Current insecticide resistance management programme for *Helicoverpa armigera* in Indian cotton

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Principal cotton growing areas of the World

– from Matthews (1989)

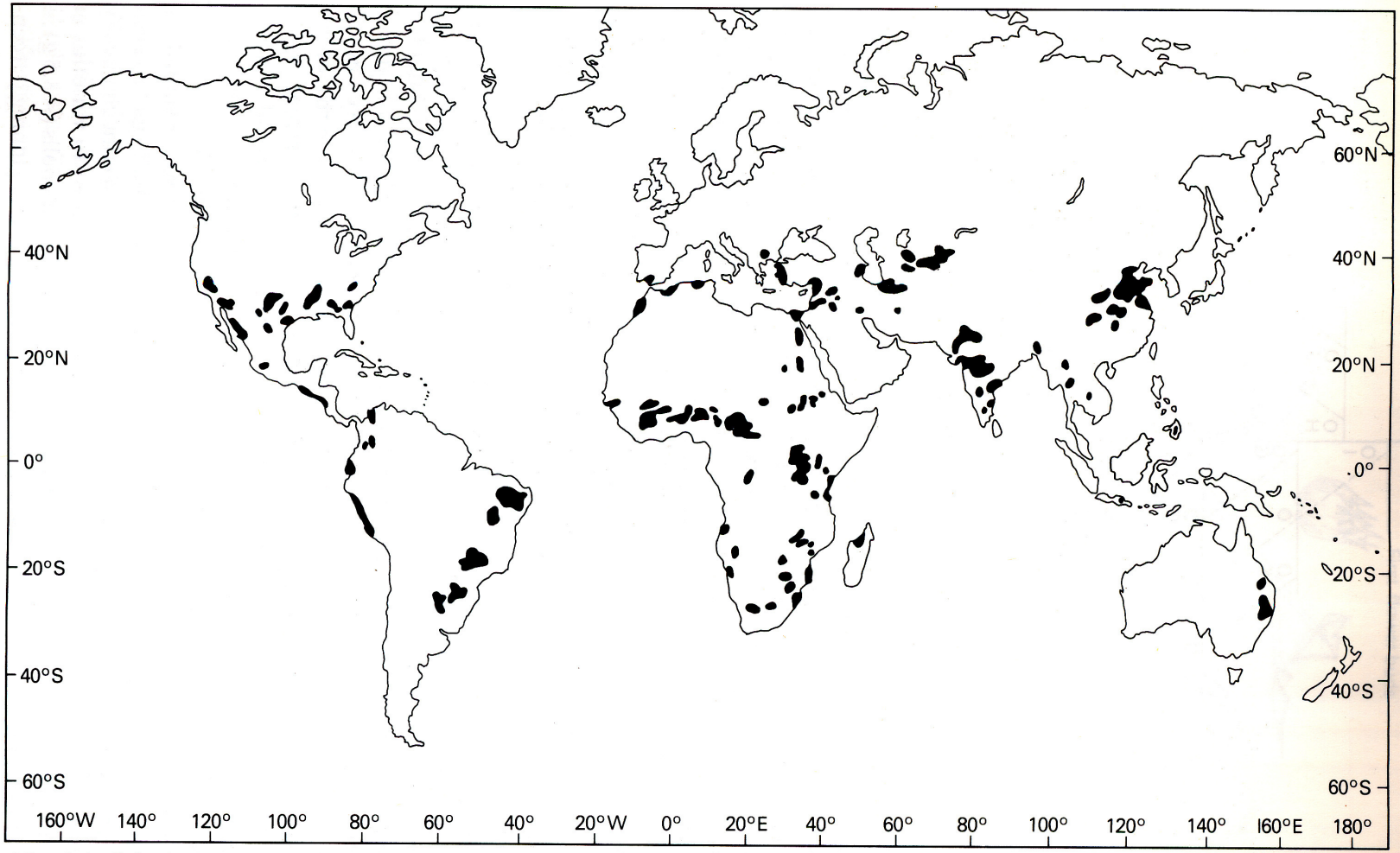


Fig. 1.4 Principal cotton growing areas of the World

Pest control – *data from ICAC (2001,2002)*

Country	Mean no. of applications per season	Cost of control (US$/ha)	Cost as % of lint value
USA (inc Bt)	2.3	$200	29%
Argentina	4	$31	4.2%
Benin	10	$39	5.3%
S.Africa	5	$64	31%
Uganda	2	$25	10.5%
Egypt	3	$50	3.2%
Israel	5	$226	18%
India (irig.)	6.5	$87	13%
Pakistan	6	$119	16.4%
China (non Bt)	15	$115	16.6%
Australia (inc. Bt)	9.9	$285	27%

INDIA

Cotton insecticide situation

Cotton

- 8.7 mill ha
- 13 % of world production
- 308 lint/ha mean yield

Insecticide usage in late 1990s

- 45% of all insecticides are used on cotton
- 37,000 tonnes of a.i. used on cotton
- 42% of cotton growing costs
- 7% p.a. growth in use in the 1990s

Resistance management strategy

Aims

- **Save growers money**
- **Prevent further increases in selection pressure**
- **Prolong the life of useful insecticides**
- **Allow a gradual return to a more biologically based control**

- **Establish cotton pest management systems which are:**
  - **Simple, practicable**
  - **sustainable,**
  - **farmer based -user friendly &‘expert-independent’**

IRM components
Agronomic principles

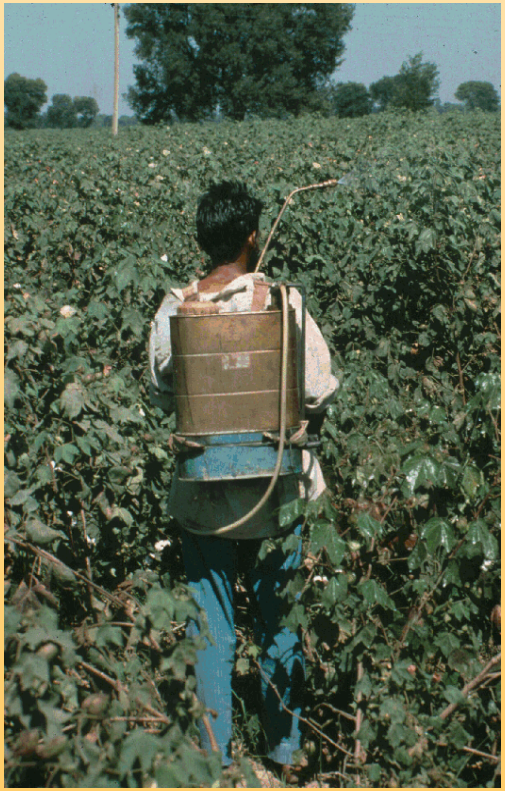
- Appropriate genotype selection
- Timely sowing - late May north, mid-July south
- Wide plant spacing
- Soil test and fertiliser
- Good weed control
- Destruction of residues
- Summer ploughing

IRM components
Social principles

- Village participatory
- simple and robust
- not experimental
- easy availability of components
- each component effective
- reduce work load
- maintain yields

IRM components Insecticide principles

- Need-based at thresholds
- Right - timing
  - chemical
  - dosage
  - method
- Target younger stages
- Rotate resistance groups



Mechanisms and their importance

	Metabolic			Target Site			Penetration
	Oxidase Pyreth	Esterase OP/Car/ Pyr/Endo	GST Pyr	Ache OP/ Carb	Nerve Insen Pyreth.	rdl Endo	Pyrethroid (others?)
India	***	**	*	*	**	*	?
China	***	**	*	*	*	*	*
Pakistan	**	**	*	*	?	*	*
Australia		***		**		**	
W.Africa	***					*	

