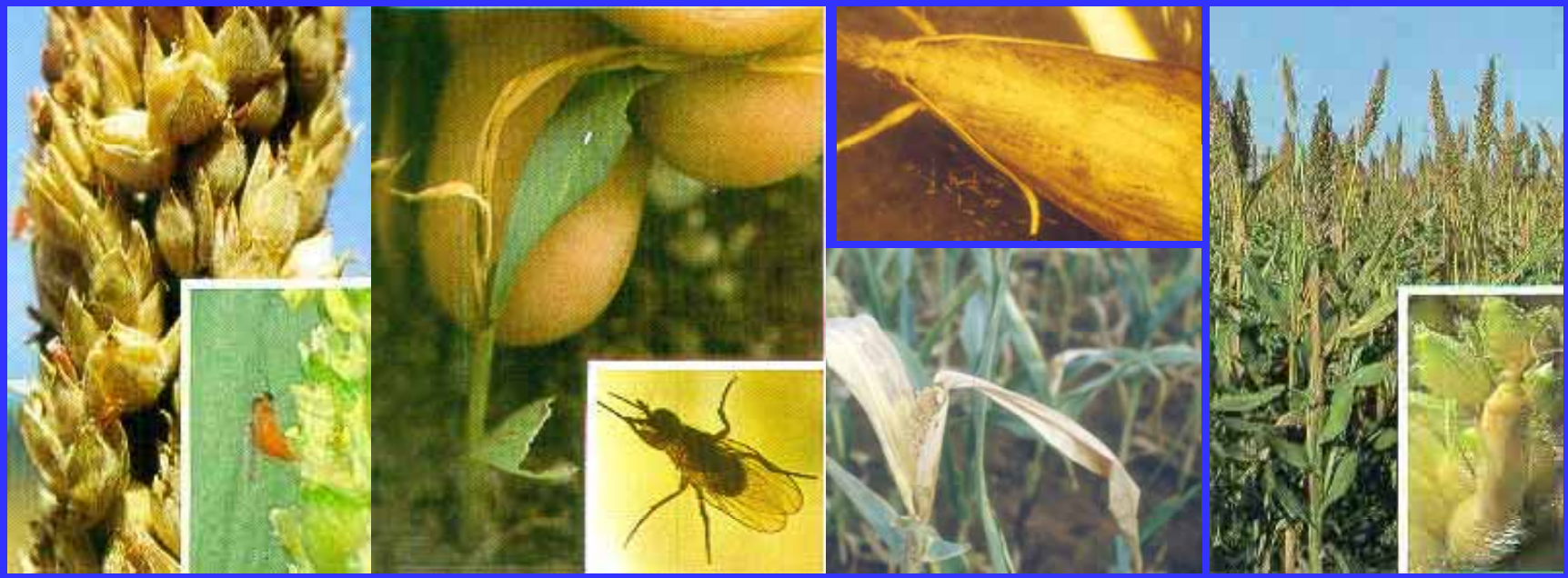
Role of HPR to Insects in Pest Management in Sorghum

Current Status and Need for Future Research

HC Sharma, BL Agarwal, John Stenhouse, BVS Reddy, Ashok Kumar, P Srinivasa Rao, TG Hash, SP Deshpande , N Seetharama + Students + Staff + NARS Scientists



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Insect Pest Problems in Sorghum and Pearl Millet

Shoot fly – *Atherigona soccata* in sorghum and *A. approximata* in pearl millet. The larvae migrate to the growing point and produces a deadheart.

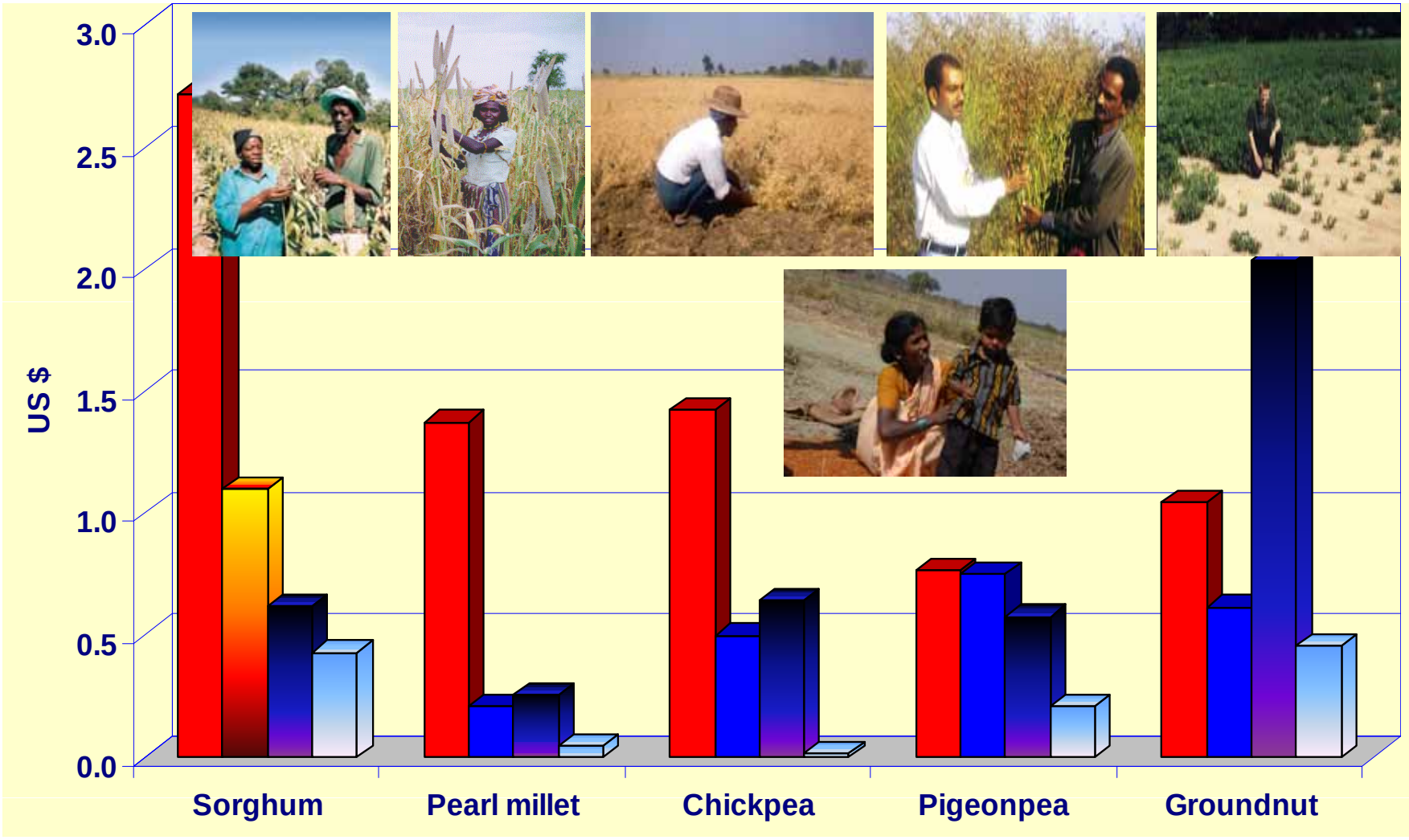
Stem borers. *Chilo partellus* and *Busseola fusca* in sorghum and *Ascigona ignefusalis* in pearl millet. Larvae feed on leaves, cause deadheart and stem tunneling.

Midge – *Stenodiplosis sorghicola* in sorghum. Larval feeding results in chaffy spikelets.

Head bugs – *Calocoris angustatus* and *Eurystylus oldi* result in tanning and shriveling of grain in sorghum.

Head miner, caterpillars, beetles – *Heliocheilus albipunctella, Helicoverpa armigera,* and the chafer and blister beetles feed on rachis/grain.

