Biology and Management of the Red Palm Weevil : India

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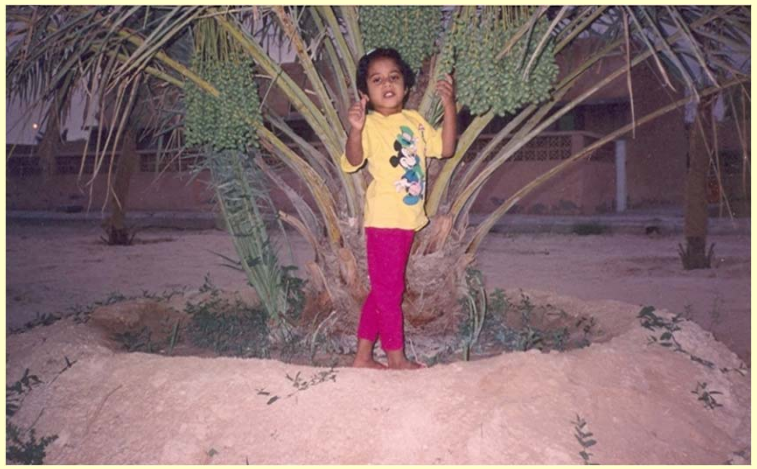
Early references on the red palm weevil *Rhynchophorus ferrugineus*

- 1891 in Indian Museum Notes (1891/3).
- Lefroy, 1906 described it as a deadly insect pest of coconut palm throughout India.
- Ghosh (1912) gave a brief life history of the weevil.
- Fletcher (1914, 1917, 1919) described the biology and habits of the pest and suggested the destruction of all attacked, dying and dead palms for the effective control in India.
- Buxton (1918) – Mesopotamia ???

Host range of *R. ferrugineus*. (1956 to 1998)

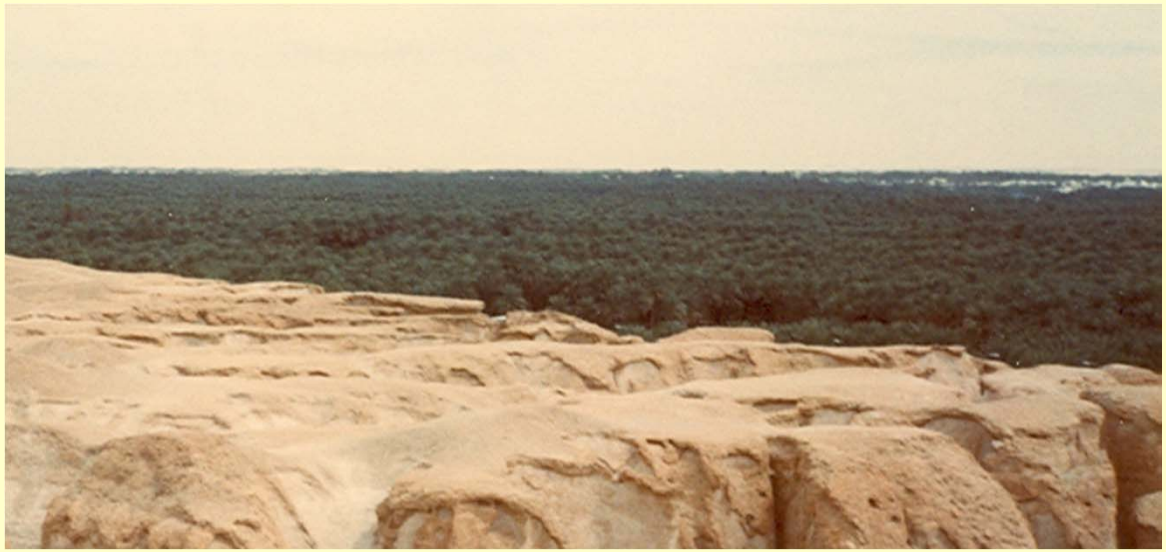
Sr. No.	Host Palm Species	Reference
1	*Cocos nucifera*, *Phoenix dactylifera*, *Metroxylon sagu* and *Corypha umberaculifera*	Nirula, 1956
2	*Cocos nucifera*, *Areca catechu*, *Arenga pinnata*, *Caryota* sp. *Coelococcus* sp., *Corypha* sp., *Elaeis guineensis*, *Livistona* sp., *Metroxylon sagu*, *Nypa* sp., *Oncosperma* sp. and *Phoenix* sp.	Lever, 1969
3	*Areca catechu*, *Arenga pinnata*, *Borassus flabellifer*, *Caryota maxima*, *Caryota cumingii*, *Cocos nucifera*, *Corypha gebanga*, *Corypha umberaculifera*, *Corypha elata*, *Elaeis guineensis*, *Metroxylon sagu*, *Oreodoxa regia*, *Phoenix canariensis*, *Phoenix dactylifera*, *Phoenix sylvestris*, *Sabal umbraculifera*, and *Washingtonia* sp. *Chamaerops humilis and Howea forsteriana (syn. Kentia forsteriana)*	Esteban-Duran *et al*., 1998 (OJEU, 2008; EPPO, 2009).

Most preferred hosts –*Phoenix canariensis*, *P. dactylifera* and *Cocus nucifera*



