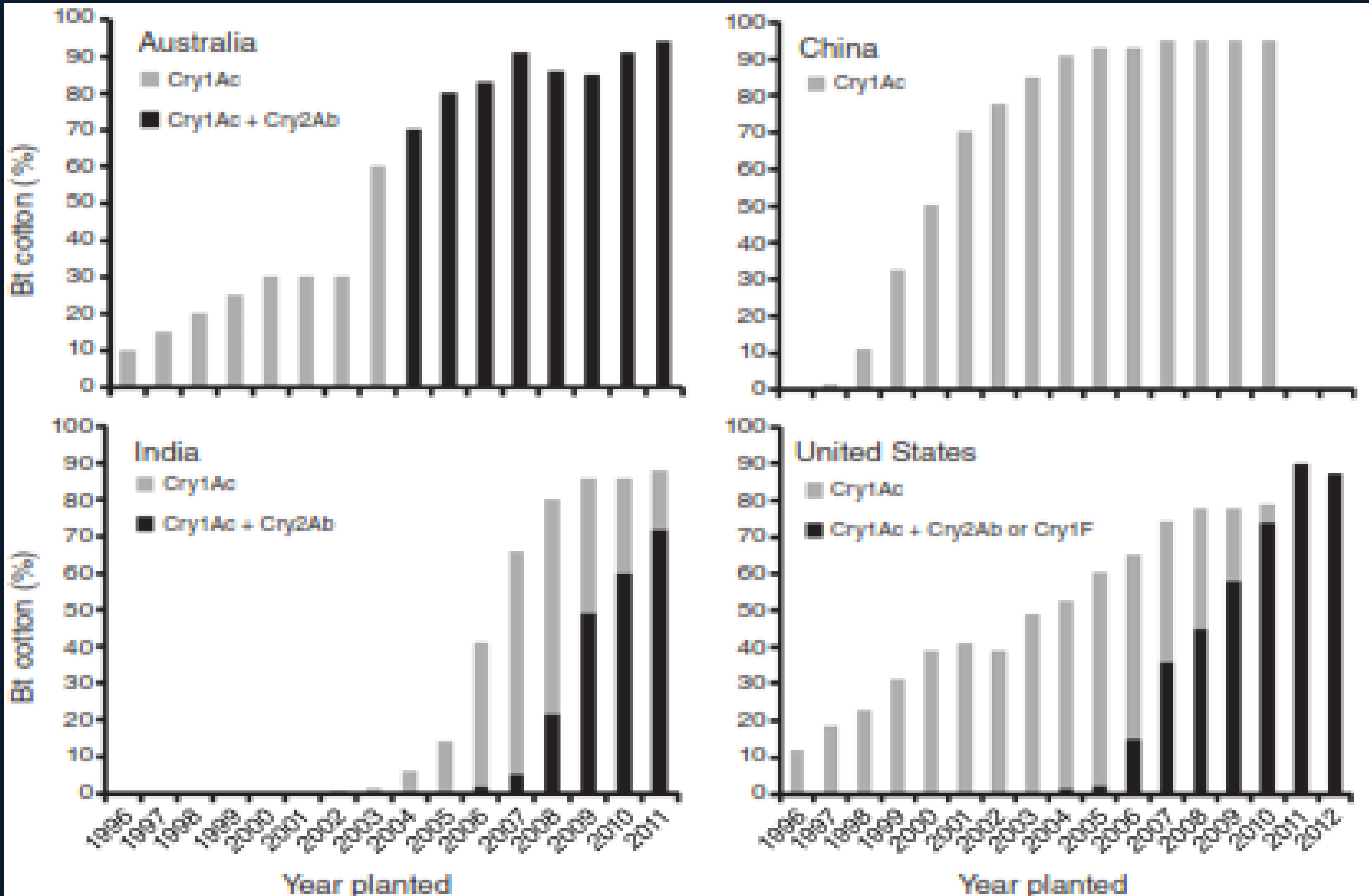


Figure 2. Percentage of cotton hectares planted with *Bt* cotton producing one toxin (gray) or two toxins (black) in four countries

Source: Bruce E Tabashnik, 2013

Conclusion

Country	Insect Pest	Status
The USA	*H. zea*	Additional Sprays needed
India	*H. armigera*	*Bt* is still working
China	*H. armigera*	Early warning
Australia	*H. armigera* and *H.punctigera*	Incipient resistance

Strategies to delay the development of resistance

- Strict compliance of Refuge
- Increasing use of combination of *Bt* toxins
- Novel *Bt* toxins – VIP
- Modified *Bt* toxins- Cry 1Ac
- RNAi and fusion proteins
- Integrated Pest Management

THANK YOU