Yield Loss Due to Insect Pests in ICRISAT Mandate Crops



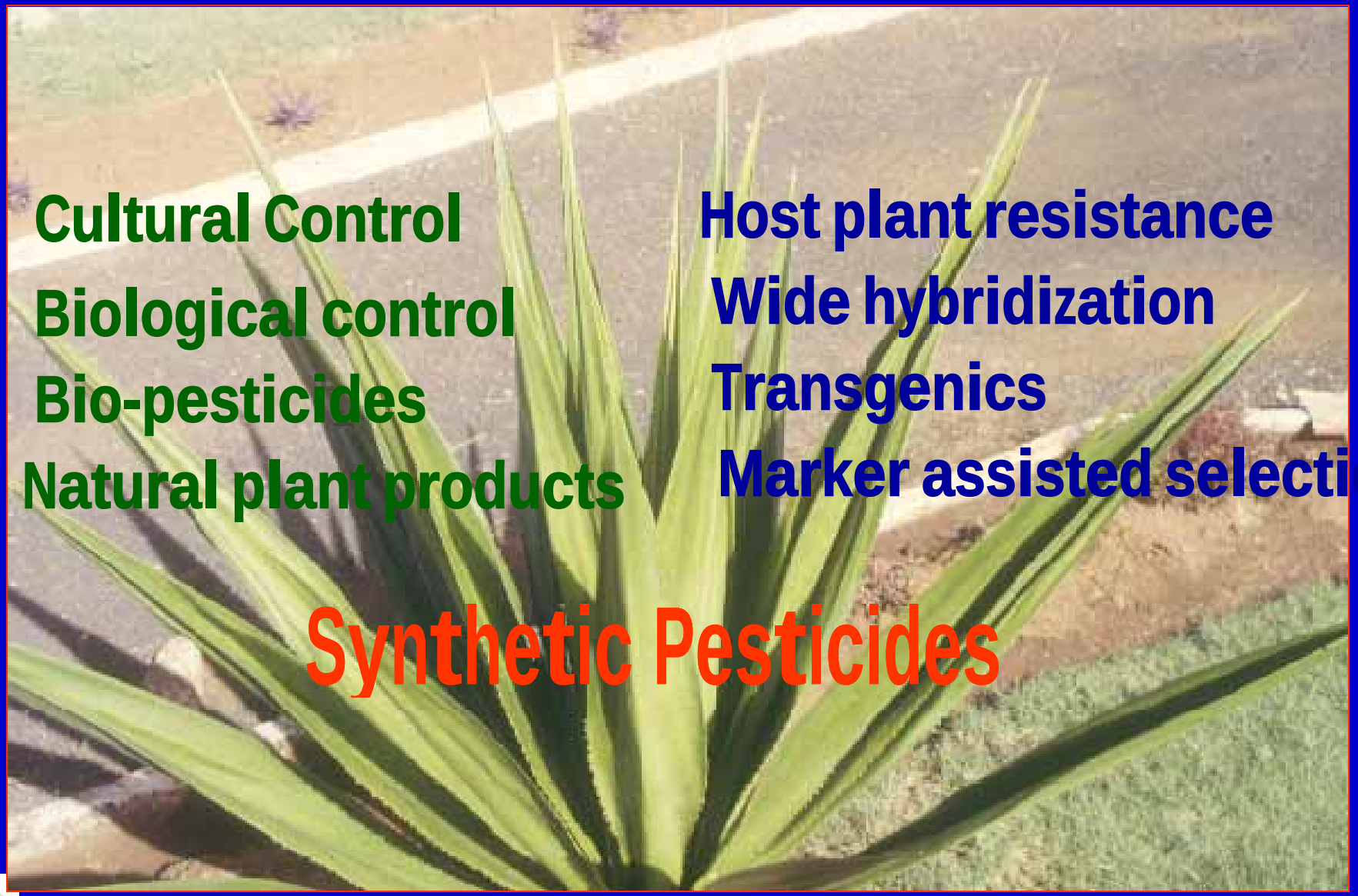
High-yielding Cultivars

Need a Pesticide Umbrella to Maximize Crop Production

- Pest resurgence and development of resistance to insecticides.
- Adverse effects on natural enemies.
- Health hazards, environmental contamination, and harmful residues in food and food products.

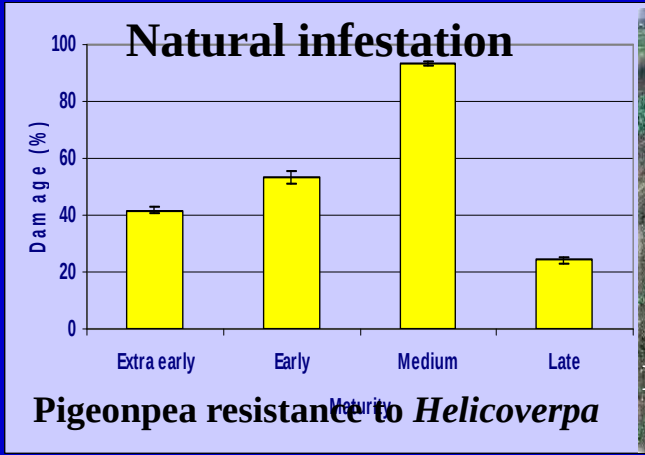
Insect Pest Management

The Options



Identification and Utilization of Resistance to Insects

Use of Infester Rows and Artificial Infestation

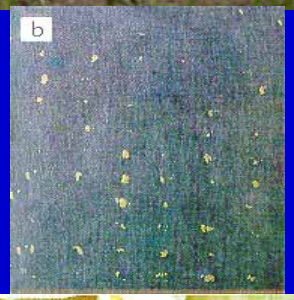


Pigeonpea resistance to *Helicoverpa*

Interlard fishmeal technique
Sorghum shoot fly

Artificial infestation: Stem borer

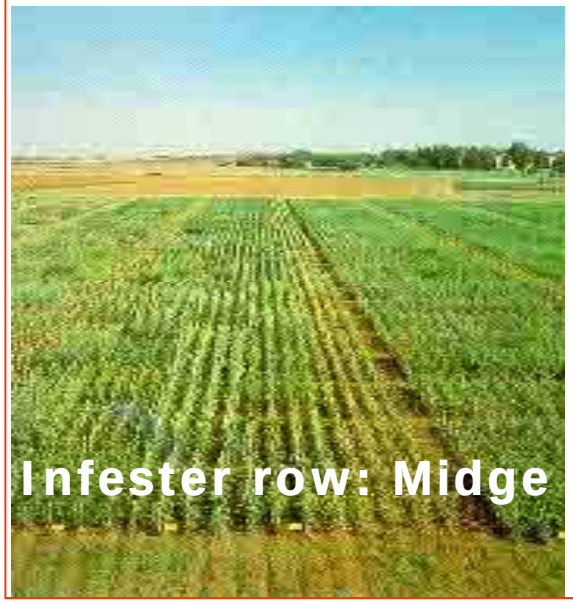
- Adjust the sowing time and use hot spots.
- Use infester rows and sequential plantings.
- Group the material according to maturity.
- Infest the plants with artificially reared insects.



Techniques to Screen for Resistance to Insects

Interlard: Shoot fly

c Cage: Shoot fly


Infester row: Midge

b Headcage: Midge

Headcage: Bugs

Infester row: Head bugs

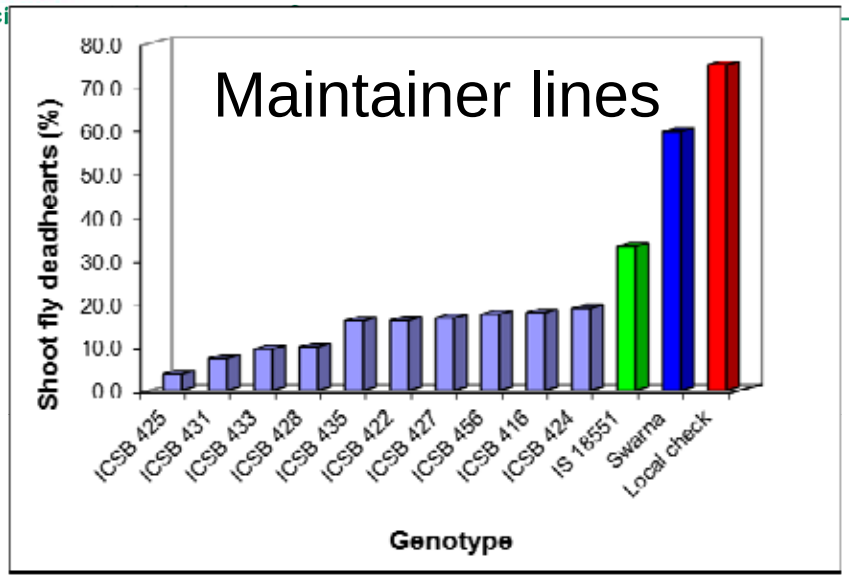
Identification and Utilization of Resistance to Insects