Elche, Spain

Heritage/ Historic Date Palms

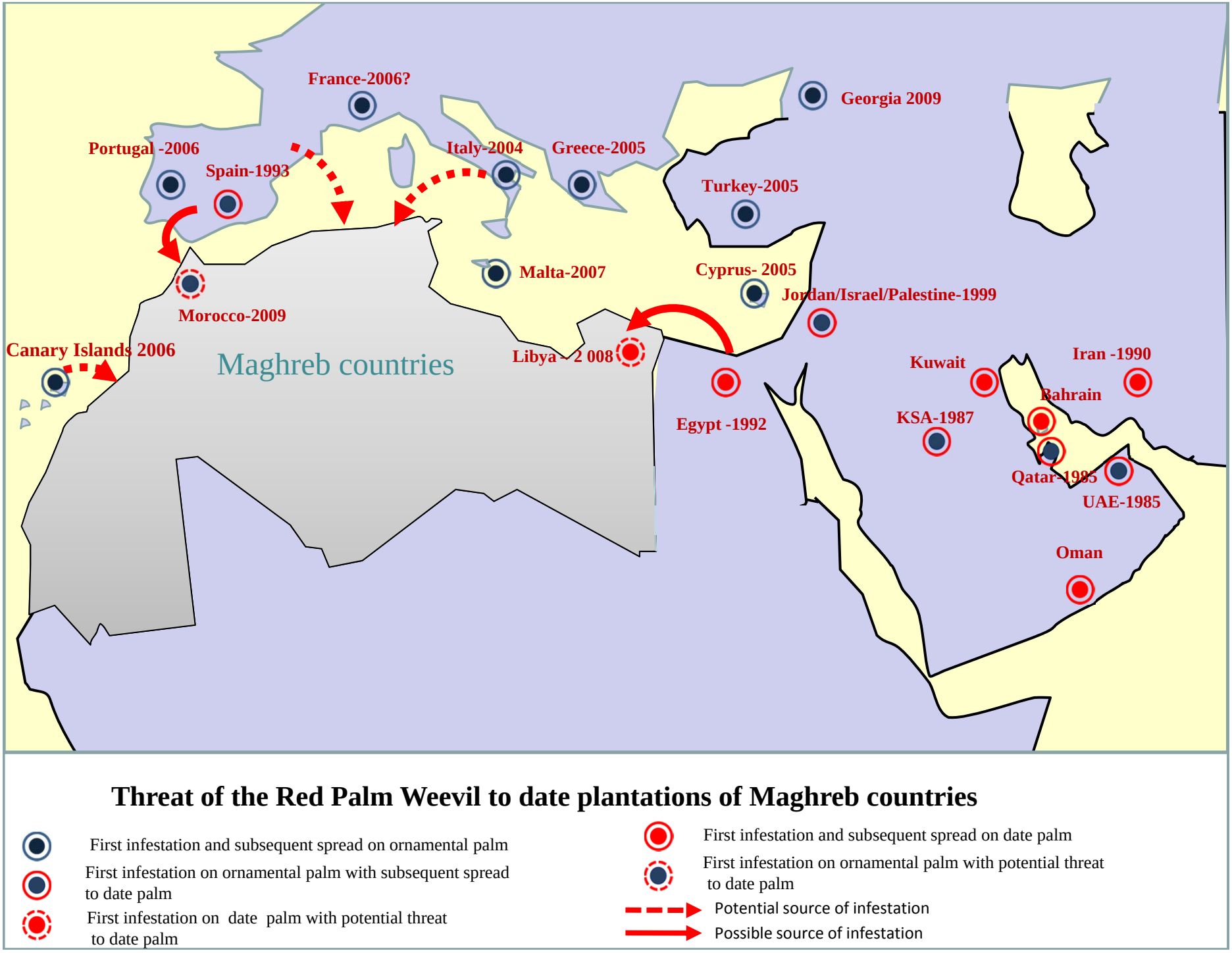


Al Hassa, Saudi Arabia

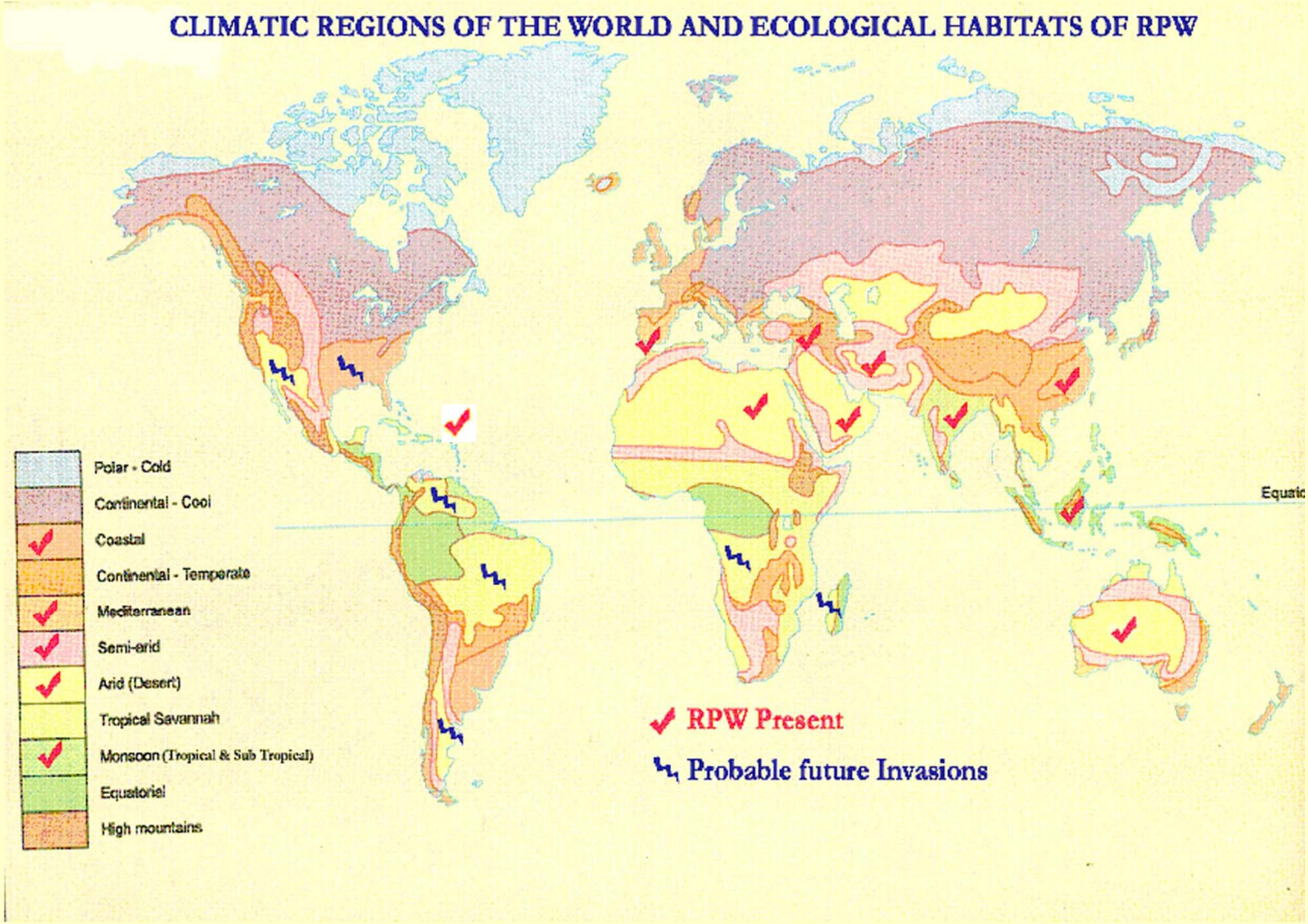
Geographical distribution of RPW

India*	Thailand	UAE (1985)	Egypt** (1992)	Spain** (1995)	Curacao Islands (Caribbean-2009)
Pakistan	Cambodia	Qatar	Morocco**	Turkey**	
Sri Lanka	Vietnam	Saudi Arabia	Libya** (2009)	Italy**	
Myanmar	China*	Kuwait		Greece**	
	Taiwan	Oman		France**	
	Philippines	Bahrain		Portugal**	
	Malaysia	Israel		Cyprus**	
	Indonesia	Palestine		Malta**	
	Timor	Jordan		Georgia (2009)	
	Papua New Guinea	Iran			
	Solomon Is./Australia	Iraq ? (1918)			
		Lebanon (2010)			

* Grow coconut & date palm ** *P. canariensis*


France-2006?
Georgia 2009
Portugal -2006
Spain-1993
Italy-2004
Greece-2005
Turkey-2005
Malta-2007
Cyprus- 2005
Jordan/Israel/Palestine-1999
Morocco-2009
Canary Islands 2006
Maghreb countries
Libya – 2 008
Egypt -1992
Kuwait
Iran -1990
Bahrain
KSA-1987
Qatar-1985
UAE-1985
Oman
Threat of the Red Palm Weevil to date plantations of Maghreb countries
First infestation and subsequent spread on ornamental palm
First infestation on ornamental palm with subsequent spread to date palm
First infestation on date palm with potential threat to date palm
First infestation and subsequent spread on date palm
First infestation on ornamental palm with potential threat to date palm
Potential source of infestation
Possible source of infestation

CLIMATIC REGIONS OF THE WORLD AND ECOLOGICAL HABITATS OF RPW



Cultivation of coconut & date palm vis-à-vis RPW

- Coconut cultivated in 92 countries (26 million ha)
  - Indonesia, Philippines, India
  - 14 countries infested with RPW (15 %)

- Date palm grown in 30 countries (12 million ha)
  - Egypt, Iran, Saudi Arabia
  > 15 countries infested with RPW (50 %)

Gulf region of the Middle-East : GCC countries

(Saudi Arabia, UAE, Oman, Bahrain ,Kuwait ,Qatar)

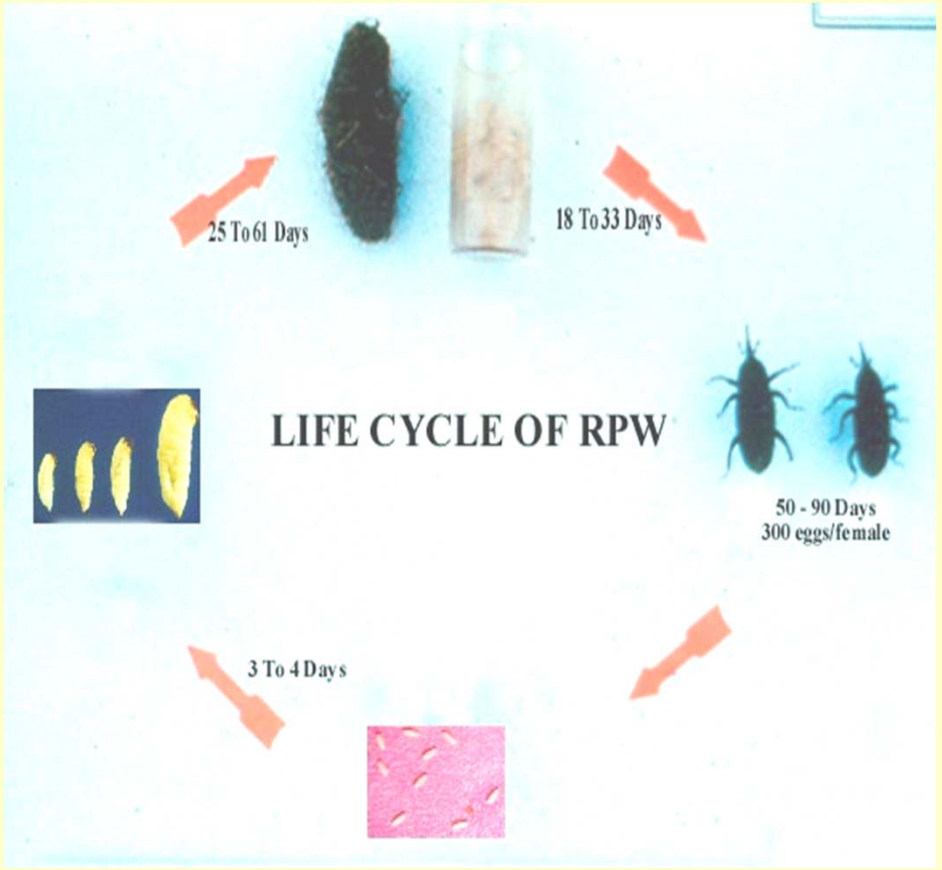
30 per cent of the global date production

70 % of the area :26million palms in the susceptible age group (< 20 years)

At 1 and 5 per cent infestation (20% Eradication @USD 100/palm)
Estimated annual loss : $ 5.18 to 25.92 million, respectively

Life history of *Rhynchophorus ferrugineus*

Character	Number in days
No. of eggs/ female	127 –276 Concealed
Incubation period	3 – 4
Larva: Larval period	25 –61 Concealed
Pupal period	18 – 33 Concealed
Adult	48 – 82 Concealed/Exposed



Minimum lethal temperature
10^0 C for eggs
15^0 C for larvae
0^0 C for pupae
(Martin and Cabello, 2005, Cabello, 2006)