Potential for rotations

	Major mech.	Minor mech.	Rotation groups
Pyrethroids	Oxidase	Esterase Nerve insensitivity Penetration	• **Most pyrethroids** • **Bifenthrin**
Organo-phosphates	Insensitive Ache	Esterase	• **Phosphatic –** **- monocrotophos** • **Phosphothioronate** **- profenophos** **- most others**
Carbamates	Esterase	Insensitive Ache	• **Methomyl/carbaryl** • **Thiodicarb**
Endosulfan	Esterase (sequestration)		• **Endosulfan**

Early season sucking pests

Aim:

- **to mitigate early season damage while conserving natural enemies**

Strategies:

- **Jassid resistant genotypes**
  - some jassid attack discourages *H.armigera* without affecting yields

- **Seed treatment**
  - Imidacloprid 7g or Carbosulfan 20g or Carbofuran 25g/Kg

Bollworm Window 1:

Vegetative and early reproductive stage

Aim:

To suppress the first generation of *H.armigera* while minimising the effect on beneficials

Strategies:

- **Scouting** - early season (60-90 DAS) - ETL 0.5 larvae/plant
- **Biologicals** - **Trichogramma**/Neem/HaNPV
- **IGR** - Novaluron, Lufenuron
- **Endosulfan** - 'soft' on beneficials
  - resistance levels low early season (Aug/Sept).

Bollworm Window 2a:
Mid reproductive stage

Aim:

To protect boll formation by controlling the mixed instars of overlapping *H.armigera* generations

Strategies:

- **Scouting**
  - 90-110 DAS - ETL 1 larva per plant

- **Spinosad:** no resistance so far
- **Indoxacarb:** no resistance so far

Bollworm Window 2b:
Mid reproductive stage

Aim:

To protect boll formation by controlling the mixed instars of overlapping *H.armigera* generations

Strategies:

- **Scouting**
  - 110-120 DAS - ETL 1 larva per plant
- **Organophosphates and carbamates**

  - Resistance is low to moderate (quinlphos/chlorpyriphos/profenophos)
  - Avoid early use - disrupts beneficials
  - Avoid broad spectrum e.g. monocrotophos/ acephate

Bollworm Window 3:
Peak fruiting phase

Aims:

To control *P.gossypiella* and *Earias* spp. as well as *H.armigera*

Strategies:

- **Scouting**
  - 120-140 DAS - ETL 1 larva per plant
- **Pyrethroids**
  - High *H.armigera* resistance (cypermethrin/ fenvalerate). Can be synergised with OPs *(ethion, quinalphos or chlorpyriphos)*
  - Still effective on spotted and pink bollworm
  - Avoid early use - disrupts beneficials

Summary spray management schedule (days after sowing)

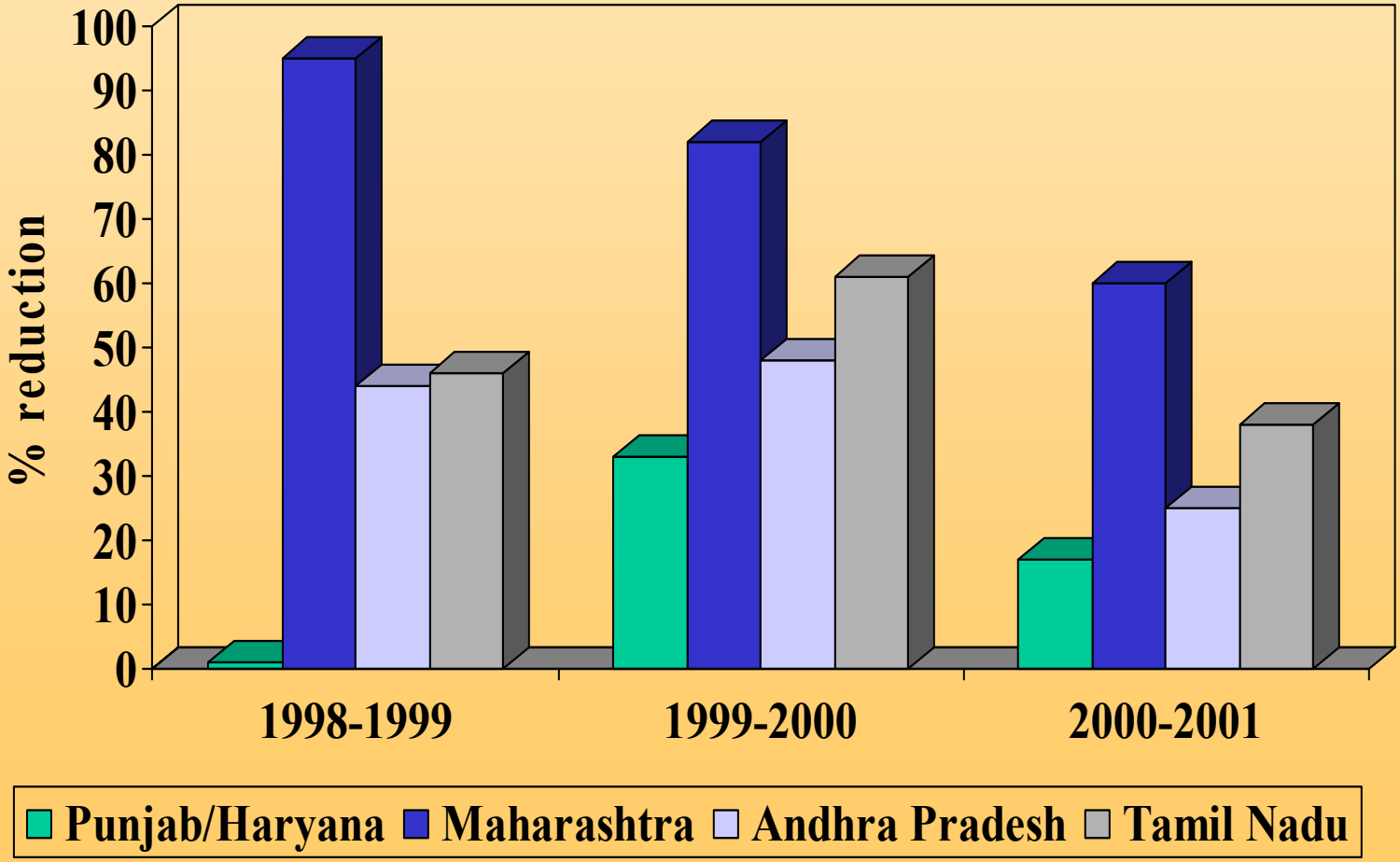
Sucking pests	Bollworm Window 1	Bollworm Window 2		Bollworm Window 3
0-60	60-90	90-105	105-120	120-140
Zero sprays	Endosulfan Neem/HaNPV	Spinosad Indoxacarb	Organo-phosphate/ carbamate	Pyrethroid

IRM programme History

	Funder
1992-95 – Research with ICRISAT, CICR,TNAU	•ICAR,DFID
1996-98 - Demonstrations - increasing to 4 states, 23 villages and 3,000 growers	•ICAR, DFID
1999-2001 - Expanding scale in 4 states	•ICAR (DFID)
2002-2007 - National programme now in 28 districts in 10 states and growing	•Govt. of India _CFC (research)