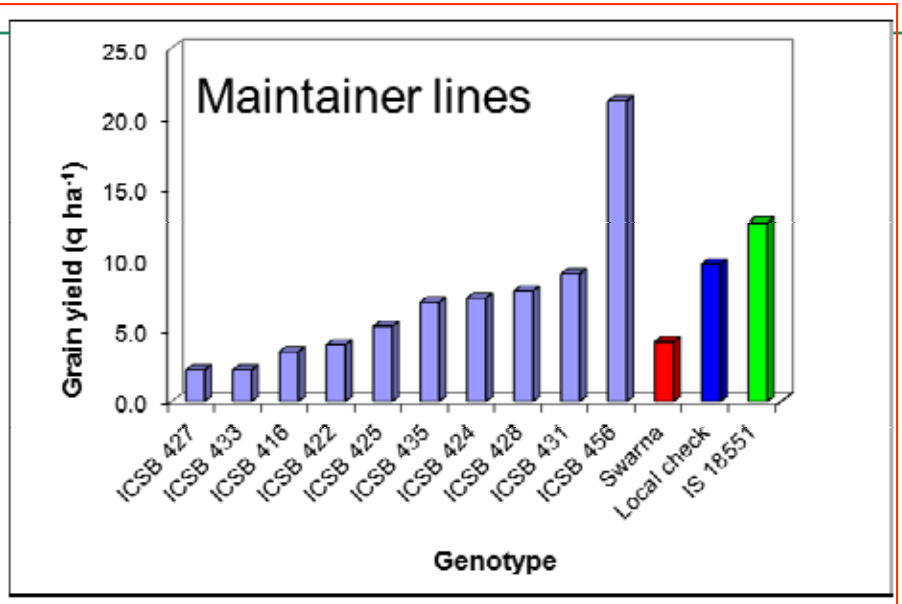
Measurement of Resistance

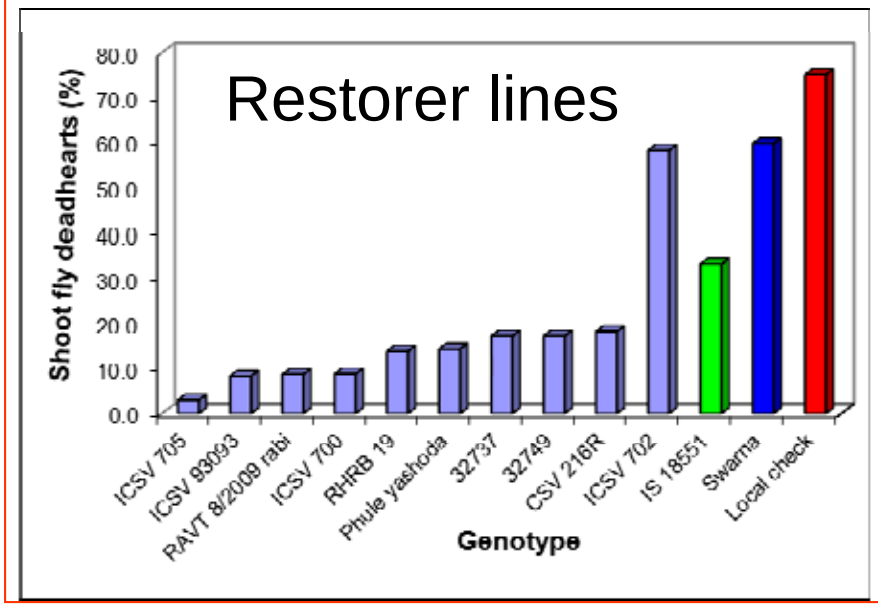
- **Direct measurements**
  - Insect damage: Root, stem, leaf, flower, fruit/grain damage.
  - Yield loss
  - Tolerance: Tiller production or second flush

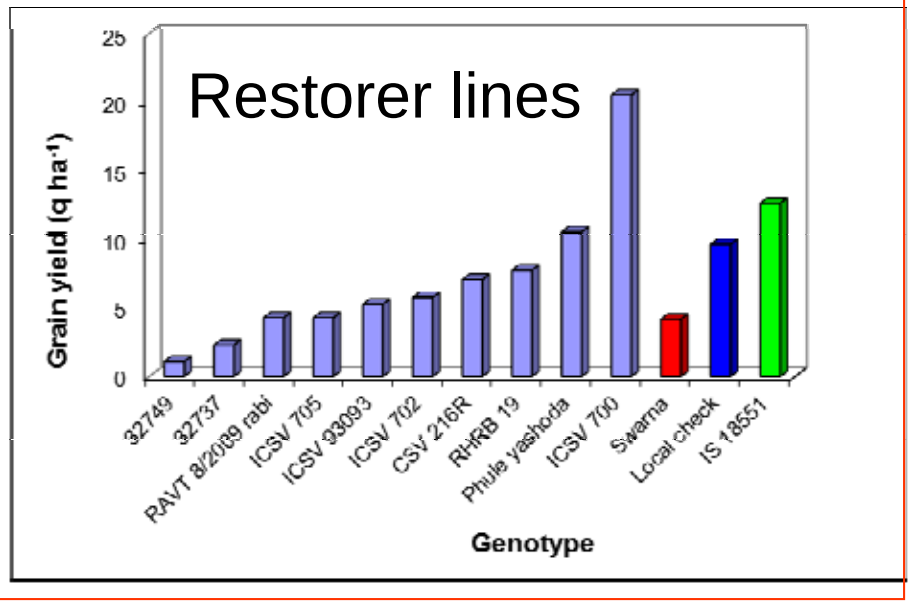
- **Indirect measurements**
  - Oviposition and larval abundance
  - Feeding behavior, electroantennogram, etc.
  - Plant characteristics: Trichomes, leaf hairs, tissue structure, etc.
  - Secondary metabolites such as organic acids, flavonoids, protease inhibitors, etc.

Genotypic Resistance to Sorghum Shoot Fly









Sources and Improved Cultivars of Sorghum with Resistance to Insect Pests

Insect pest	Sources of resistance	Improved varieties
Shoot fly	M 35-1 (IS 1054), IS 1057, IS 2123, IS 2146, IS 4664, IS 2205, IS 5604, and IS 18551.	Swati* (SPV 504), CSV 8R*, Phule Yashoda*, ICSV 700, ICSV 705, ICSV 705, and ICSV 717
Stem borer	IS 1055 (BP 53), IS 1044, IS 2123, IS 2195, IS 2205, IS 2146, IS 5469, and IS 18551.	CSV 8R*, SPV 104, ICSV 700, ICSV 708, ICSV 714, and ICSV 93046.
Midge	IS 2579C, IS 12666C, TAM 2566, AF 28, DJ 6514, IS 10712, IS 7005, IS 8891, and IS 8721	ICSV 197, ICSV 735, ICSV 745* (DSV 3), ICSV 88013, ICSV 758*, and ICSV 88032 (SPV 1010)
Head bugs	IS 17610, IS 17645, IS 21443, and IS 17618, and IS 14332.	Malisor 84-7.

* Released for cultivation. Sharma et al. (1992, 2003) and Singh and Rana (1986, 1989).

Sources of Resistance to Insect Pests in Sorghum

IS 18551: Shoot fly

CSM 388; Head bug

ICSV 745 ICSV 745

Sorghum midge

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Screening for Resistance to Sugarcane Aphid, *Melanaaphis sacchari*

Mechanisms and Inheritance of Resistance

Mechanisms of Resistance to Insects

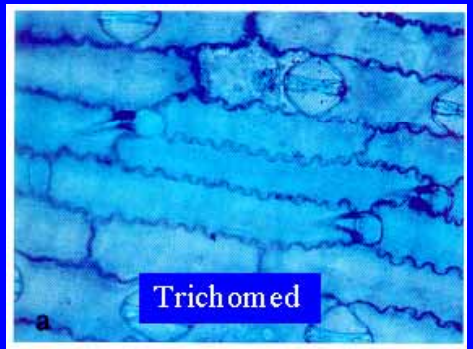
Antixenosis

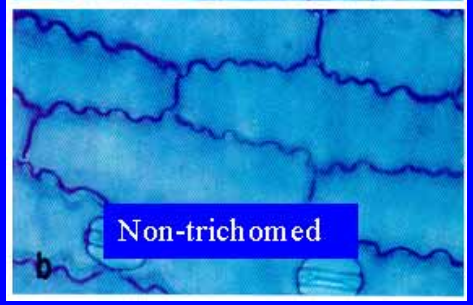
Antibiosis

Tolerance

Components of Resistance to Insects

Morphological Traits: Sorghum Shoot Fly and Stem Borer

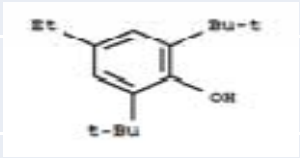
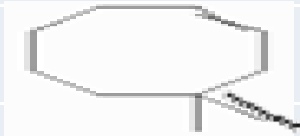
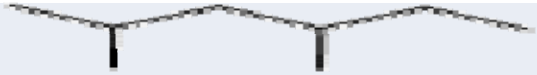




Association of Physico-chemical Traits with Resistance to Sorghum Shoot Fly, *Atherigona soccata*	
Trait	**Correlation coefficient**
Leaf glossiness (X1)	0.96**
Plumule pigmentation (X2)	0.67**
Bottom leaf pigmentation (X3)	0.56*
Trichome (abaxial) (X4)	-0.89**
Trichome (adaxial) (X5)	-0.88**
Magnesium (X6)	-0.69**
Fat (X7)	0.77**
Tannin (X8)	-0.77**
Total soluble sugars (X9)	0.72**

Deadhearts (%) = 83.87 + 1.75 X1 + 0.12 X2 - 0.15 X3 + 1.17 X4 - 0.47 X5 - 0.19 X6 + 0.04 X7 + 0.08 X8 - 0.24 X9.

Chemical Compounds Associated with Sorghum Resistance to *Atherigona soccata*

Compound	Structure
Eicosane	
Tridecane	
Hexanal	
Lonol 2	
Undecane 5- methyl	
4, 4- dimethylcyclooctene	
Decane 4- methyl	
Hexane 2, 4- dimethyl	
Pentadecane 8- hexyl	
Dodecane 2, 6, 11- trimethyl	

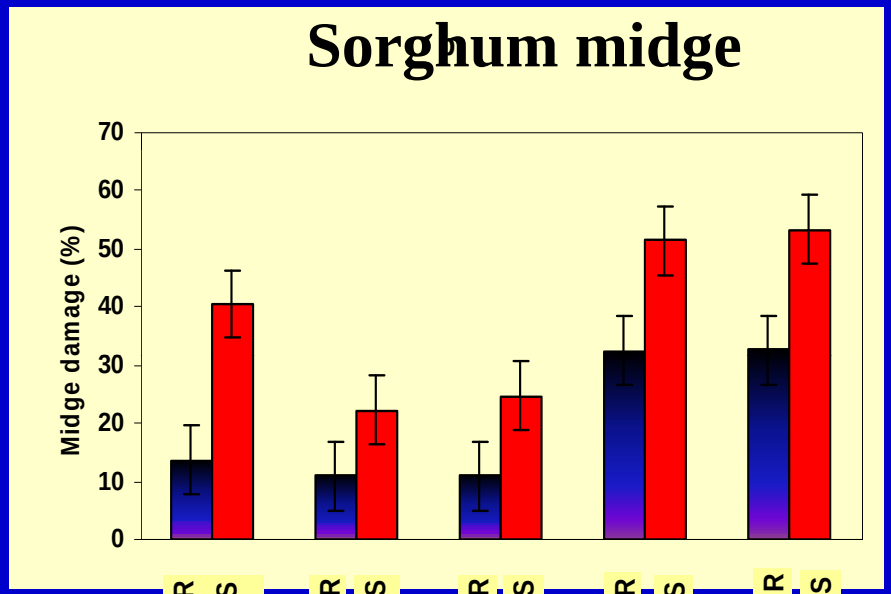
Biochemical Constituents Associated with Resistance to Shoot Fly, *Atherigona soccata*