Species of *Rhynchophorus*

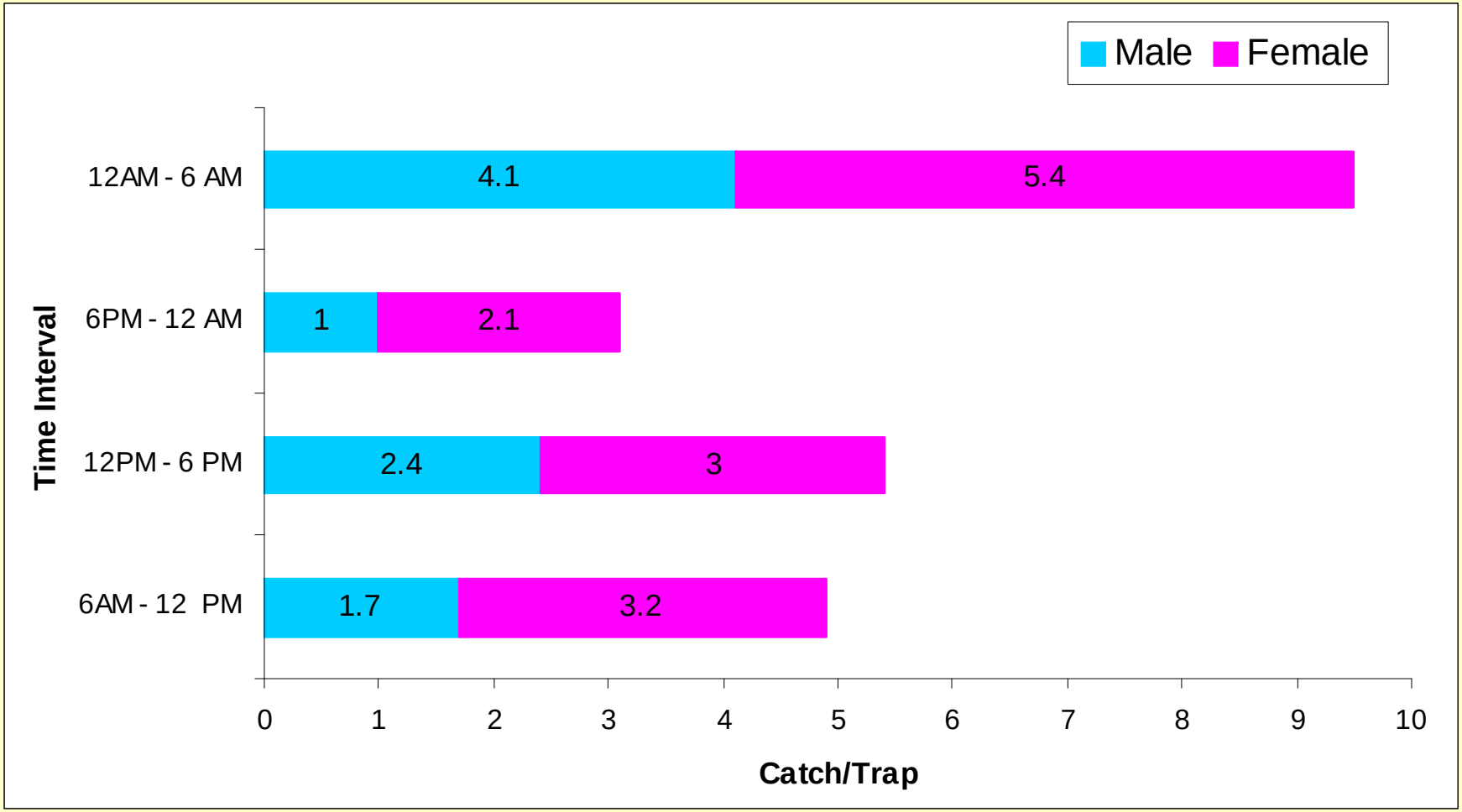
*Rhynchophorus ferrugineus***

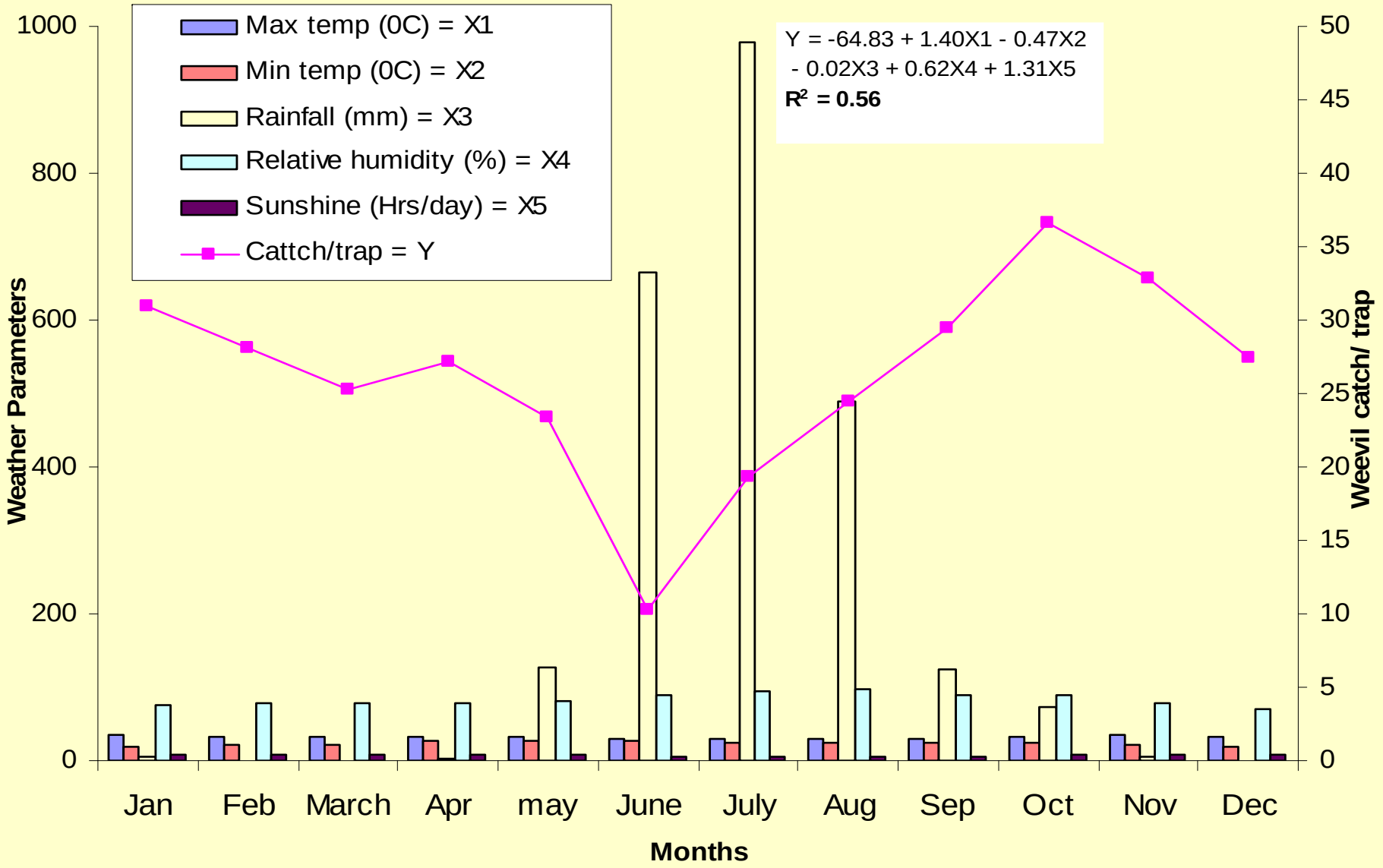
R. bilineatus
R. quadrangulus
R. palmarum
R. bilineatus
R. lobatus
R. distinctus
R. ritcheri
*R. vulneratus**

*Hallet *et. al.*, 2004 (Synonymy of *R. ferrugineus* and *R. vulneratus*) morphological / molecular-genetic and breeding data.

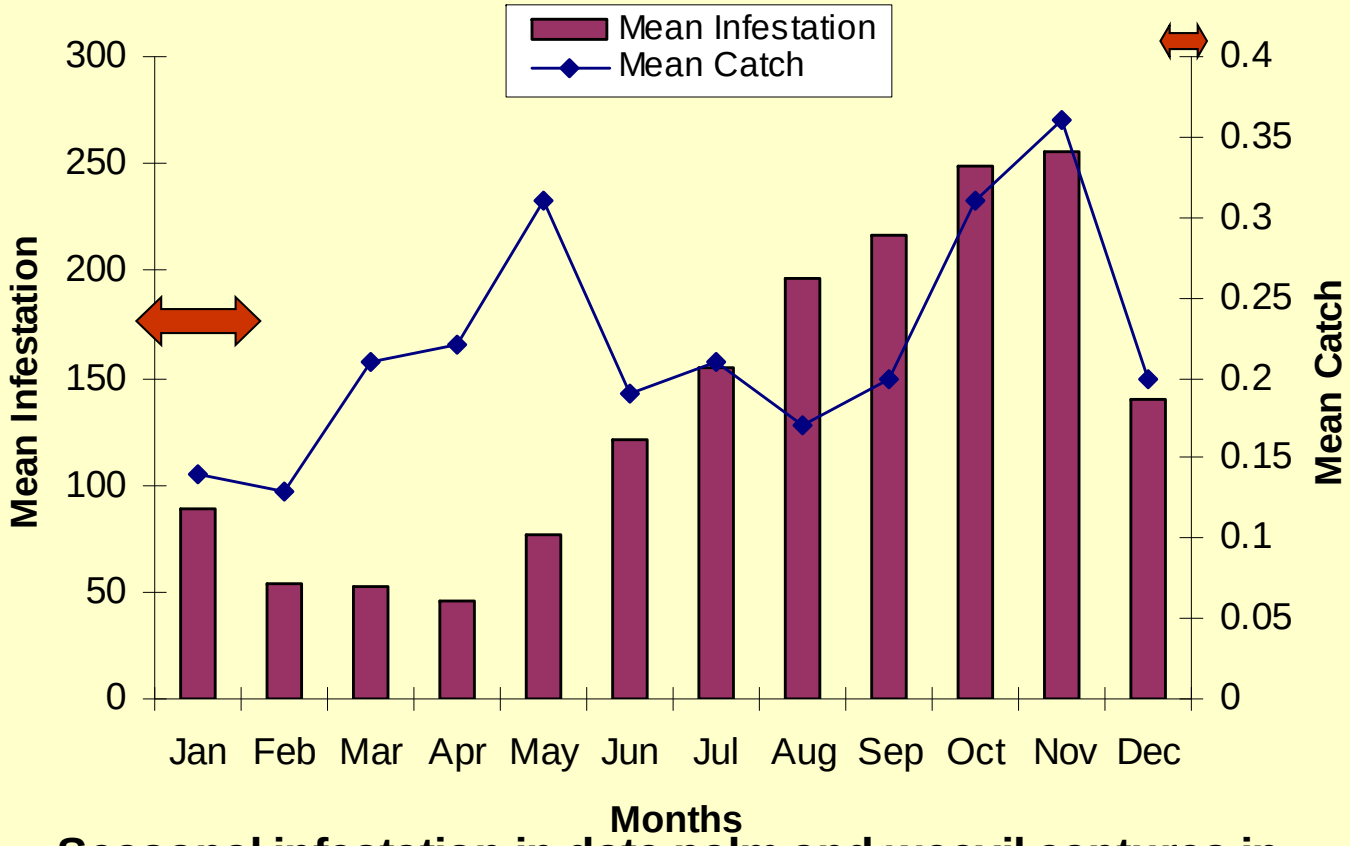
** Possibility of phenotypic forms (Al-Ayed et.al.,2006, Salama and Saker,2002)

Diurnal activity of red palm weevil *Rhynchophorus ferrugineus* Oliv. in Goa, India (May, 2002 & November, 2002).