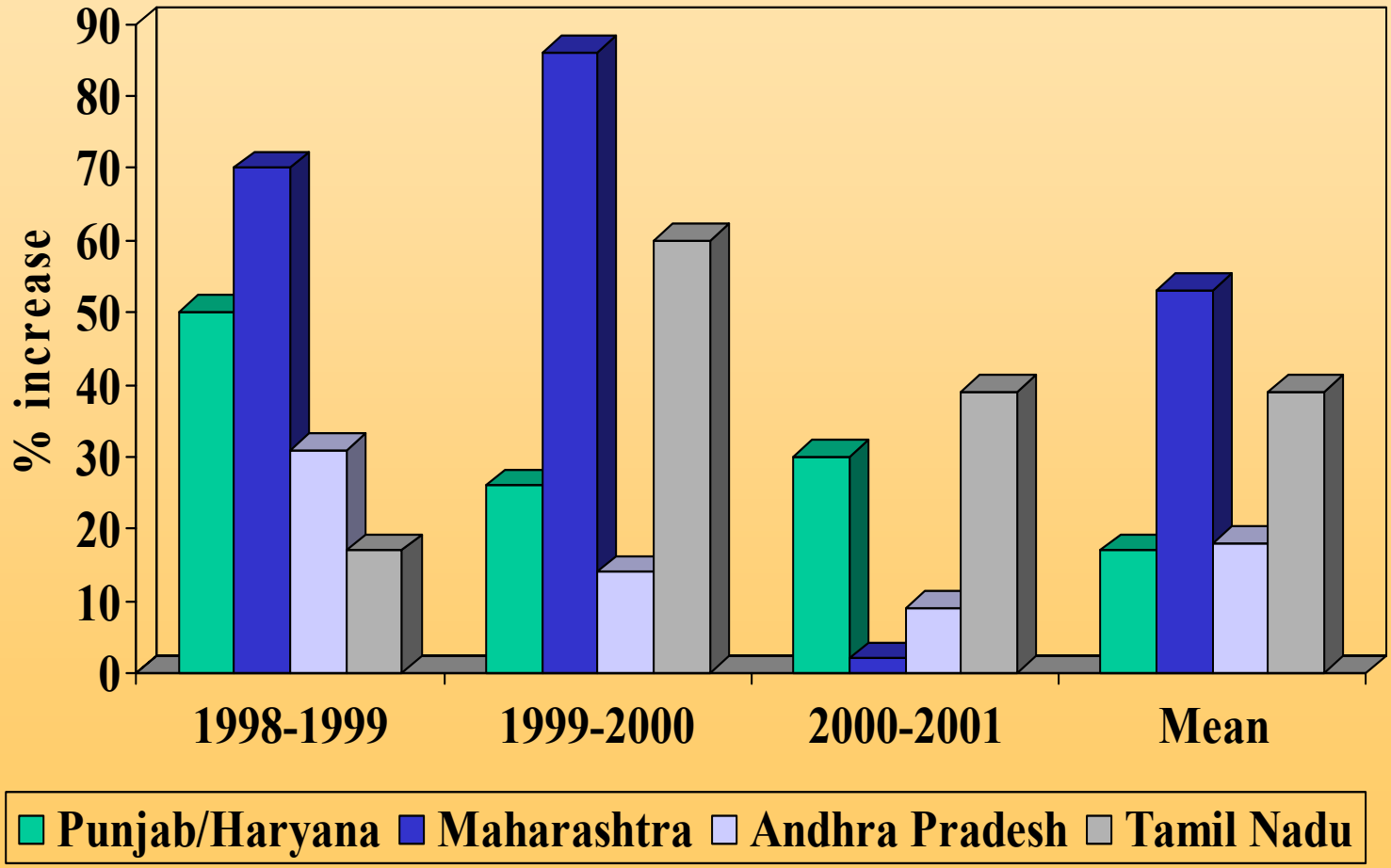
% Reduction in insecticide applications

1998-9 - DFID 1999-2001 - Govt. of India



% Yield increases

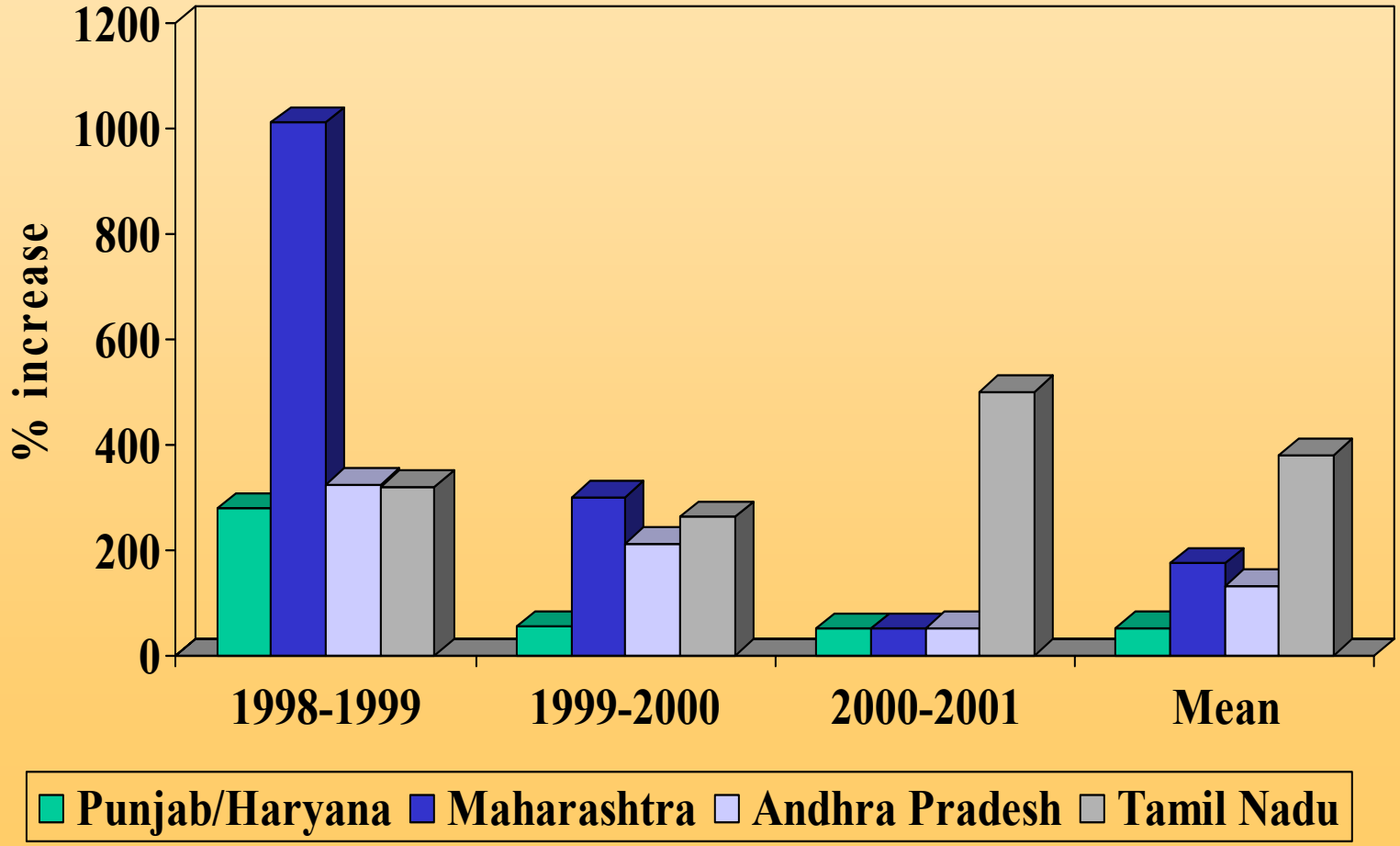
1998-9 - DFID 1999-2001 - Govt. of India