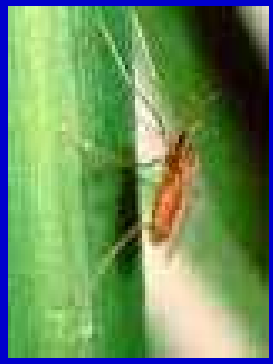
Compound	Deadhearts (%)	Eggs per 10 seedlings
Eicosane	-0.36	-0.40
Tridecane	-0.26	-0.28
Hexanal	-0.03	-0.04
Lonol 2	0.38	0.44
Undecane 5- methyl	0.54*	0.45
4, 4- dimethylcyclooctene	-0.53*	-0.59*
Decane 4- methyl	0.59*	0.52*
Hexane 2, 4- dimethyl	0.56*	0.56*
Pentadecane 8- hexyl	0.52*	0.57*
Dodecane 2, 6, 11- trimethyl	0.89**	0.88**

*, ** Correlation coefficients significant at P < 0.05 and 0.01, respectively.

Effect of CMS on Expression of Resistance to Insects

Sorghum Midge, *Stenodiplosis sorghicola*



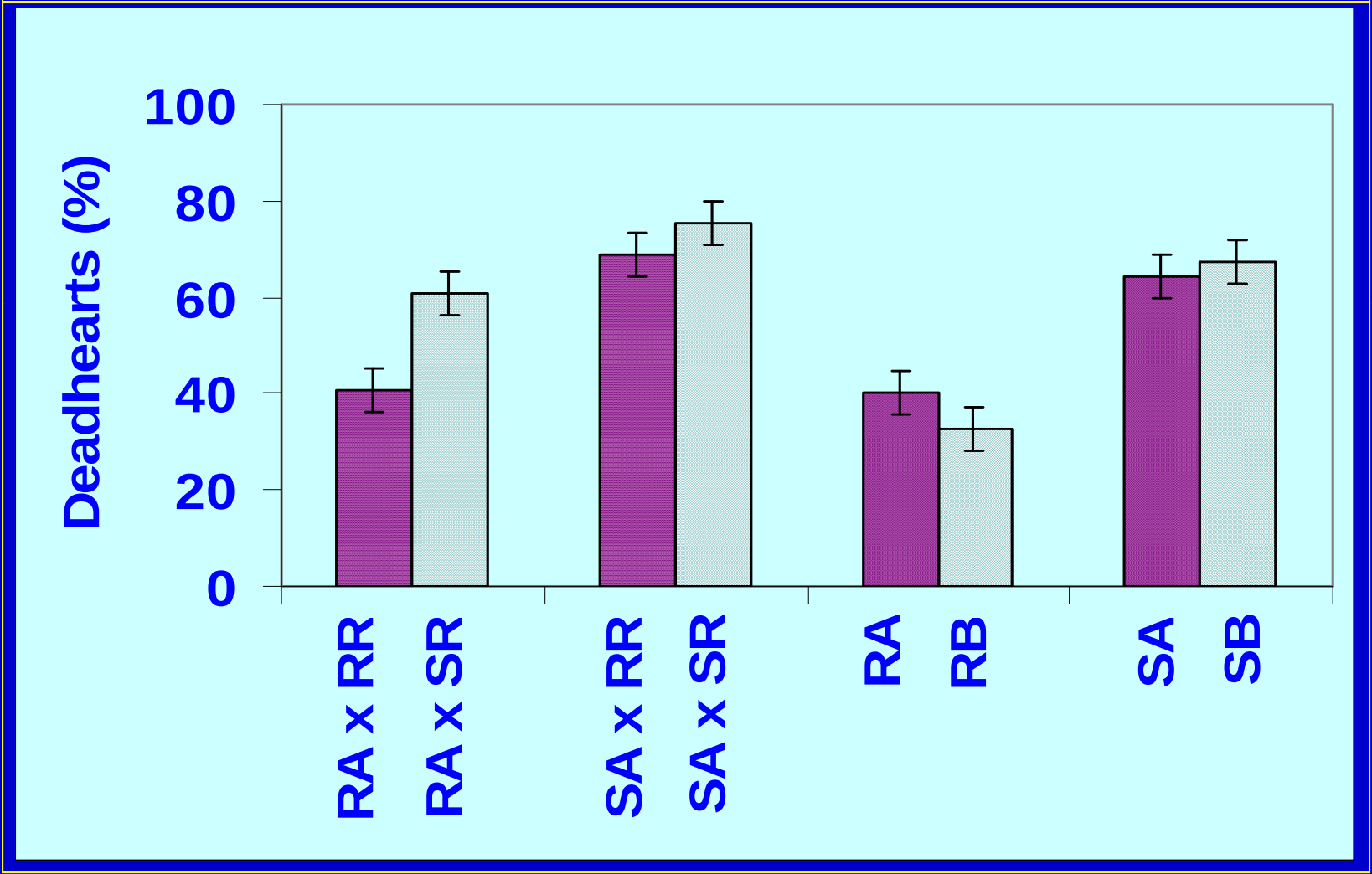


Midge - MR1 = ICSA 88019, MR2 = ICSA 88020, MS1 = 296A, and MS2 = ICSA 42).

Sharma et al. (1996)

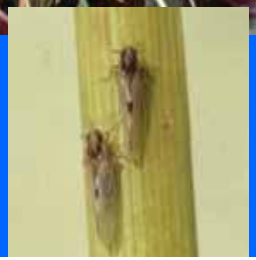
Effect of CMS on Expression of Resistance to Insects

Sorghum Shoot Fly, *Atherigona soccata*



Dhillon,Sharma, and Reddy (2005)

Wide Hybridization



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Relative Susceptibility of Wild Relatives of Sorghum to Sorghum Shoot Fly, *Atherigona soccata*

Section	Species	Accession	Shoot fly Deadhearts (%)		Adult emergence (%)
			Field conditions	No-choice conditions	
Chaetosorghum	*Sorghum macrospormum*	TRC 24112	6.7	61.5	-
Heterosorghum	*Sorghum laxiflorum*	IS 18958	0.0	7.4	6.2
Parasorghum	*Sorghum australiense*	IS 18954	0.0	10.1	4.2
Stiposorghum	*Sorghum angustum*	TRC 243499	0.0	4.0	0.0
Sorghum	*Sorghum eithiopicum*	IS 27584	88.9	-	99.5
	Sorghum virgatum	IS 18808	92.2	-	89.0
	Sorghum bicolor	CSH 1 IS 18551	30.696.7	70.2	50.8
LSD	-	-	5.8	19.6	18.9

Wild Relatives as Sources of Resistance to Insects

Relative Susceptibility of Wild Sorghums to Spotted Stem Borer, *Chilo partellus*

Section	Species	Accession	Deadhearts (%)		Larvae recovered (%)
			Field conditions	Greenhouse conditions	
Heterosorghum	*Sorghum laxiflorum*	IS 18958	0.0	82.5	6
Parasorghum	*Sorghum australiense*	IS 18954	0.0	10.5	0
Stiposorghum	*Sorghum angustum*	TRC 243499	0.0	0.0	6
	Sorghum virgatum	IS 18808	94.5	98.2	55
	Sorghum bicolor	CSH 1	95.5	98.4	90
		IS 18551	58.0	96.8	40
LSD	-	-	10.5	4.4	-

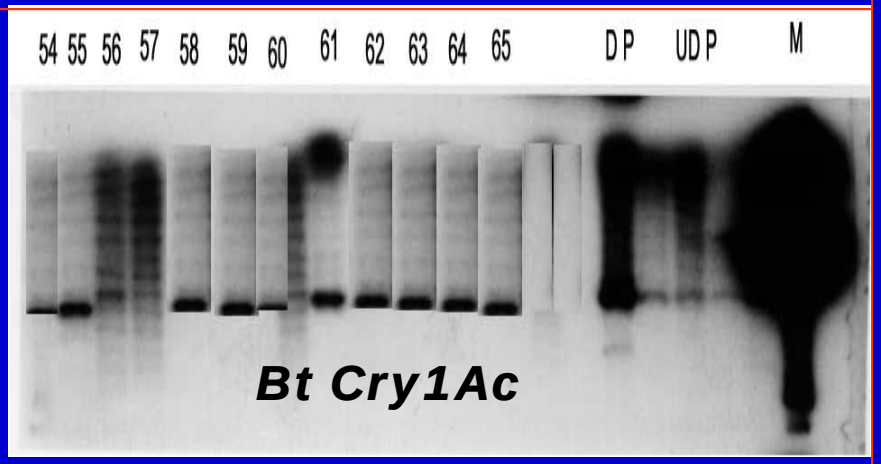
Kamala, Sharma, and Bramel (2003)

Genetic Engineering

Cotton

Genetic Engineering for Insect Resistance

Transgenic Sorghum with *cry1Ac* Bt Gene for Resistance to *Chilo partellus*



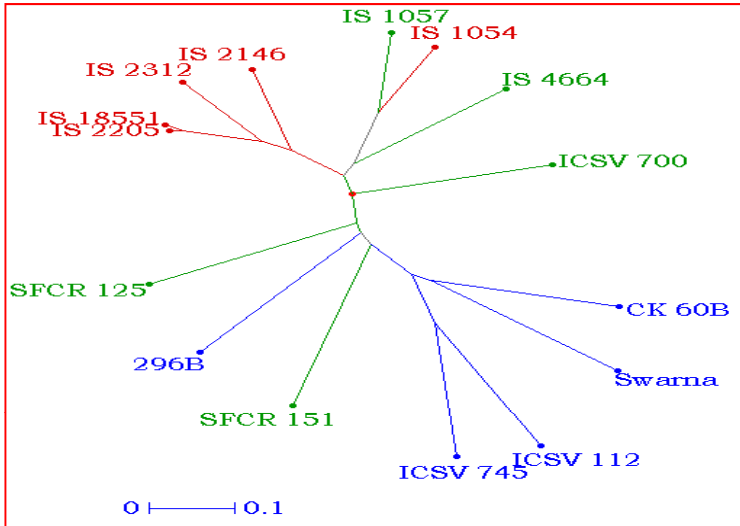
Segregation of resistant and susceptible transgenics for herbicide resistance (after Basta spray test).