Monthly mean weevil captures in relation to weather parameters in Goa, India (January, 2000 to December, 2001)



Seasonal infestation in date palm and weevil captures in pheromone traps (Al-Hasa, Saudi Arabiaa, 1994 - 1997)

Predisposing factors for RPW attack/ build up

Neglected gardens

- - - Wounds on palm - - -

Breeding site – cut palm

Closed garden

Several Offshoots

Symptoms of Damage

(i) presence of tunnels on the trunk and base of leaf petiole

(ii) gnawing sound due to feeding by grubs

(iii) oozing out of thick brown fluid from the tunnels

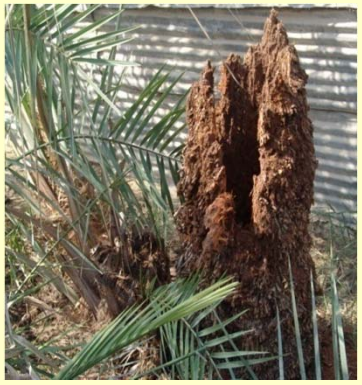
(iv) appearance of chewed plant tissues in and around opening of tunnels with a typical fermented odor

(v) fallen empty pupal cases and dead adults around a heavily infested palm and

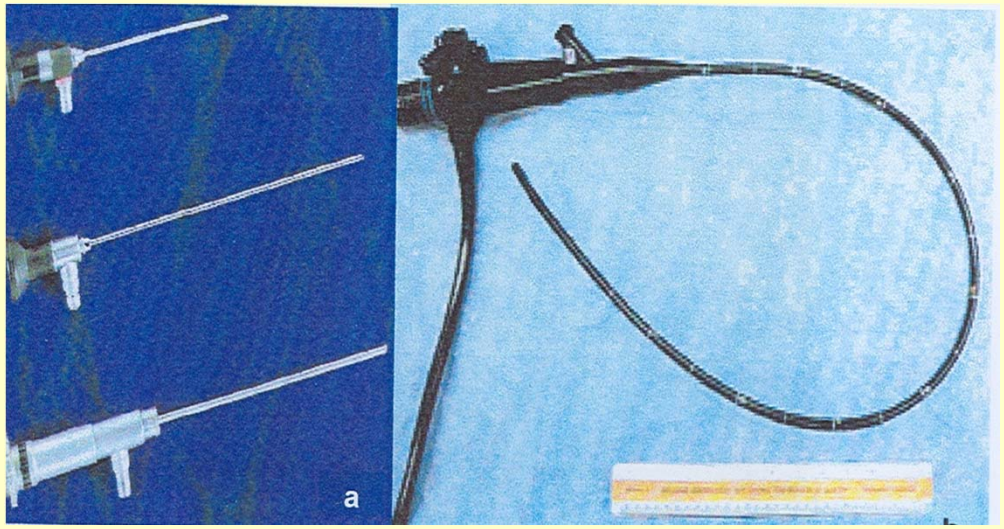
(vi) breaking of the trunk or toppling of the crown in case of severe and prolonged infestation.

(vii) Drying of Offshoots in date palm

RPW damage in major palm species



Infestation detecting aids

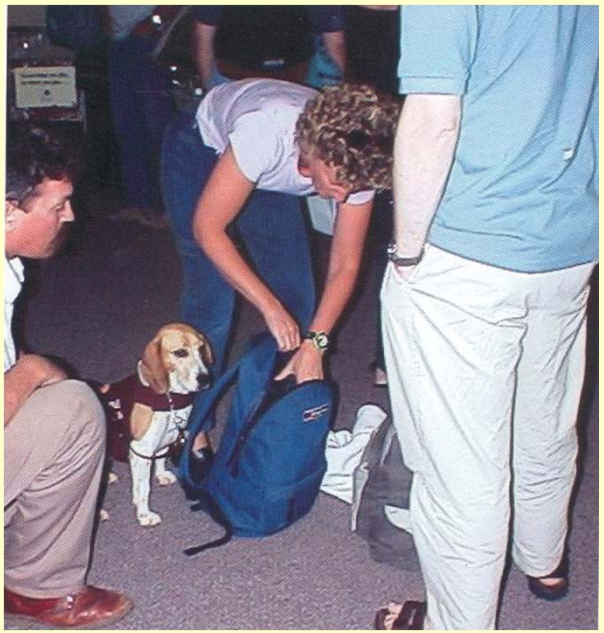


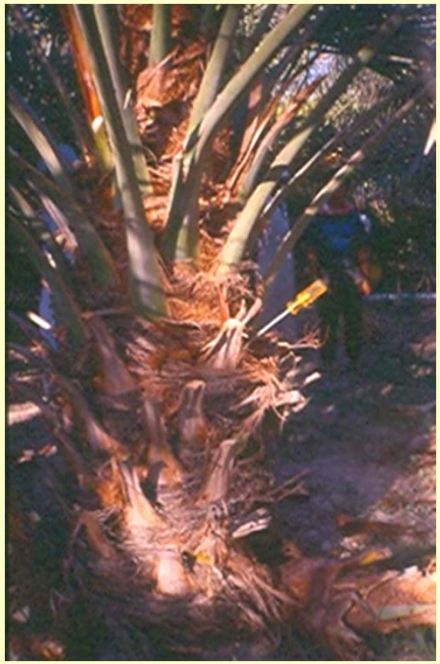
1. Endoscope (Qatar)

Al-Saad and Mohamed Amahdi, 2004

2. Sniffer Dogs

Nakash *et. al*., 2000



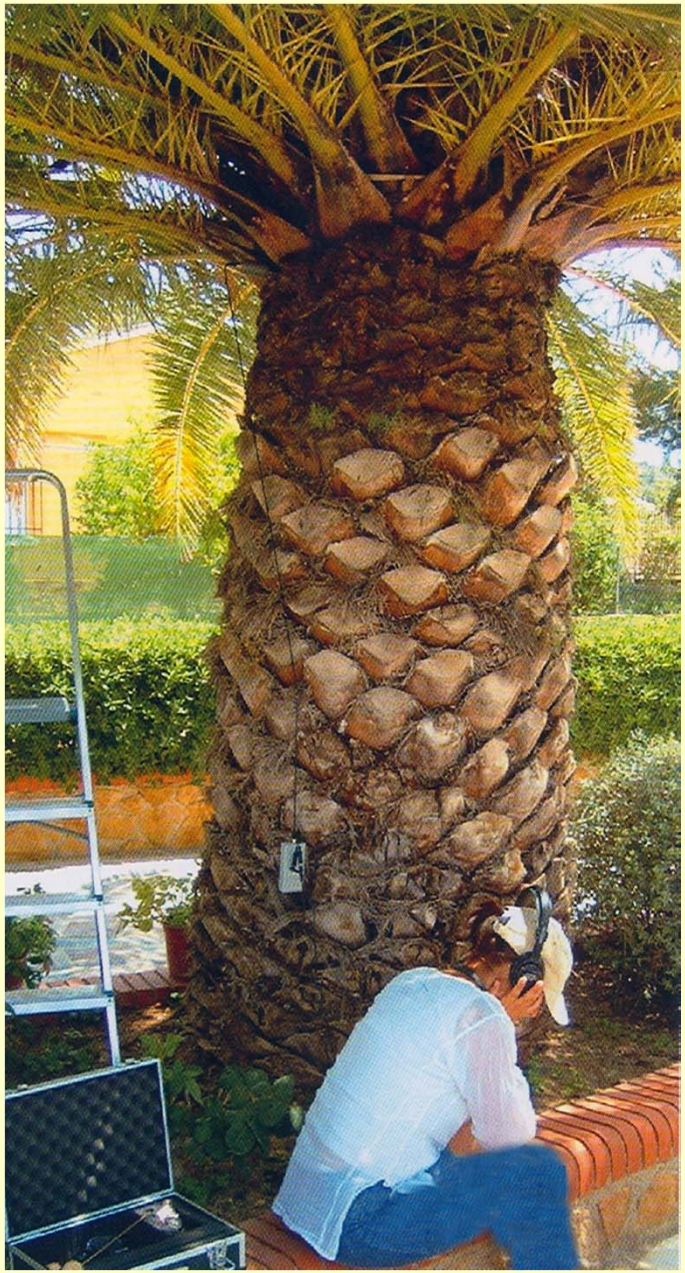


3. Screw Driver Probe

Annonymous, 1998

3. Sounding equipments

Pinhas *et al*., 2008
Tejedo 2006
Laar, 2004
Al-Manie & Al-Kanhal, 2004
Abraham *et. al*., 1966



Picture from: Tejedo 2006

What is the Action Threshold for RPW

Due to the lethal nature of the pest and high value of the crops involved the assumed action threshold for RPW in coconut and date palm is very low.

In small gardens farmers initiate action even if one infestation is detected

In big plantations one per cent infested palms is the assumed action threshold : Area-wide operation

Pheromone based RPW-IPM strategy

✓ Set monitor traps

✓ Implement mass trapping/area – wide management

- based on infestation reports and weevil captures in monitors/indicator traps)

-Sequential Sampling for necessary statistical confidence

✓ Check palms around traps

-recording weevil captures on a weekly basis

✓ Go in for repeat checking

- around traps recording high weevil capture

-in and around gardens where infested palms are eradicated.

✓ Treat infested palms (curative control)

✓ Eradicate heavily infested palms

✓ Take-up preventive insecticidal sprays/showers

- in and around eradicated/ treated palms.

✓ Enforce strict quarantine regimes.

✓ Implement other components of the routine RPW-IPM programme (phyto-sanitation, training and extension, treat breeding sites, watch closed gardens, avoid making wounds)

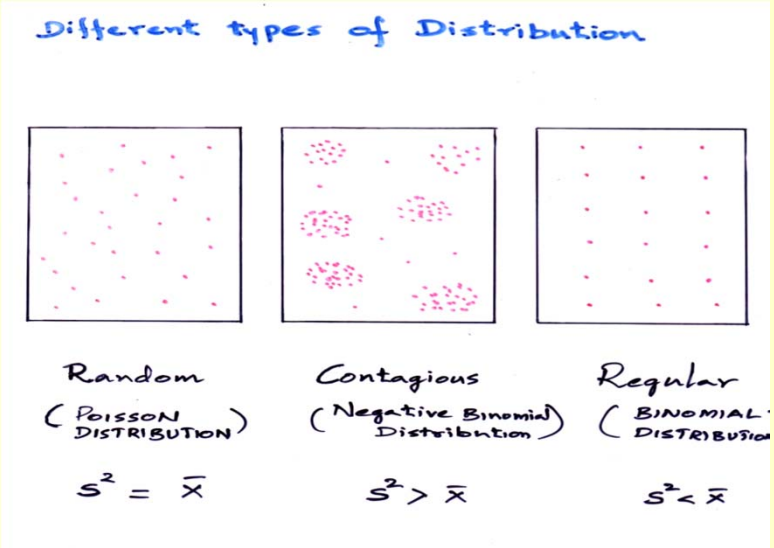
✓ Do a periodic performance analysis of the programme

- Decision-making sampling / GIS

Spatial Distribution of red palm weevil (coconut, India) August 1999 - July 2000.