% profitability increases

1998-9 - DFID 1999-2001 - Govt. of India

1989 non-participators made a clear loss in the Punjab and Maharashtra



Reduction of impact on beneficial insects

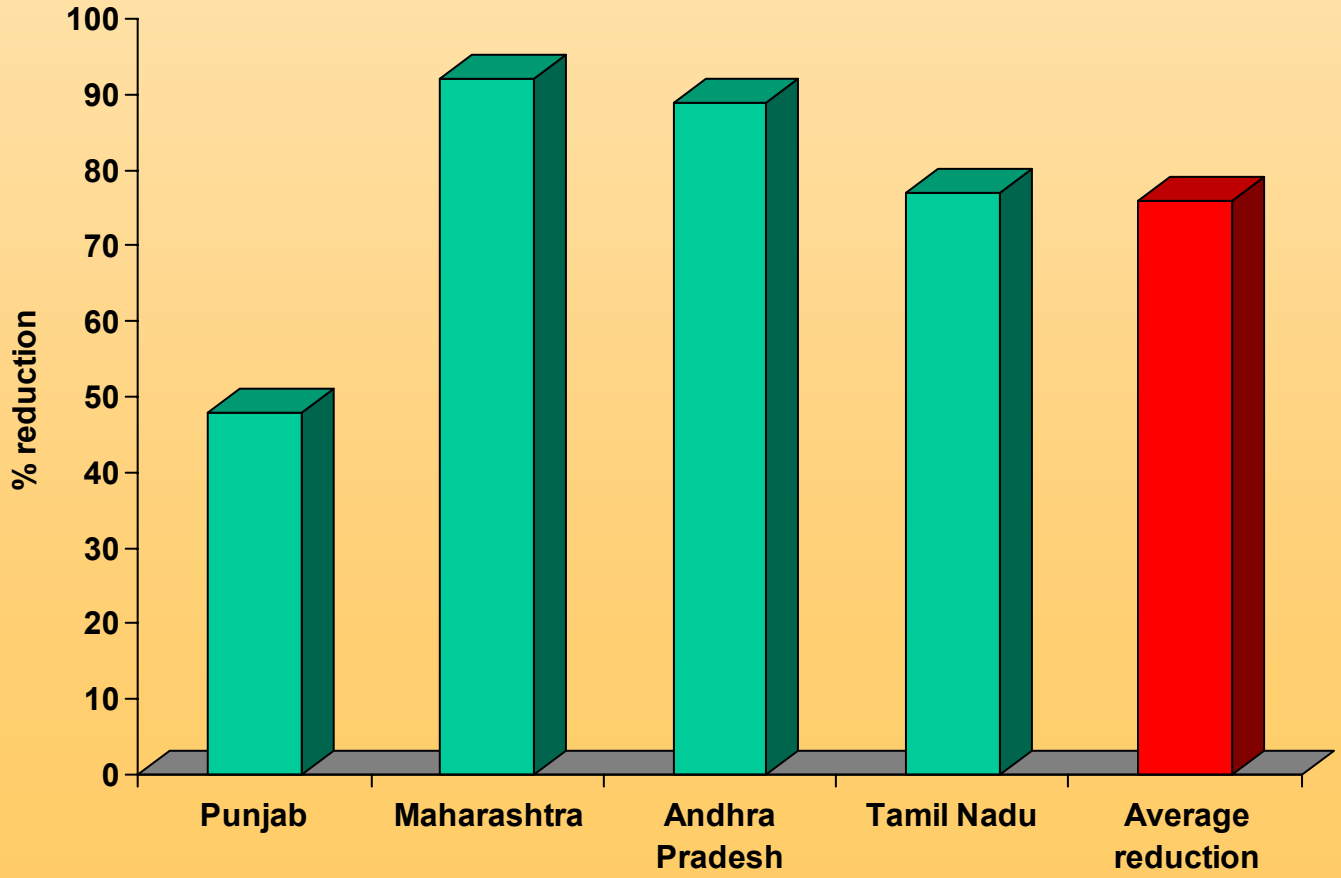
% reduction in LD_{50} doses/ha

- **Parasitoids**
  - Egg 85% (*Trichogramma* sp.)
  - Larval 62% (*Bracon* sp.)
- **Predators**
  - Ladybird 78% (*Coccenilla* sp.)
  - Lacewing 63% (*Chrysoperla* sp.)

(Iyengar and Russell 2000)

Human health benefit from 1999 demonstrations

(% reduction in No. of LD50 doses per farmer)

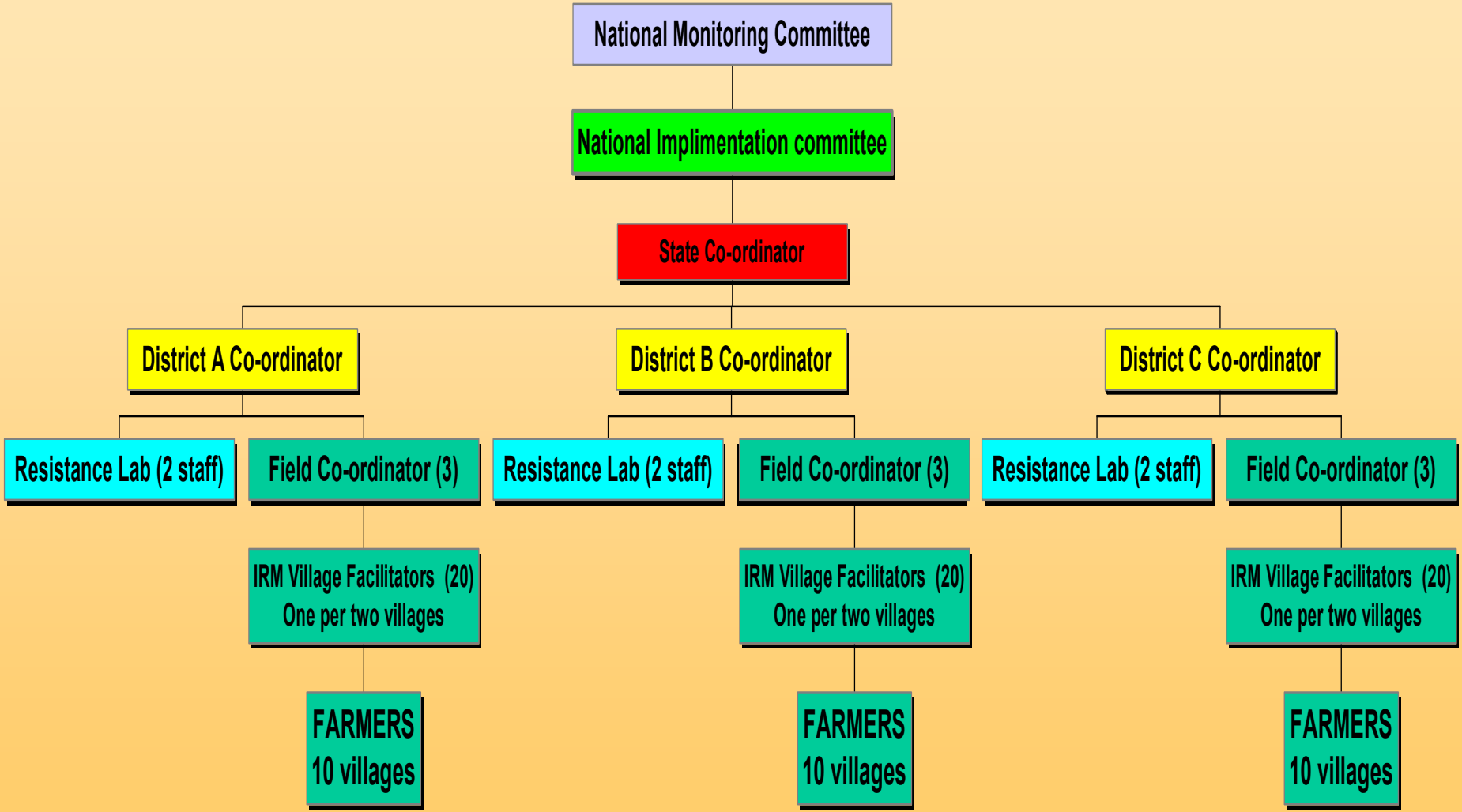


Village dissemination of IRM strategies 2002-2007

- Govt. of India - Cotton Technology Mission - $US 0.4 mill/yr.
- Focus on 28 most heavily insecticide-using districts (11 states in 2004-5)