Girija Shankar, Sharma, Narsu, and Seetharama (2005)

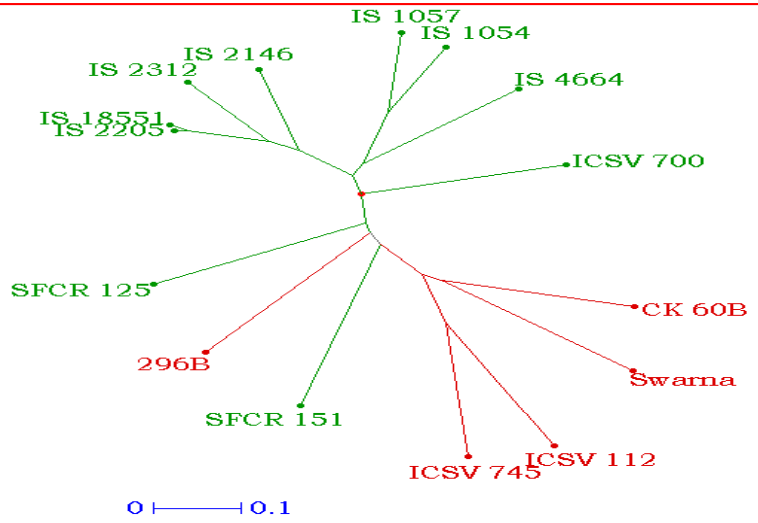
Marker-assisted Selection

Diversity Among Sorghum Lines

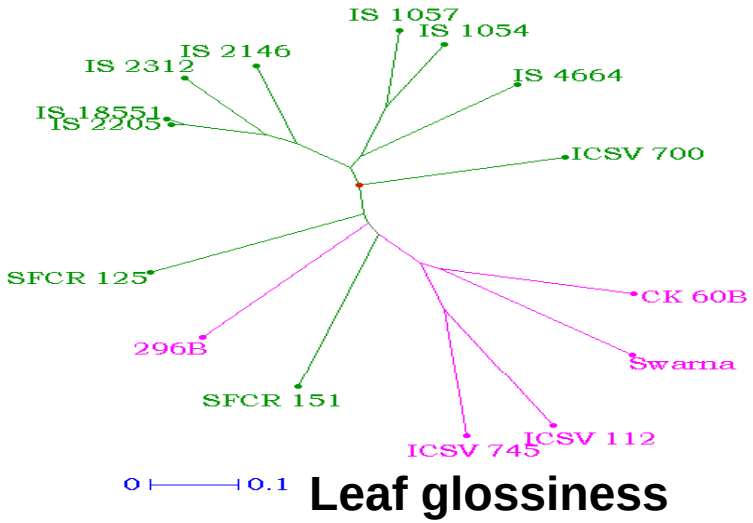
Based on Phenotypic Traits and SSR Markers