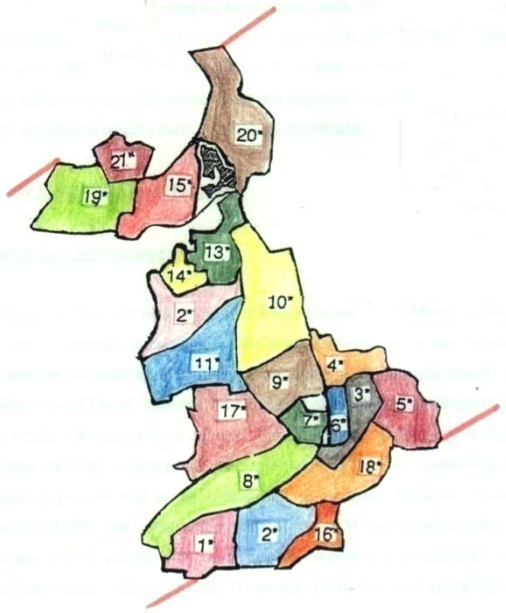
Dispersion Parameters

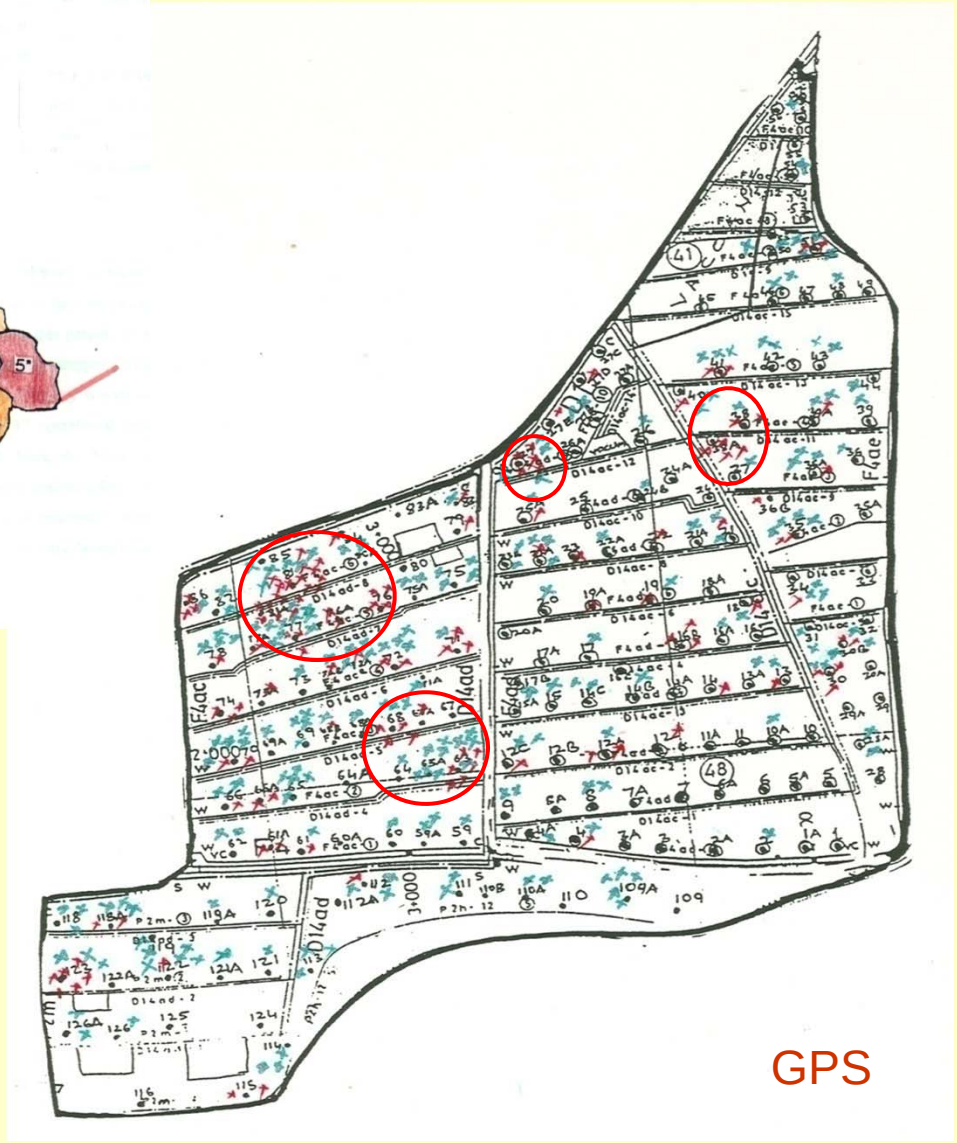
- Variance > Mean
- K & Kc – Dispersion Parameter < 8
- Statistic T < Standard Errors
- Variance to Mean Ratio > 1



Dispersion Indices

- David Moore's index > -1
- 1/K > 0
- Lloyd's index of crowding > 0





AL-SUHEMIA

Number of traps = 181

Number of infestation=127

Number of palms= 30,000

Catch/trap= 1.18

Per cent infestation= 0.45

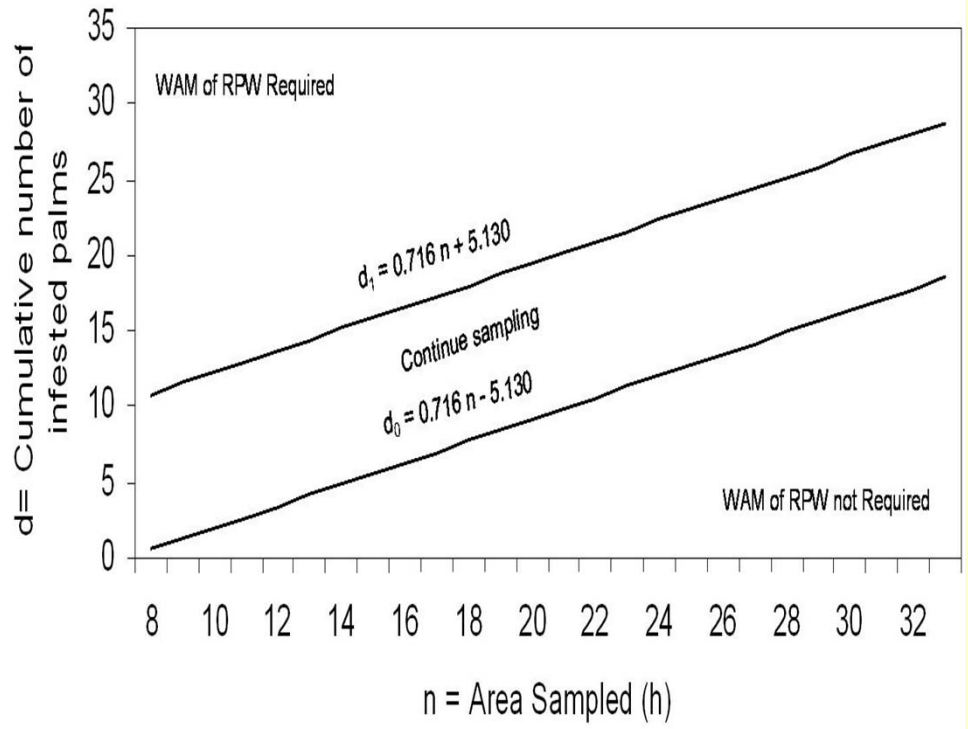
Clumped infestation pattern in 270h of date plantation during 1997

Sequential sampling- A tool to implement wide area / area-wide management of RPW and assess performance of on going programmes

1. Distribution pattern of RPW in coconut - highly aggregated. Aggregation index = 3.45 (Faleiro *et al*. 2002).

2. Risk factor of making the wrong decision = 0.05

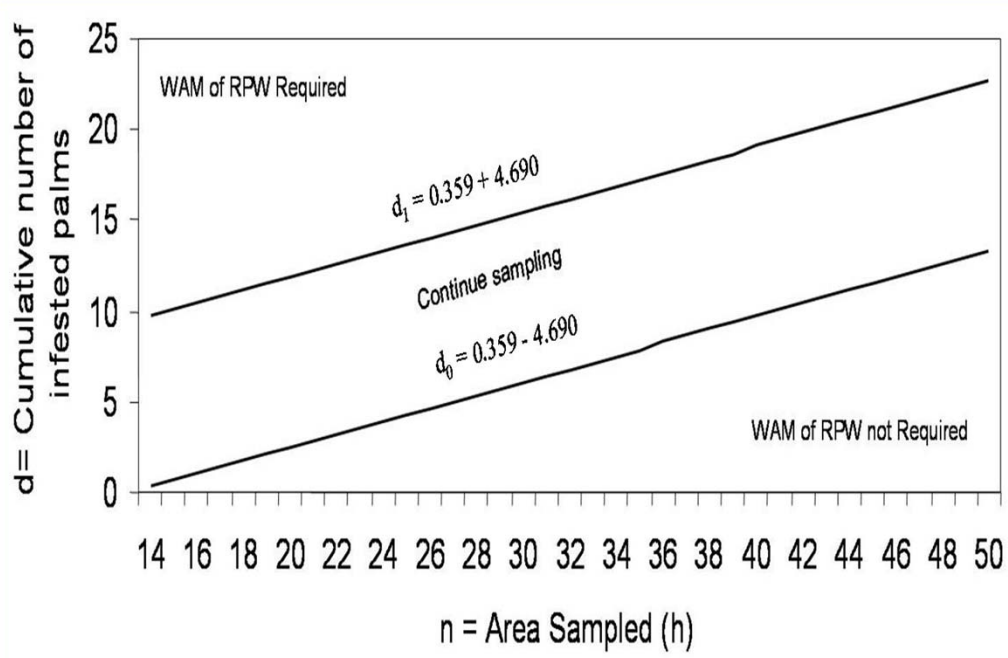
3. Assumed the action threshold = 1 per cent (Plan A) and 0.5 per cent (Plan B) infested palms



Plan A

Plan B

Sequential Sampling plans for wide area management of *R. ferrugineus* in coconut



Sequential sampling table for initiating area-wide management of *R. ferrugineus* in coconut

Area sampled (h)	Number of palms sampled	Cumulative number of infested palms			
		Assumed action threshold (1%)		Assumed action threshold (0.5%)	
		Lower limit	Upper limit	Lower limit	Upper limit
1	**150**	**ND**	**6 (2)**	**ND**	**5**
2	300	ND	7 (3)	ND	5
3	450	ND	7	ND	6
4	600	ND	8	ND	6
5	750	ND	9	ND	6
6	900	ND	9	ND	7
7	1050	ND	10	ND	7
8	1200	1	11	ND	8
9	1350	1	12	ND	8
10	1500	2	12	ND	8
11	1650	3	13	ND	9
12	1800	3	14	ND	9
13	1950	4	14	ND	9
14	**2100**	**5**	**15 (20)**	**0**	**10**
15	2250	6	16	1	10
16	2400	6	17	1	10
17	2550	7	17	1	11
18	2700	8	18	2	11
19	2850	8	19	2	12