	Villages	Core farmers	Participating farmers
2002-3	260	2,801	12,500
2003-4	331	5,372	18,545
2004-5	350	10,000	47,500

National Programme Implementation structure (2002-7)



Implementing partners

- **North India**

Punjab -	Punjab Agric. University
Haryana -	Central Institute for Cotton Research
Rajisthan -	Rajistan Agric. University

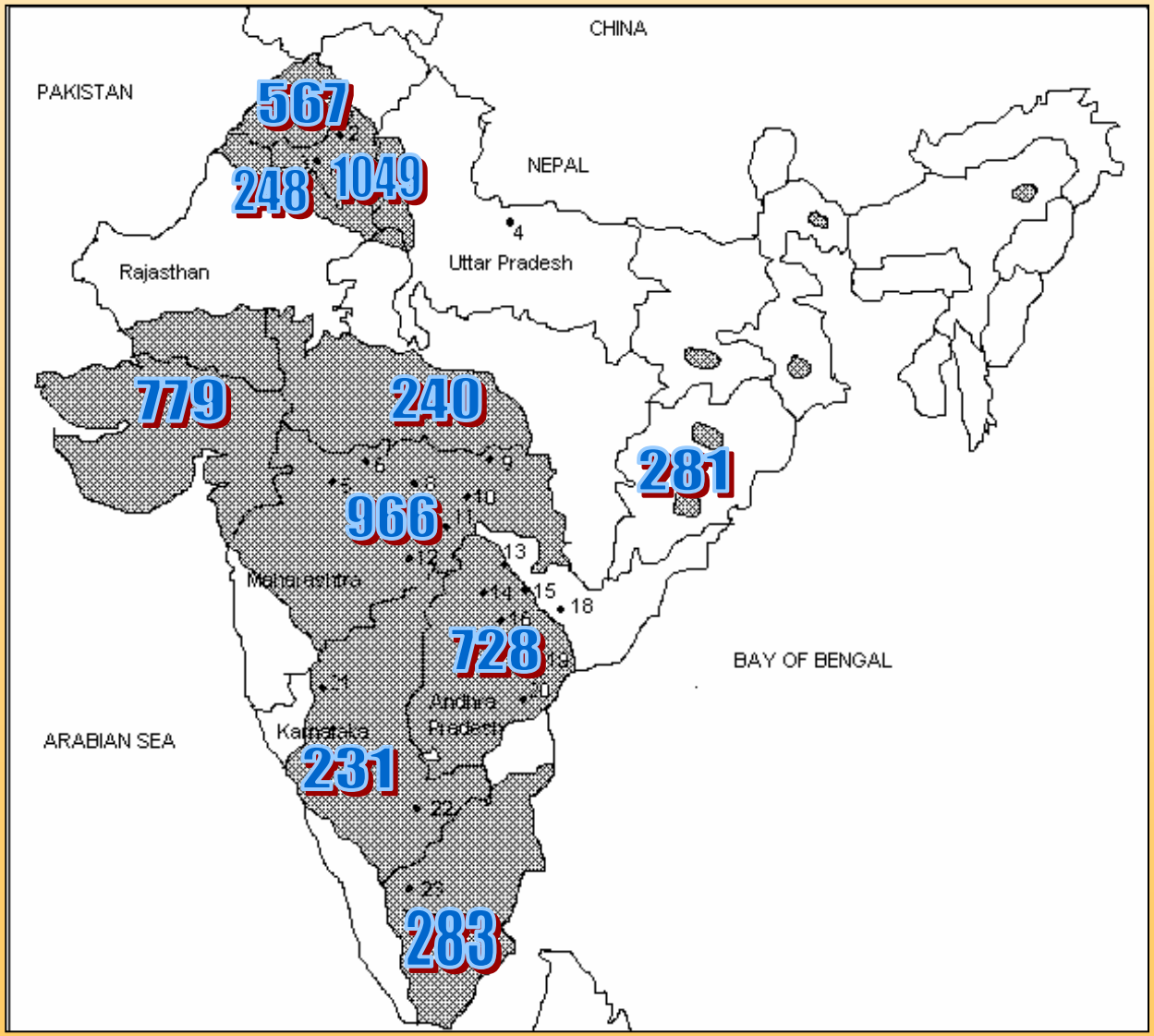
- **Central India**

Maharashtra -	Polytechnic, Wardha
	Marthwada Agric. Univ.
Myda Pradesh -	J.Neru Krishi Viswa Vidyalay
Gujarat -	Gujarat Agric. Univ.

- **South India**

Andhra Pradesh-	Andhra Pradesh Agric. Univ
Karnataka -	Univ. of Agric Sci., Dharwad
Tamil Nadu -	Central Institute For Cotton Research
Orissa -	Orissa Univ. of Agric and Tech.