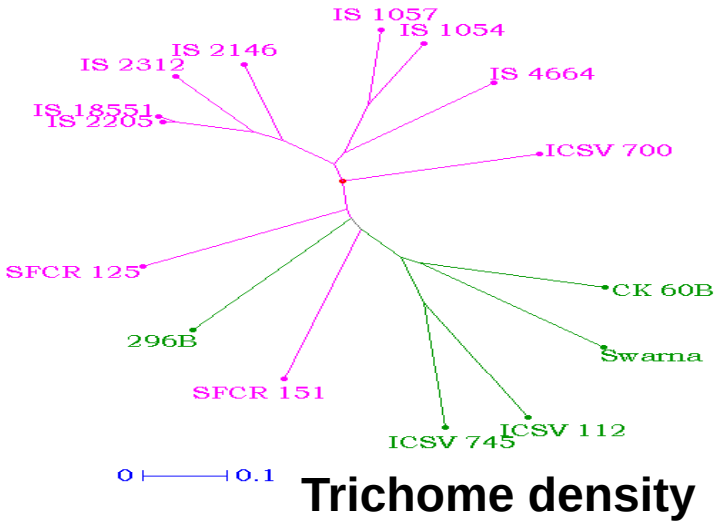
Deadhearts



Leaf surface wetness

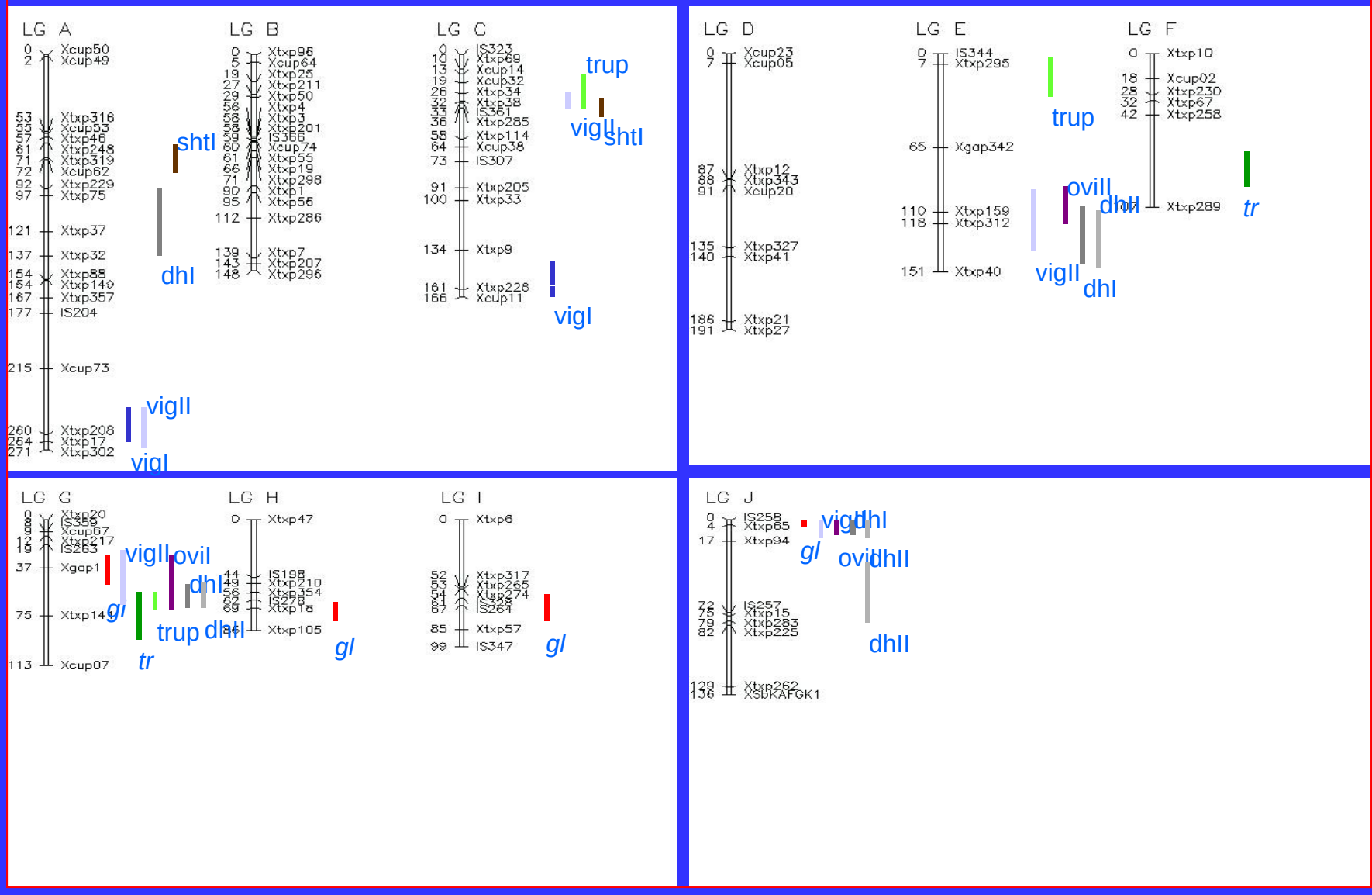


Leaf glossiness



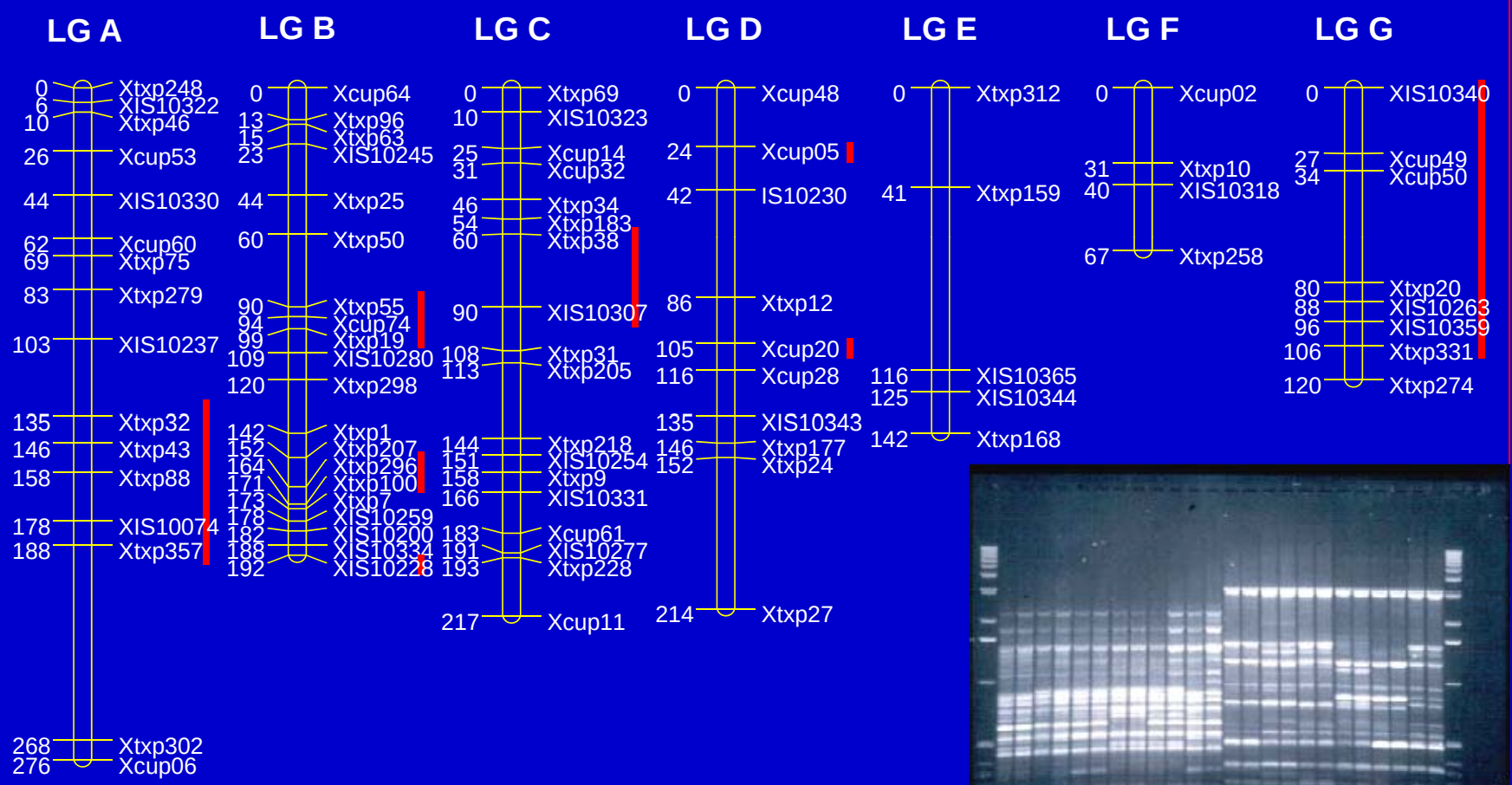
Trichome density

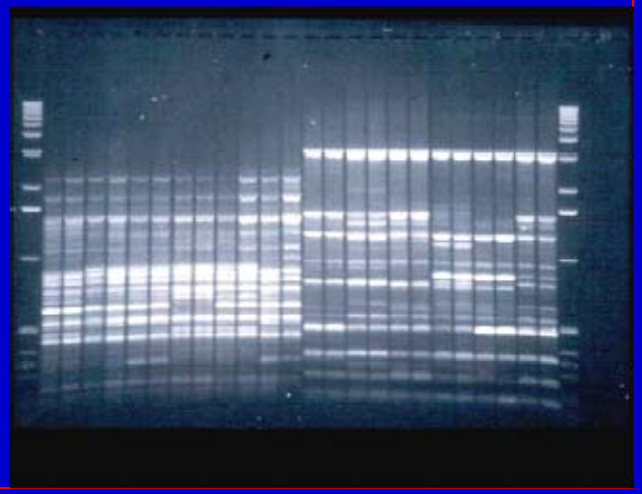
Genetic Linkage Map of Sorghum with QTLs for Resistance to Sorghum Shoot Fly, *Atherigona soccata*



Marker assisted Selection

QTLs for Resistance to Spotted Stem Borer, *Chilo partellus*



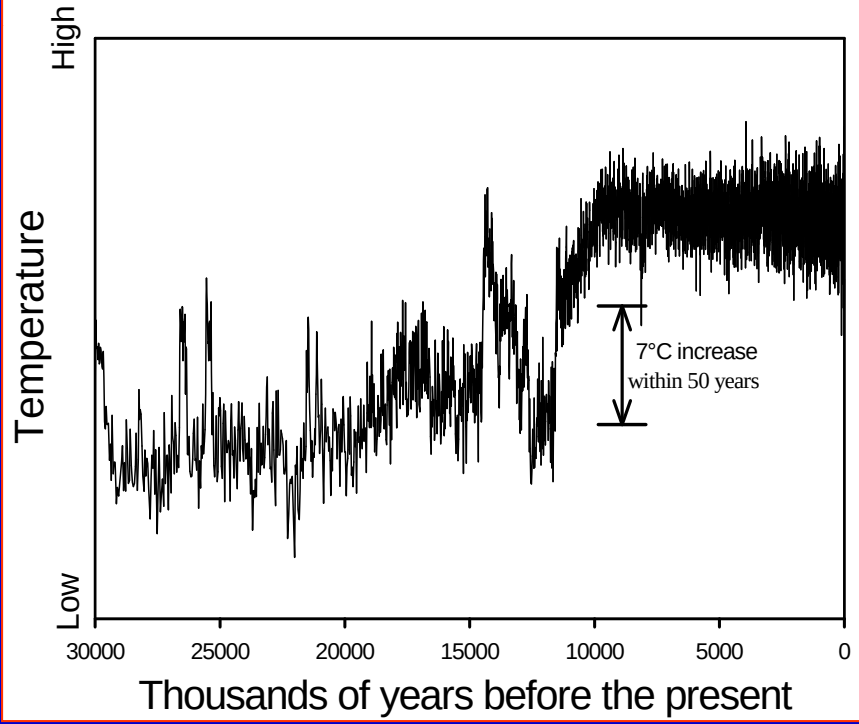


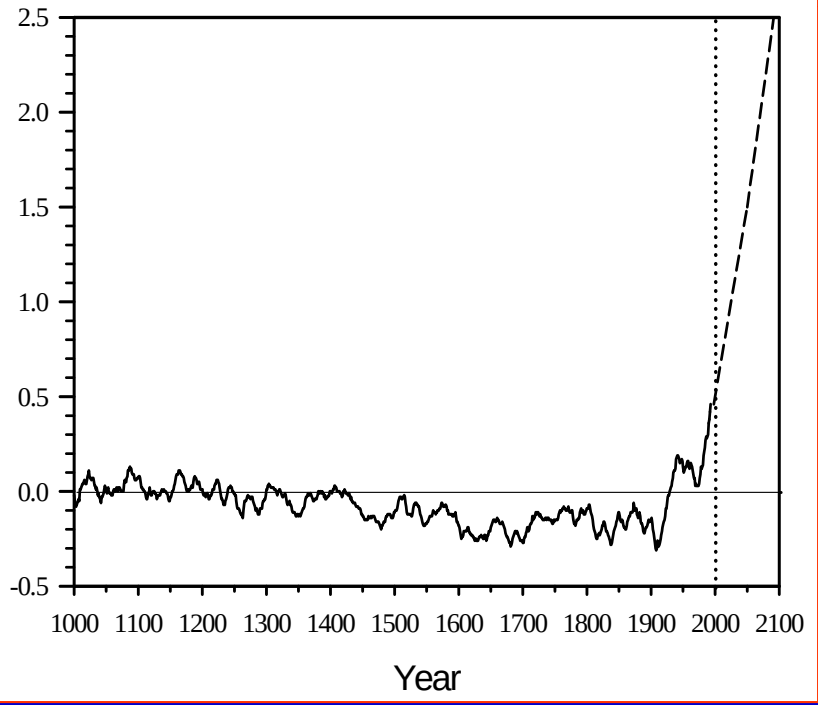
Research in progress on MAS for shoot fly stem borer in sorghum, and *Helicoverpa* in chickpea

Roelfs, Hash, and Sharma (Unpublished)

Climate Variability and Climate Change
Possible Effects on Expression of Resistance to Insect Pests