ND= Not Detectable . Figure in parentheses= 1% infestation

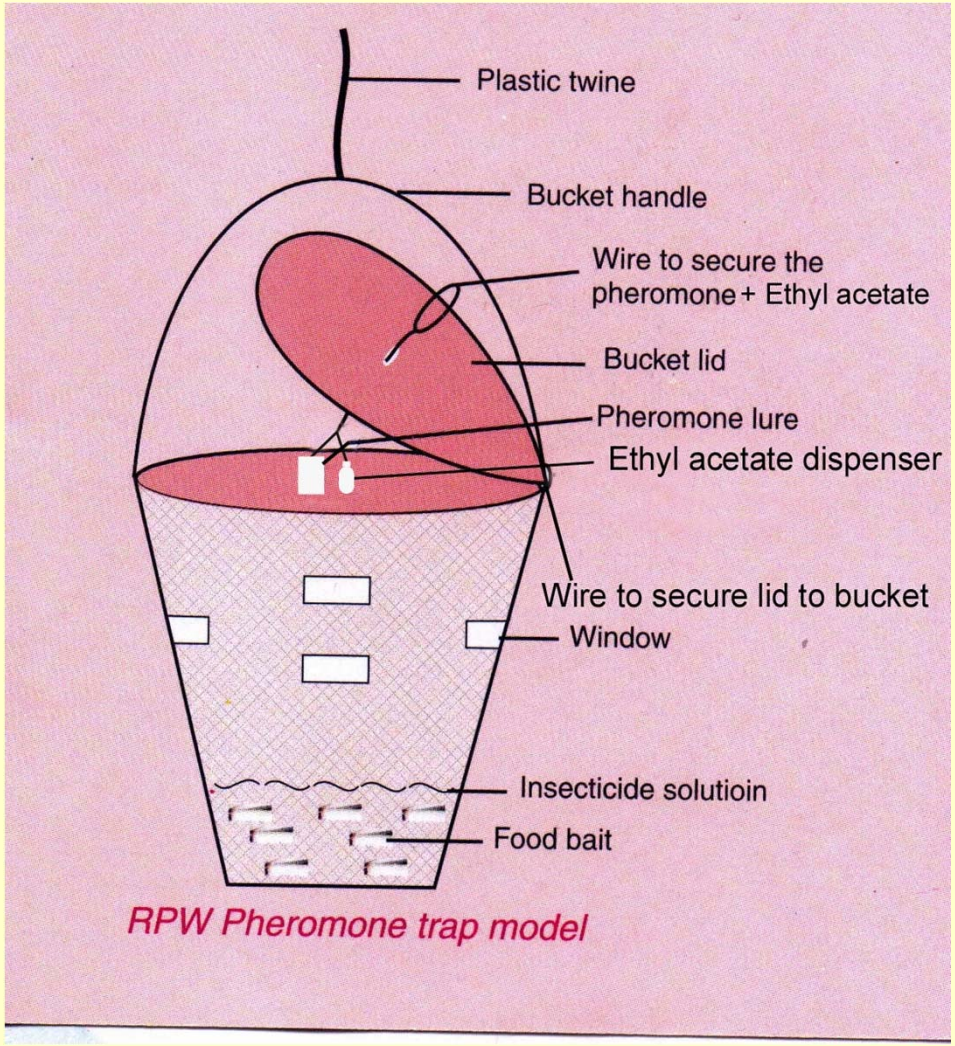
Standard Pheromone Trapping Practices –

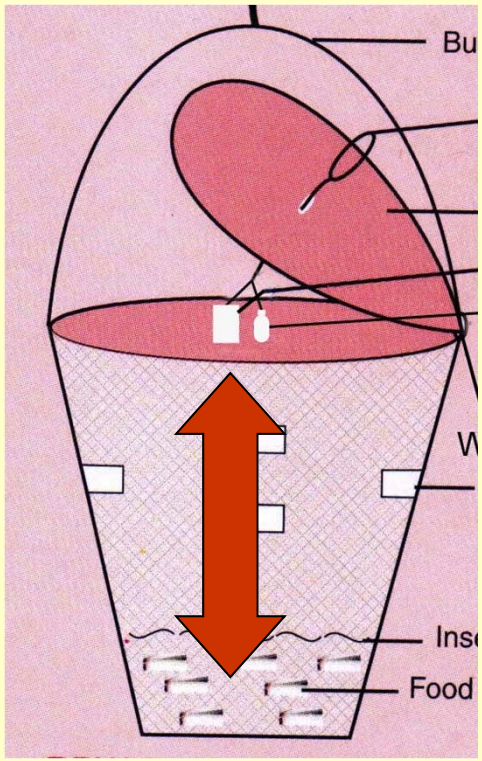
- Trap Design
- Lure Bait Synergy
- Servicing
- Trap Placement and Density
- Lure Longevity