India – 5,372 IRM farms for data collection in the 10 main cotton states 2003-4

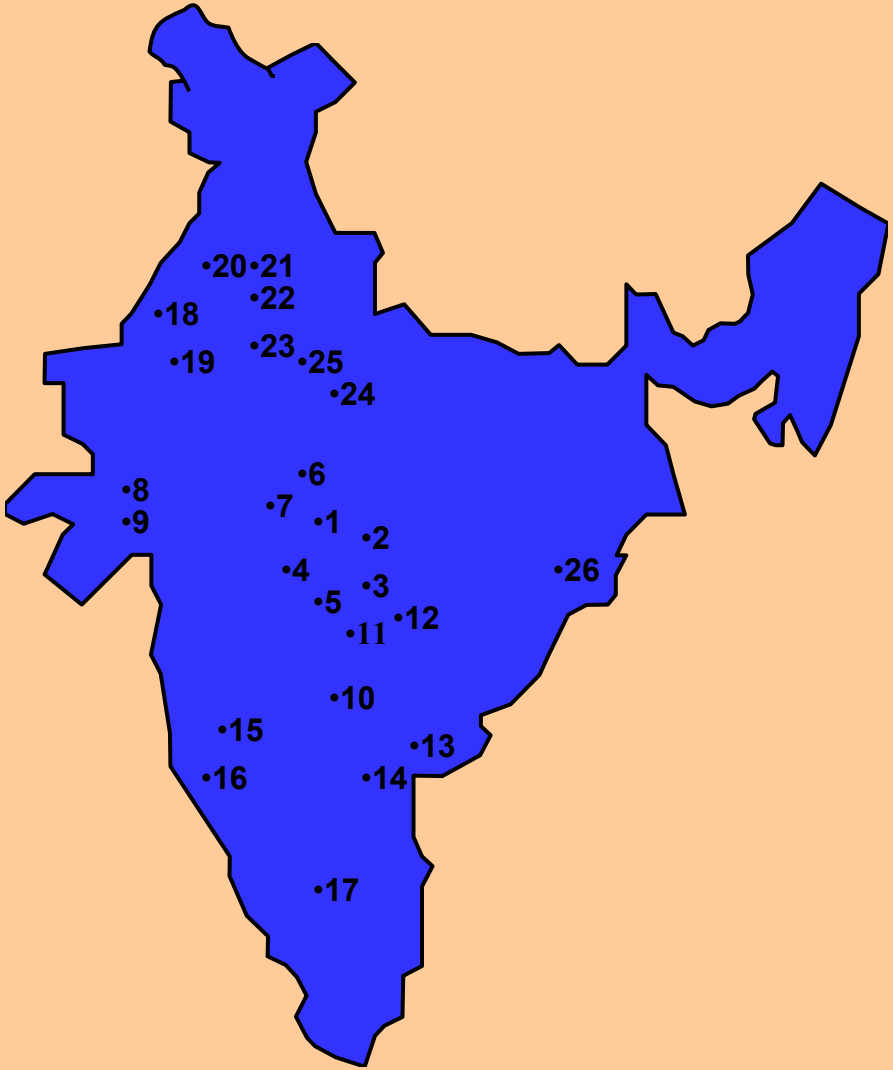


Network of 26 Resistance Monitoring labs

- Training imparted
- Material supplied

Resistance Monitoring LABS

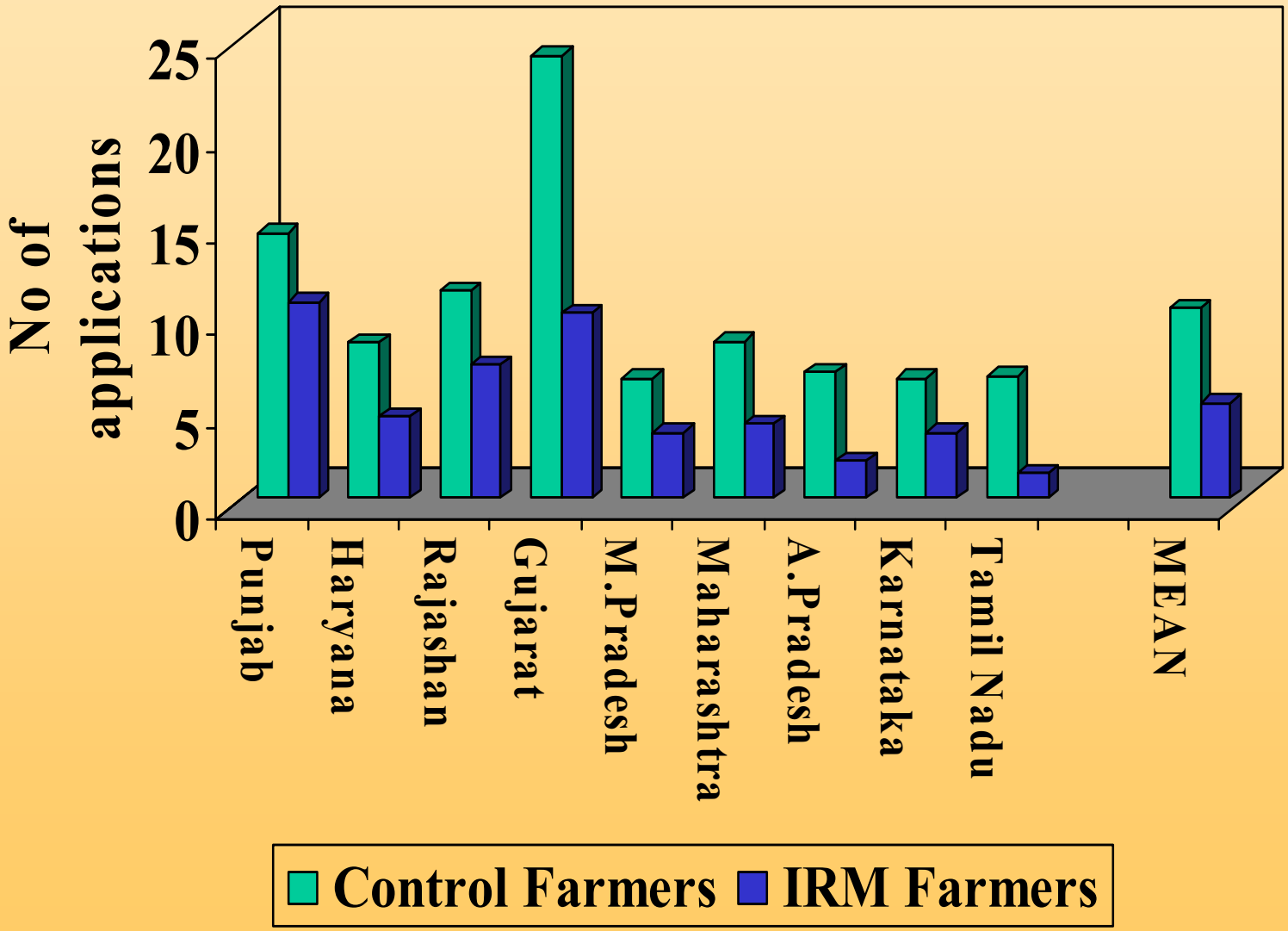
1. Amaravati
2. Wardha
3. Yavatmal
4. Hingoli
5. Parbhani
6. Chindwara
7. Khandwa
8. Bharuch
9. Vadodara
10. Kurnool
11. Adilabad
12. Warangal
13. Guntur



14. Prakasam
15. Belgaum
16. Bellary
17. Coimbatore
18. Sriganganagar
19. Hanumangarh
20. Bhatinda
21. Mansa
22. Ferozepur
23. Sirsa
24. Hisar
25. Fatehabad
26. Kalahandi

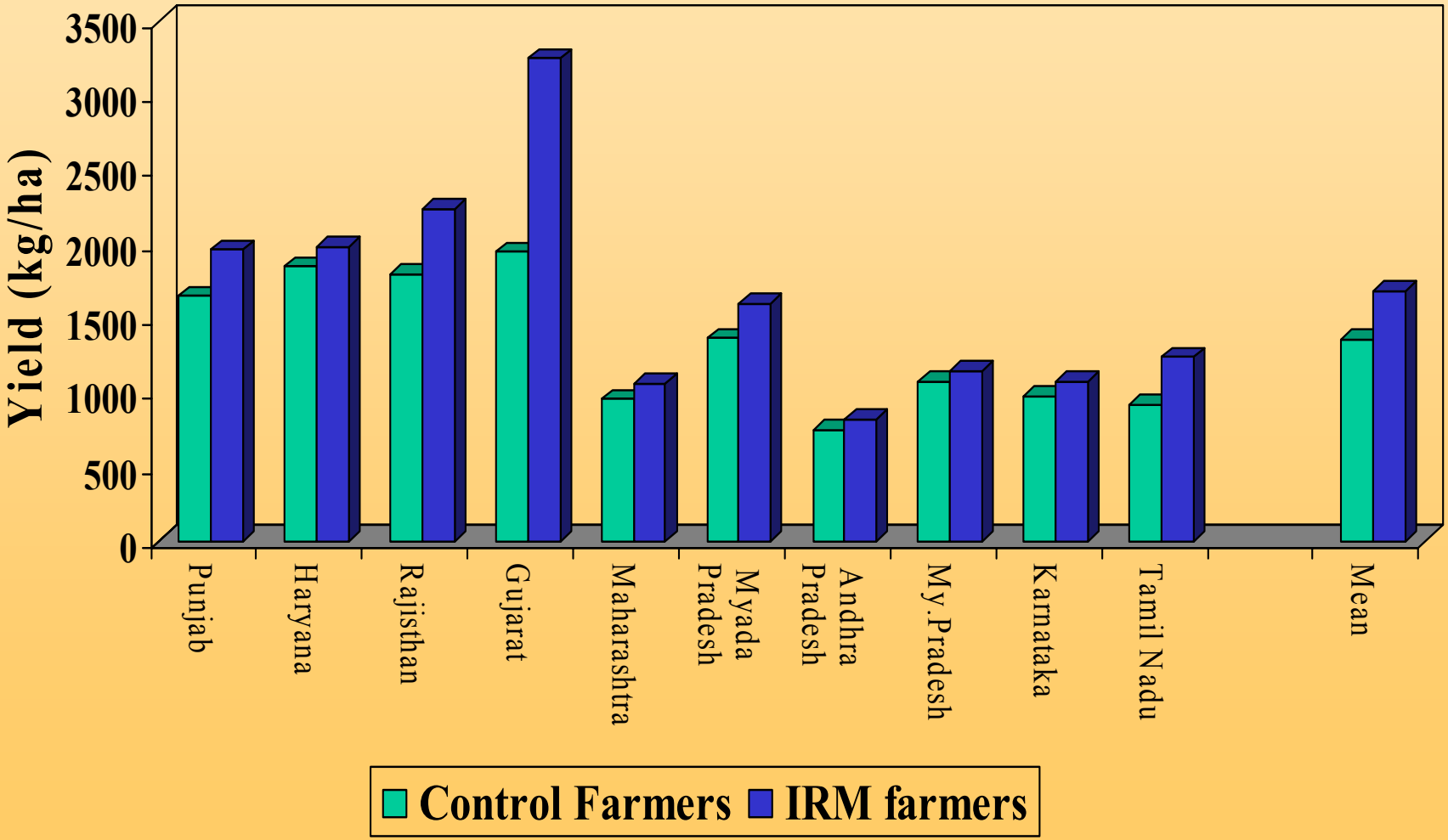
Number of insecticide applications 2003-4