Climate Change: Bjorn Lomborg's Linear Model



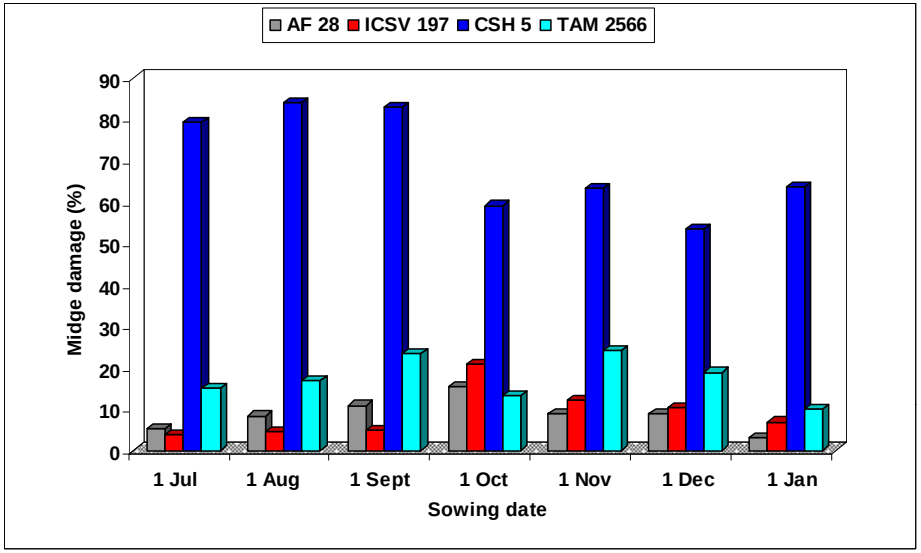


Crowley (2000)

Climate Change Effects on Pest Spectrum in Sorghum

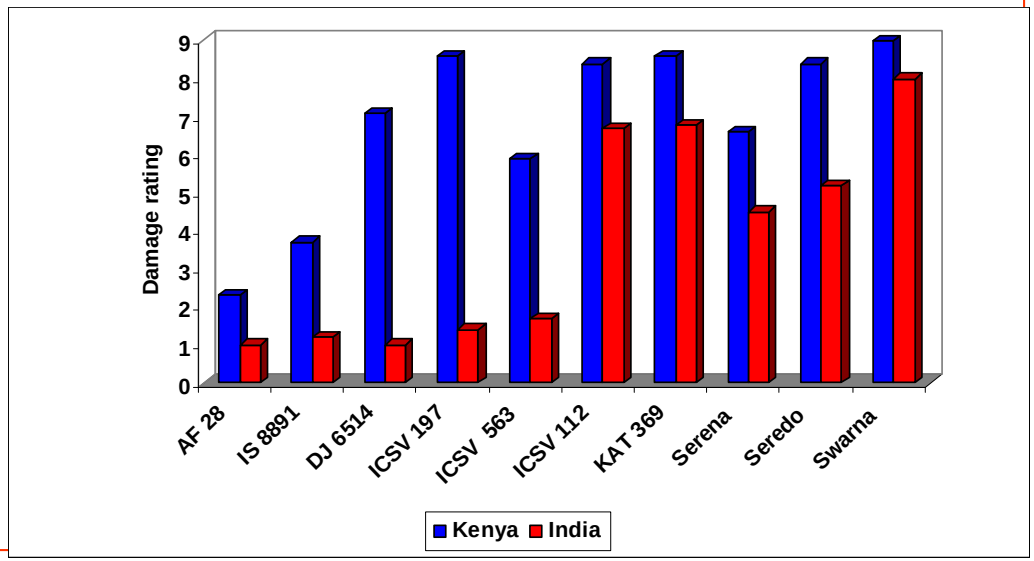
- Many insect pests will extend their geographical range to temperate regions with global warming and climate change.
- The activity of natural enemies of insects will decrease under high temperatures and dry conditions.
- Losses due to stem borers, aphids, and mites will increase under extended periods of drought.
- Lower foliar nitrogen due to high CO_2 increases food consumption by insects.
- Expression of resistance to shoot fly, stem borers, midge, and aphids will decrease under high temperatures in drought stress.

Expression of Resistance to Sorghum Midge, *Stenodiplosis sorghicola* Across Sowing Dates and Locations



Change in resistance reaction across sowing dates in India

Change in resistance reaction across locations in India and Kenya



Sharma et al. (1994, 1997)

Host Plant Resistance in Pest Management

Helicoverpa: ICPL 332 - R

Helicoverpa: ICPL 88039 - MR

As a principal component of pest control.
As an adjunct to cultural, biological, and chemical control.
As a check against the release of susceptible cultivars.

Shoot fly: IS 18551 - R

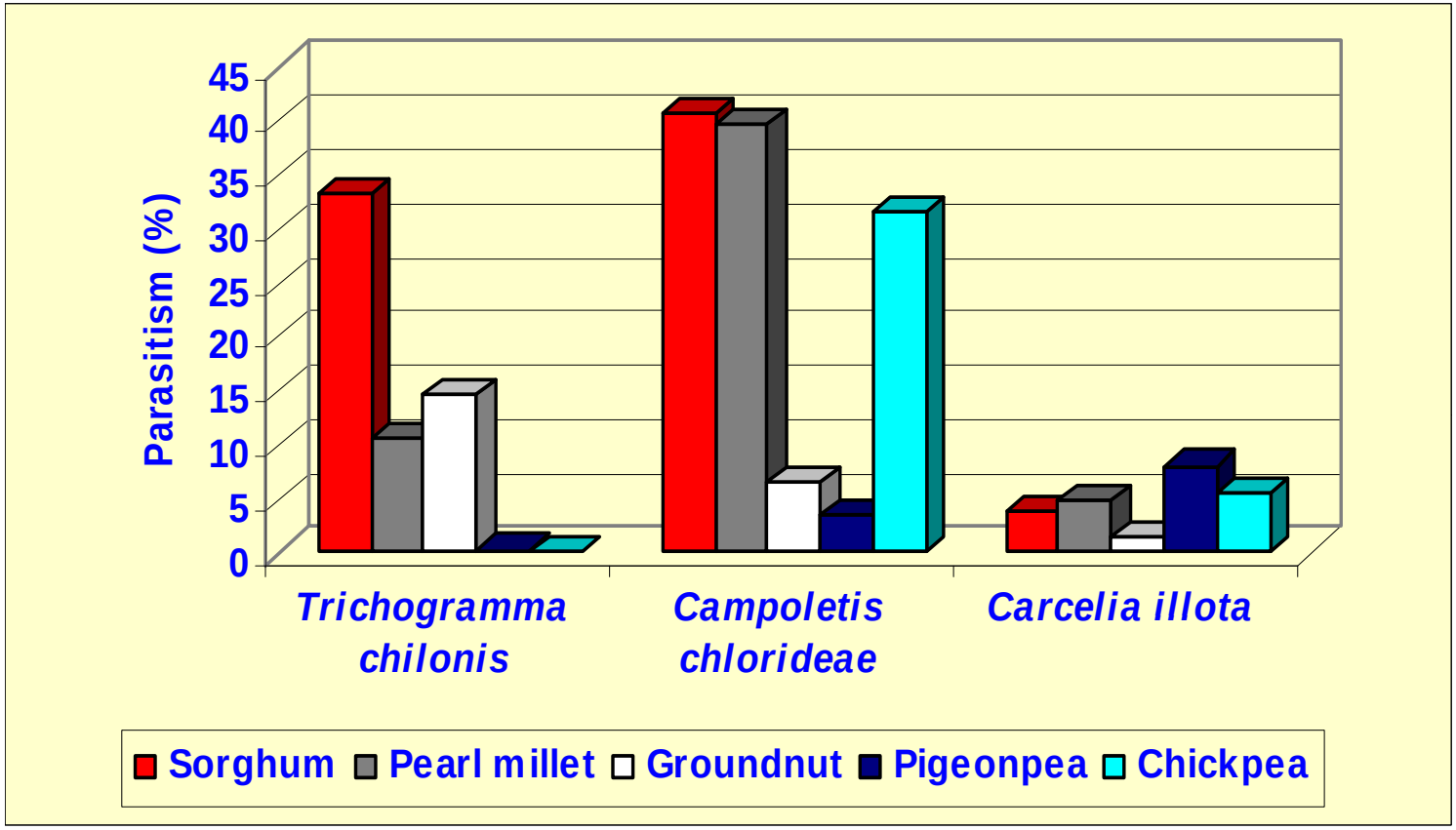
Sorghum Midge: ICSV 745 - R

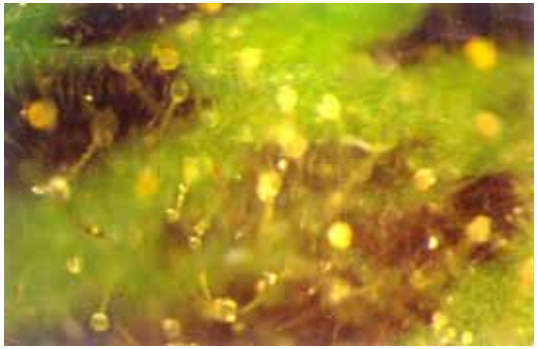
Cultural and Mechanical Control

Timely planting.
Synchronous maturity.
Interculture and flooding.
Hand picking of insect larvae.
Crop diversification.
Water and nutrient management.
Use of inter, strip and trap cropping.

Farmers will not follow them unless physically practical and economically viable.