Log traps

First pheromone trap trial in Saudi Arabia – January, 1994

RPW Pheromone (Ferrugineol) trap model





✘ **PALM LURE SYNERGY**

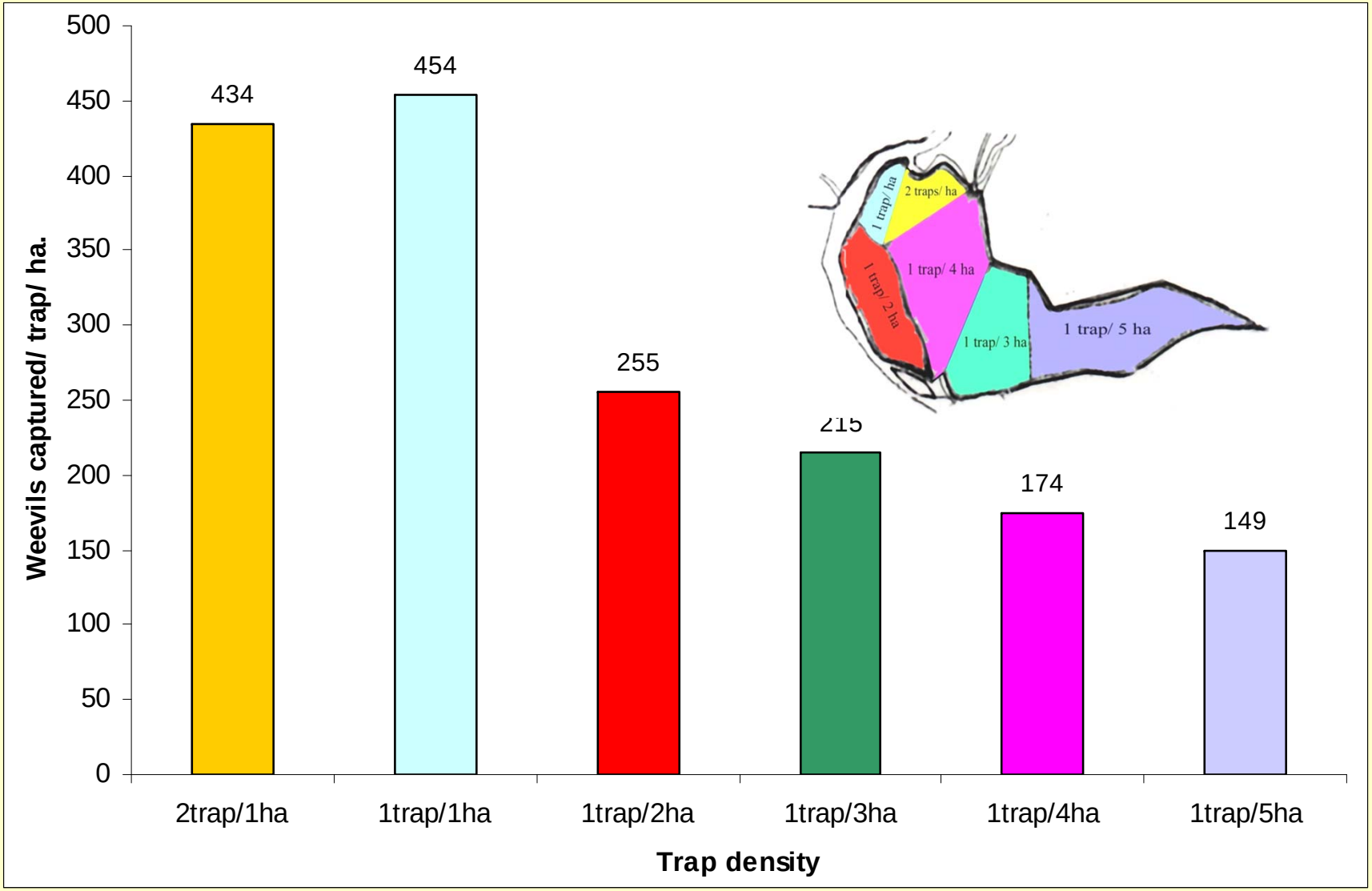
✓ **BAIT LURE SYNERGY**

Pheromone trap protocols for trapping RPW

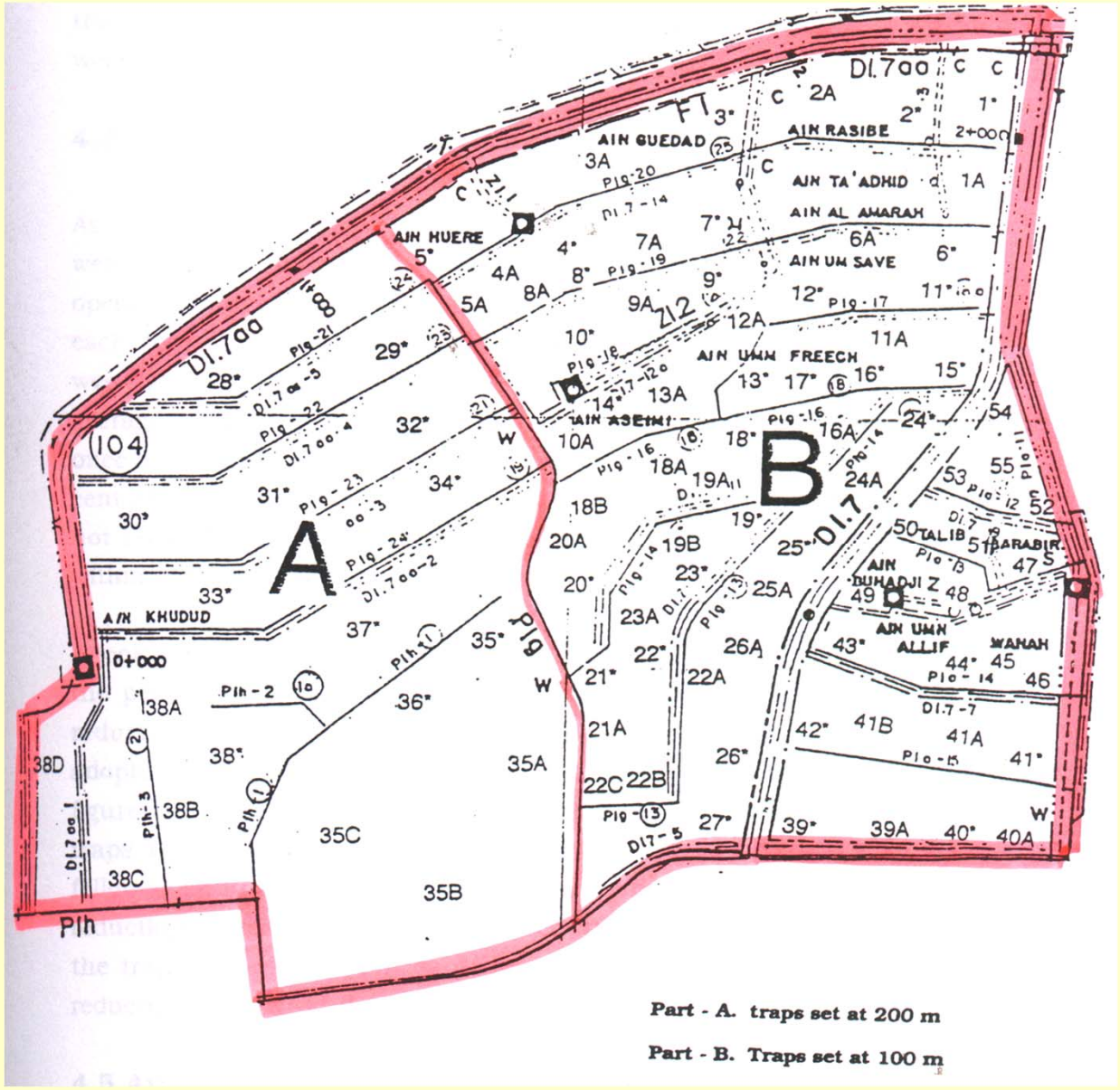
TRAP SURFACE

Without jute sack – 16.5 (± 7.93) weevils

With jute sack – 18.5 (± 6.86) weevils

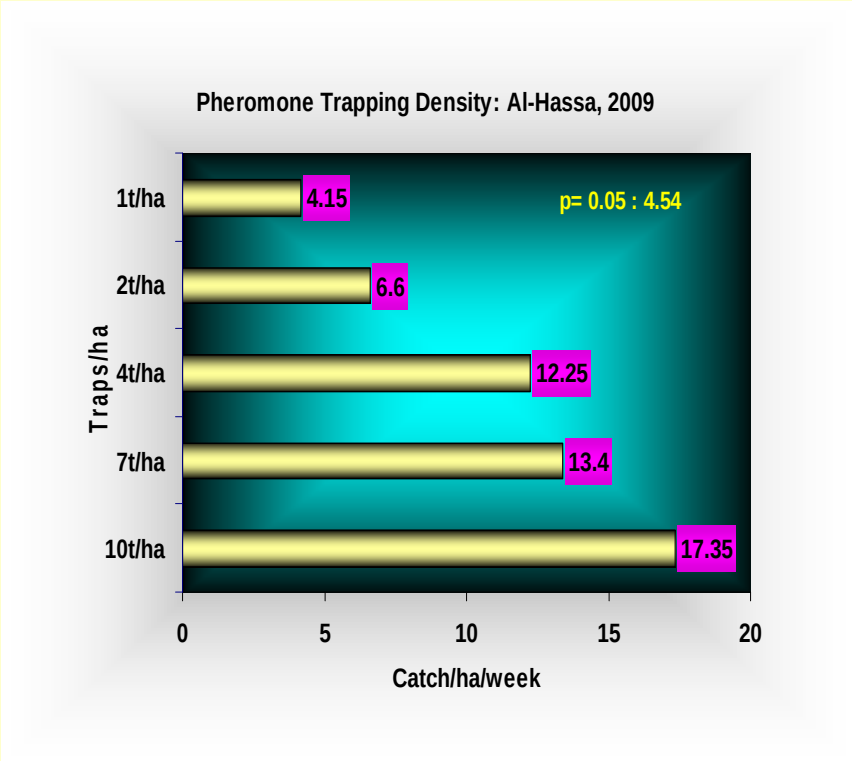


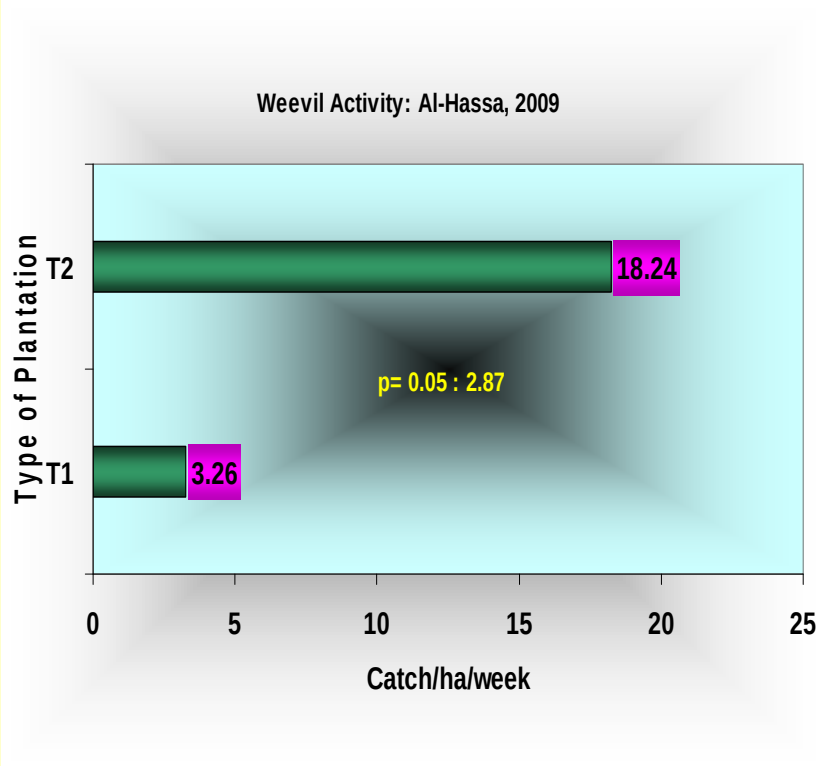
Red palm weevil captures at different trapping densities (November, 1999 to June, 2002)



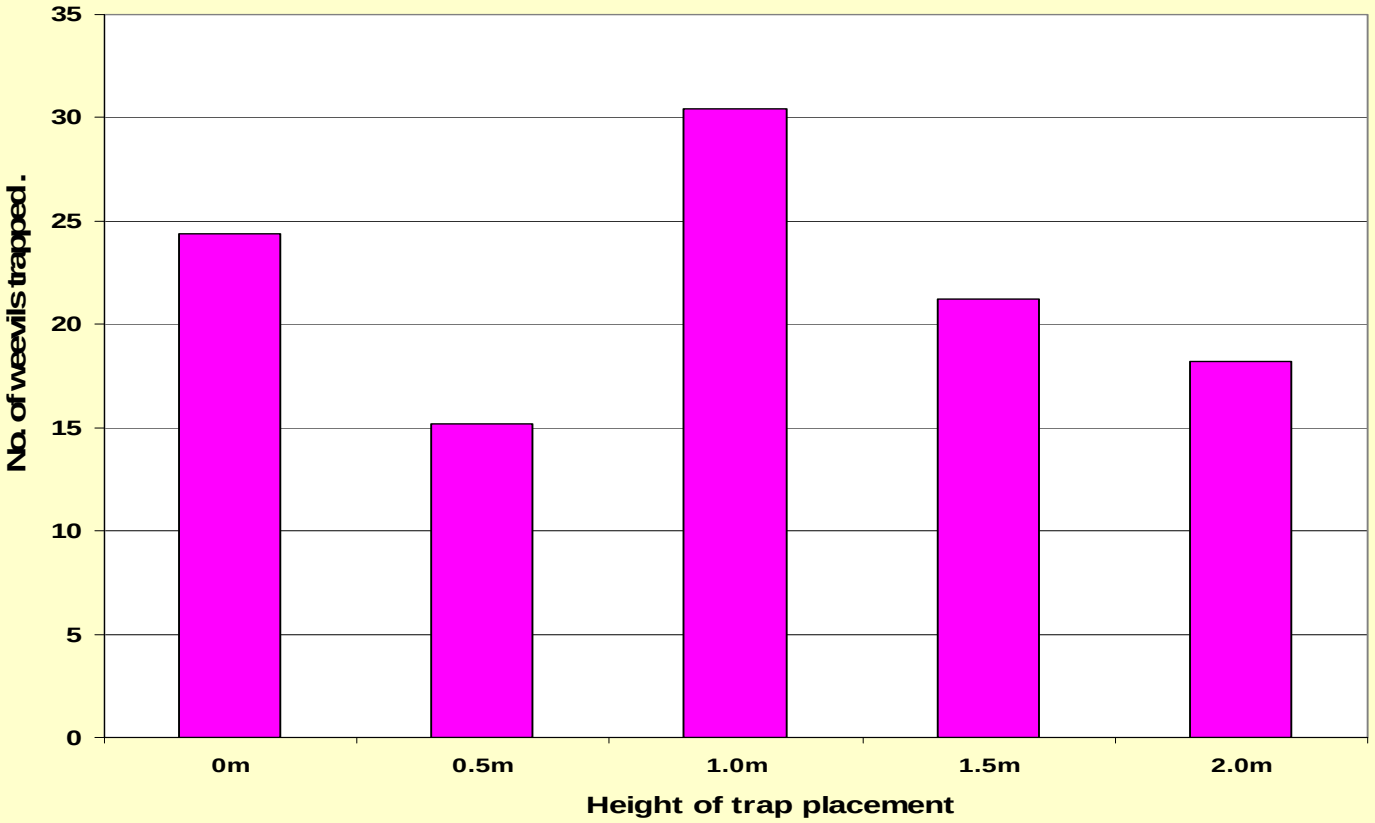
Pheromone traps set at two densities in date palm (1994-1998)