North on left South on right



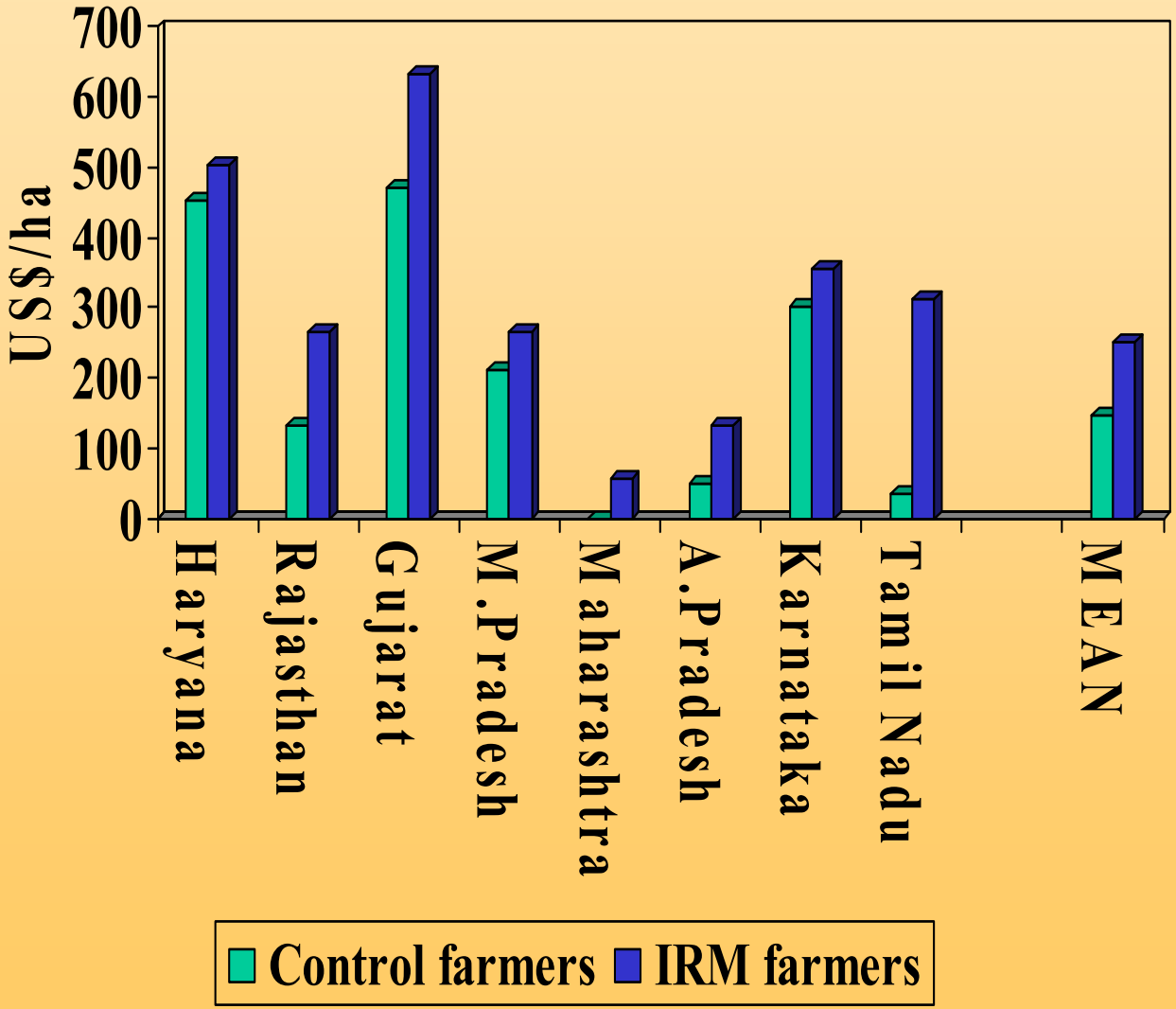
Seed cotton yield 2003-4

North on left - South on right



Net income (US$/ha) 2003-4

North on left South on right



Impact of recommendations - Punjab

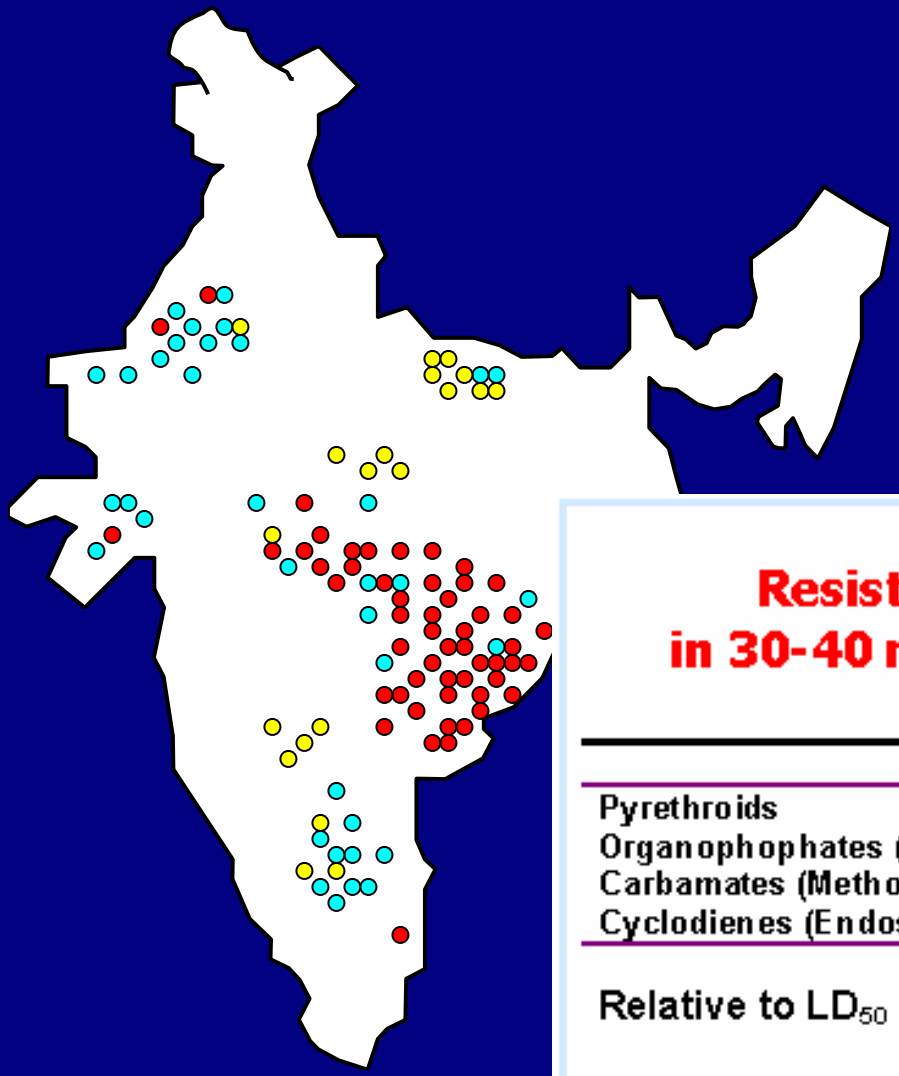
Source: NATP project report

	Mixtures - Proportion of sprays	Pyethroids – proportion of sprays
2001-2	79%	48%
2002-3	43%	32%
2003-4	27%	28%

H.*armigera* resistance frequencies 1997 -2003
IRM district - Wardha, Maharashtra

	1997 Status	1997 RF	1998 RF	1999 RF	2000 RF	2001 RF	2002 RF	2003 RF	2003 Status
Pyrethroid: (Cypermethrin)	Medium	96	7	10	6	7	9	3	Low
Cyclodiene: (Endosulfan)	Medium	29	35	7	5	3	2	1	None
OP: (Quinalphos)	Low	2	3	1	1	1	1	1	None
Carbamate: (Methomyl)	None	1	1	1	1	1	1	1	None

Insecticide resistance in *H. armigera* 1992-2001

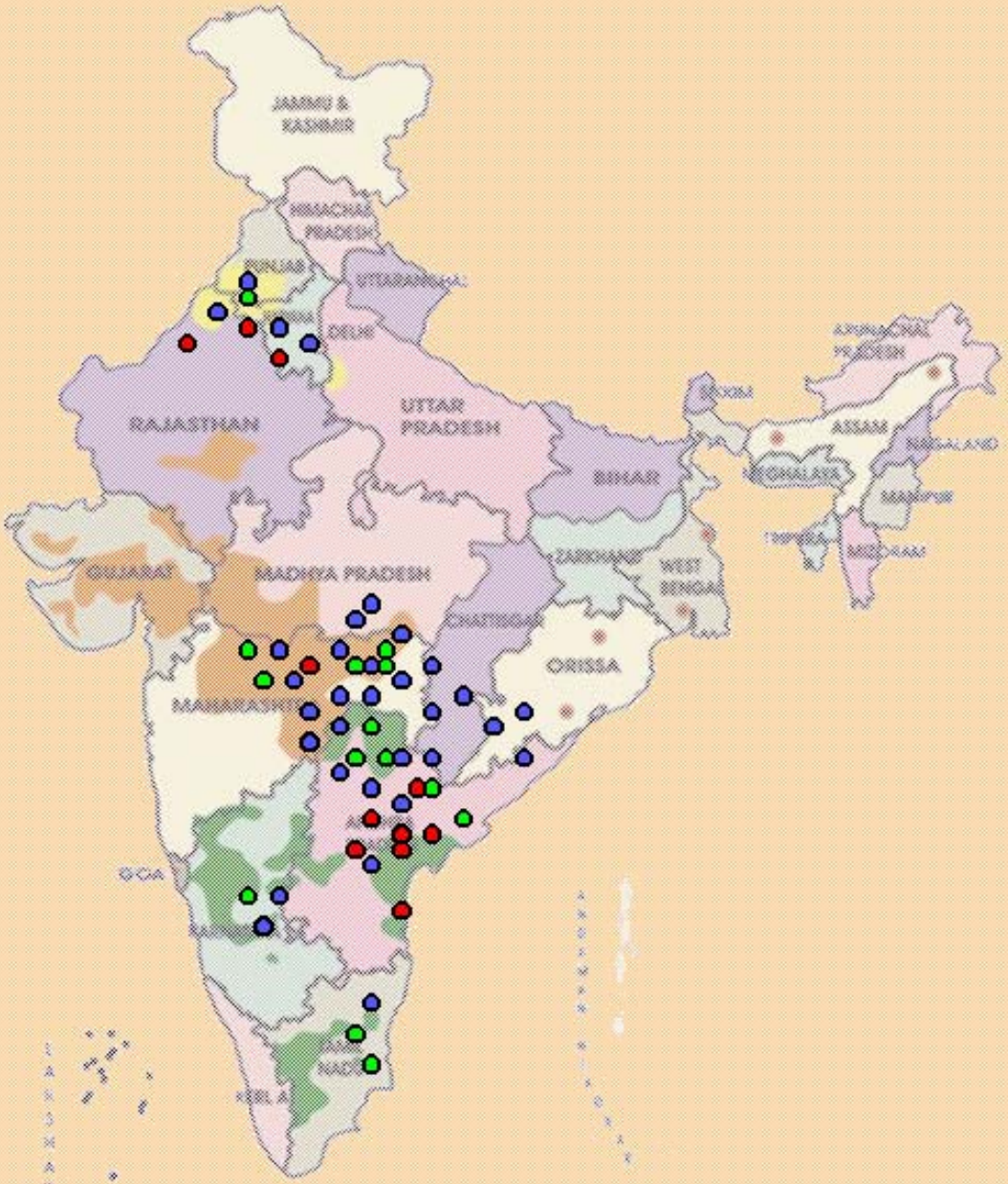


Resistance factors from LDP assays in 30-40 mg H. armigera larvae 1992-2001

	North India	Central India	South India
Pyrethroids	48 - 1340	54 - 6,000	73 - 21,000
Organophophates (Quinalphos)	6 - 33	4 - 41	6 - 67