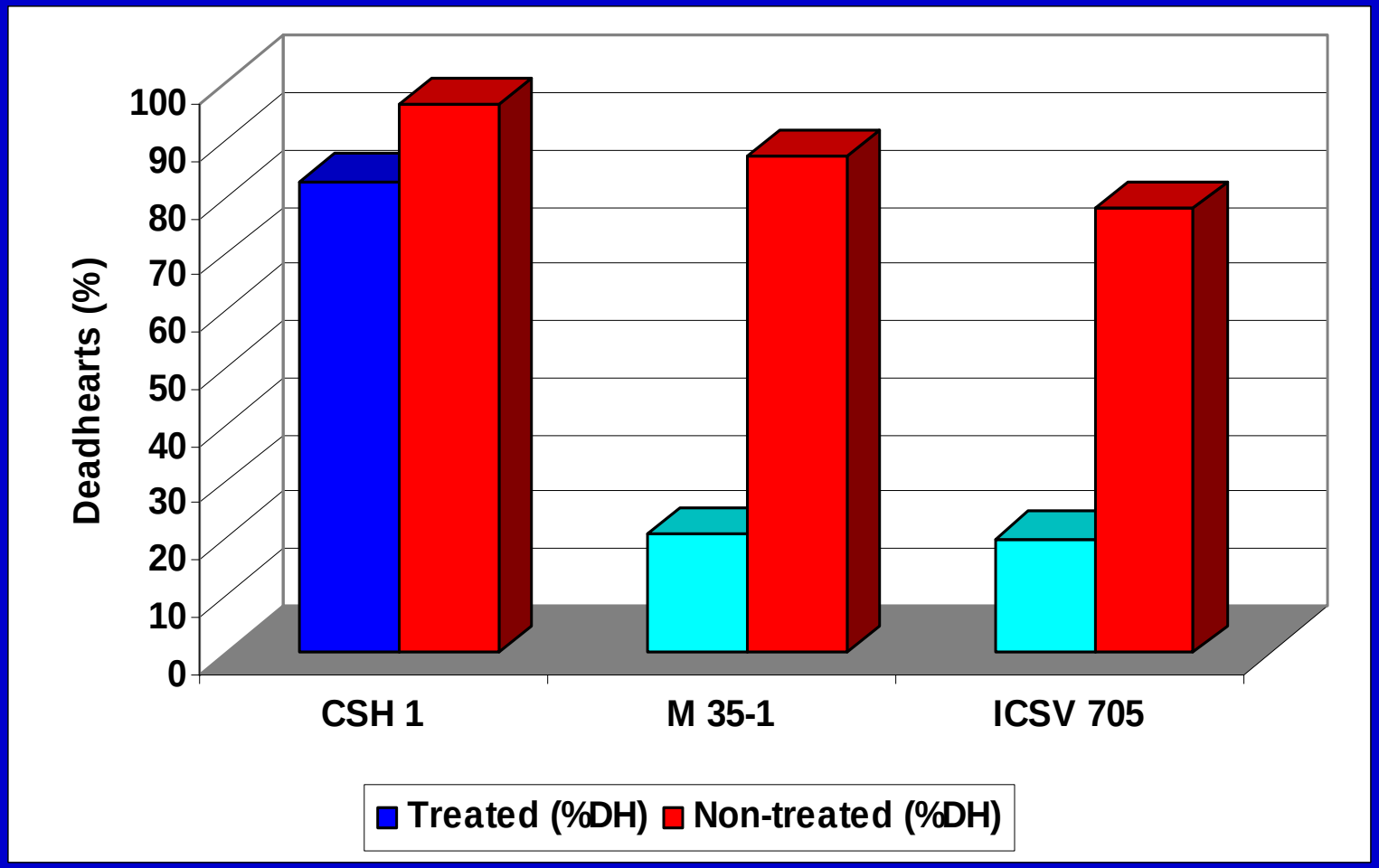
Biological Control: Effectiveness and Limitations





Host Plant Resistance to Insects

Synergism of HPR to Shoot Fly in With Insecticides Sorghum



Sharma (2002)

HPR in Integrated Pest Management

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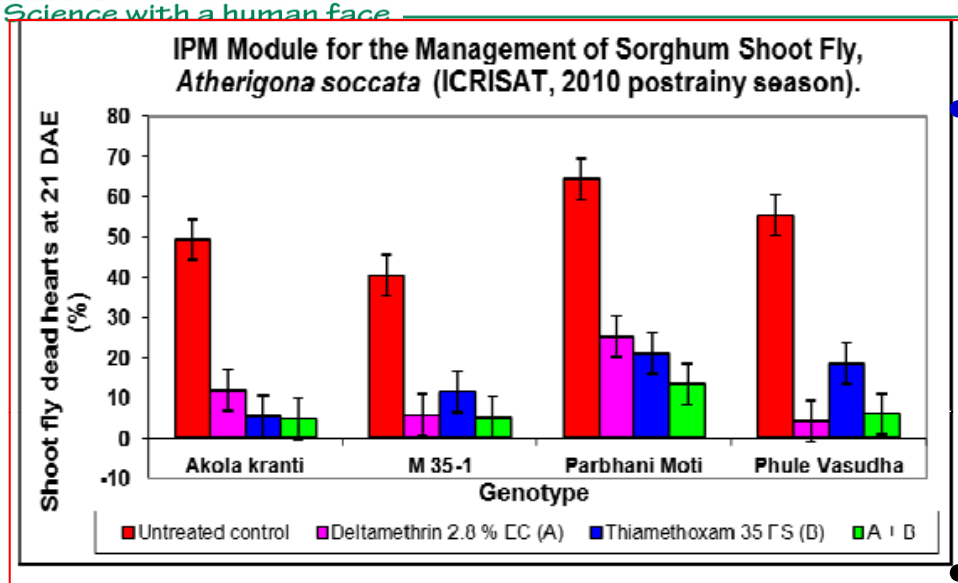
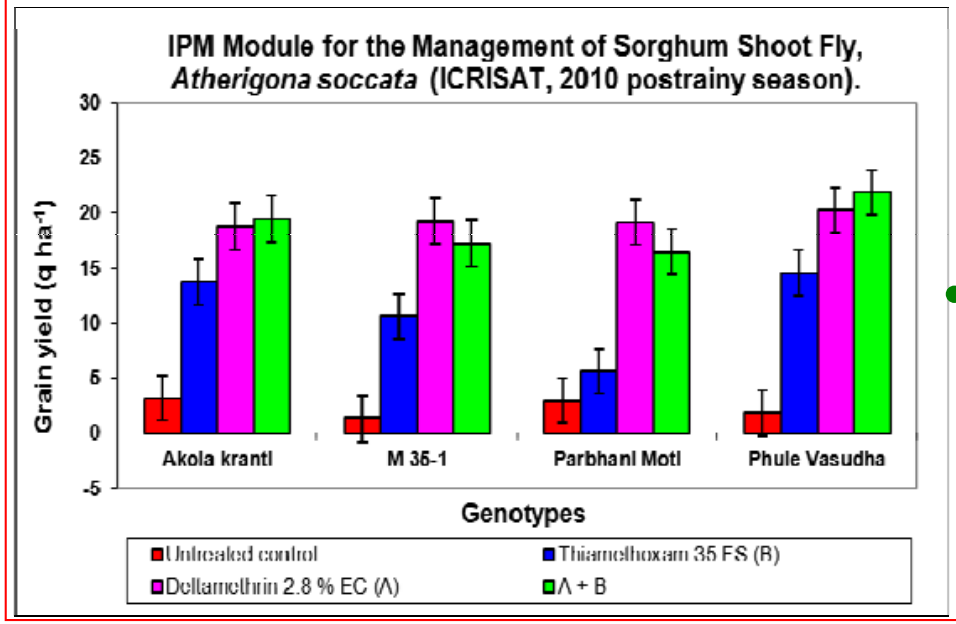




- **Shoot fly-resistant varieties + seed treatment with thaimethoxam + sprays of deltamethrin are very effective for shoot fly control.**
- **IPM resulted in yield increase by 3 – 5 times over the untreated control plots.**
- **This technology has been adopted on a large-scale in Maharashtra under HOPE project funded by BMGF.**

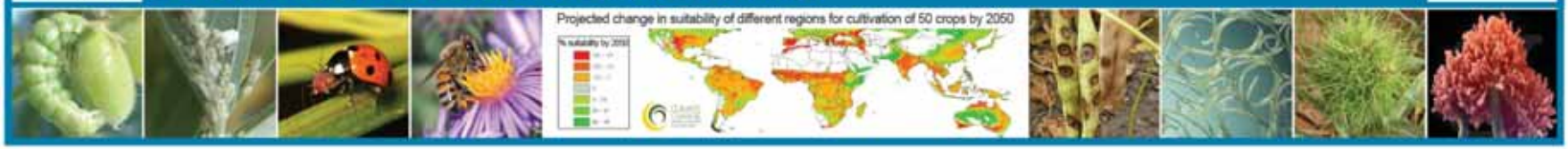
HPR to Insect in Sorghum IPM

Conclusions

- HPR is, and will continue to be an important component of IPM for sustainable crop production.
- Both conventional and biotechnological approaches should be used to increase the levels and pyramid the resistance genes for insect pests and diseases.
- There is great potential to introgress insect resistance genes from wild relatives through wide hybridization and gene cloning.
- Need to combine HPR with other components of pest management and assess their usefulness for sustainable crop production.

XIX International Plant Protection Congress | IPPC2019

10 - 14 Nov 2019, Hyderabad, Telangana, India



Crop Protection to Outsmart Climate Change for Food Security and Environmental Conservation

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Society of Pesticide Science India

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Thank You

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