Carbamates (Methomyl)	2 - 27	1 - 19	9 - 83
Cyclodienes (Endosulfan)	7 - 23	12 - 45	5 - 39

Relative to LD_{50} of lab reared field susceptible strain

Kranthi et al., J.Econ.Entomol., 2001, 2002



Resistance Summary 2004

- Pyrethroid resistance on the decline
- Organophosphate still useful
- Endosulfan regaining susceptibility
- New chemistries, spinosad/ indoxacarb moving towards resistance

Priorities for 2005 and beyond

- Expand participation in each village
  - Target 90%
- Expand farmer numbers
  - Target 120,000 2005
    1mill 2009
  - Cost Rs400 ($8)/ farmer
  - Cost benefit ratio 1:12
- Reduce cotton pesticide load
  - Contribute to 30% reduction in insecticide use nationally1997-2007

IRM Support

RESEARCH

- ICAR – Crop Protection ADGs
  Dr A.K. Raheja, Dr O.P.Dubey
- DFID - Crop Protection Programme
  Dr S.Eden-Green, Dr F.Kimmins
- CICR - Directors
  Dr M.S.Kairon, Dr C.D.Mayee, Dr S.P.Singh
- NRI – Project leaders
  Dr A.B.S.King, Dr N.Armes

UPTAKE

- MOA - Union Agriculture Commissioners
  Dr Hazra, Dr C.D.Mayee