Pheromone trap density, Al Hassa, 2009

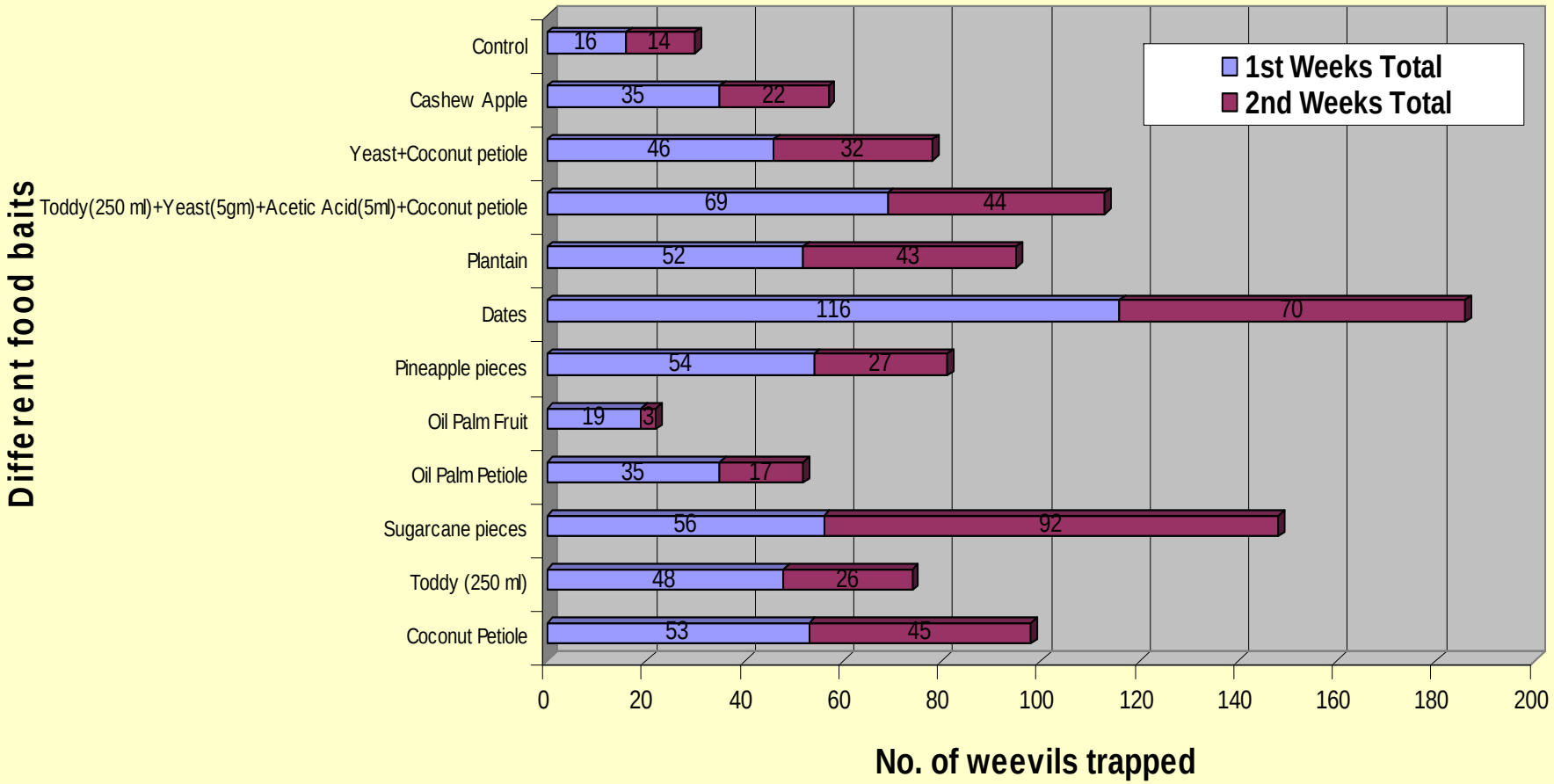




Vertical distribution of RPW

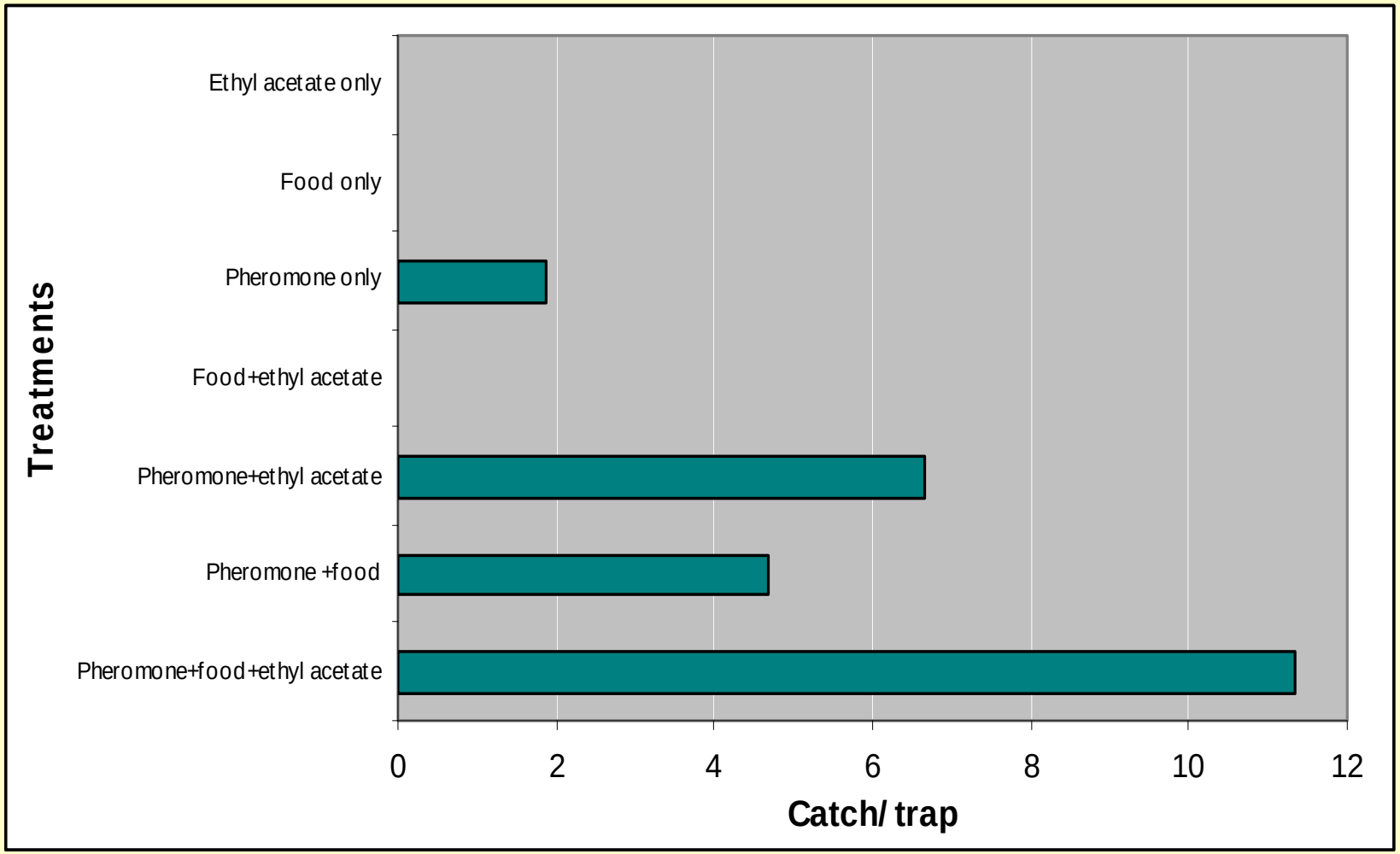


Kairomone producing food baits

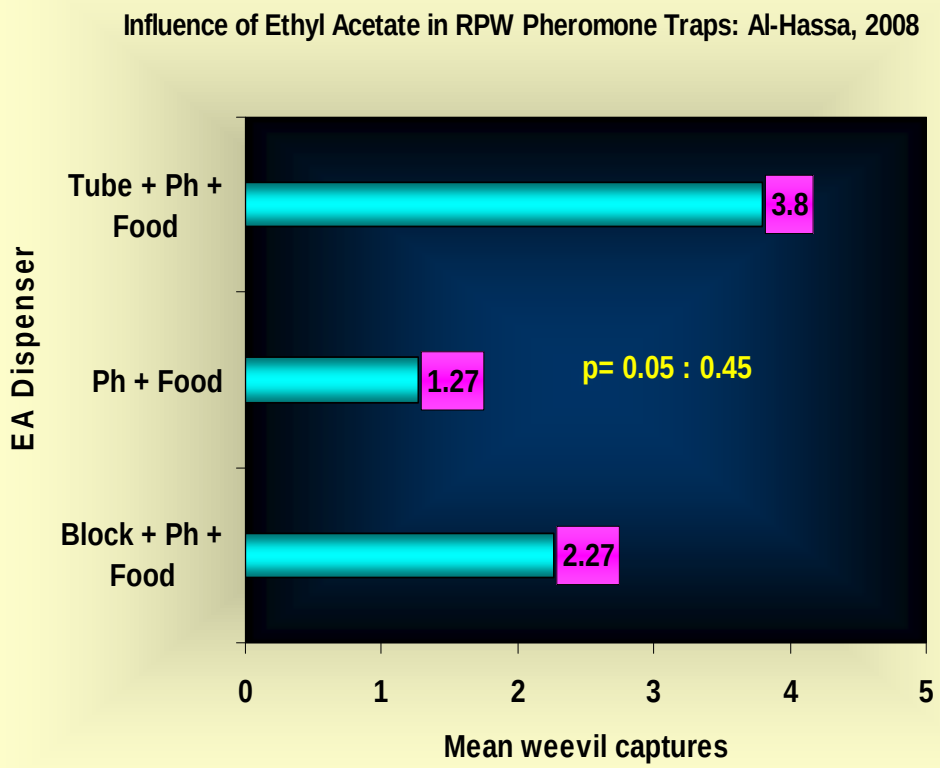


Comparative weevil catches in red palm weevil pheromone traps using different food baits (13/3/2001-11/5/2001)

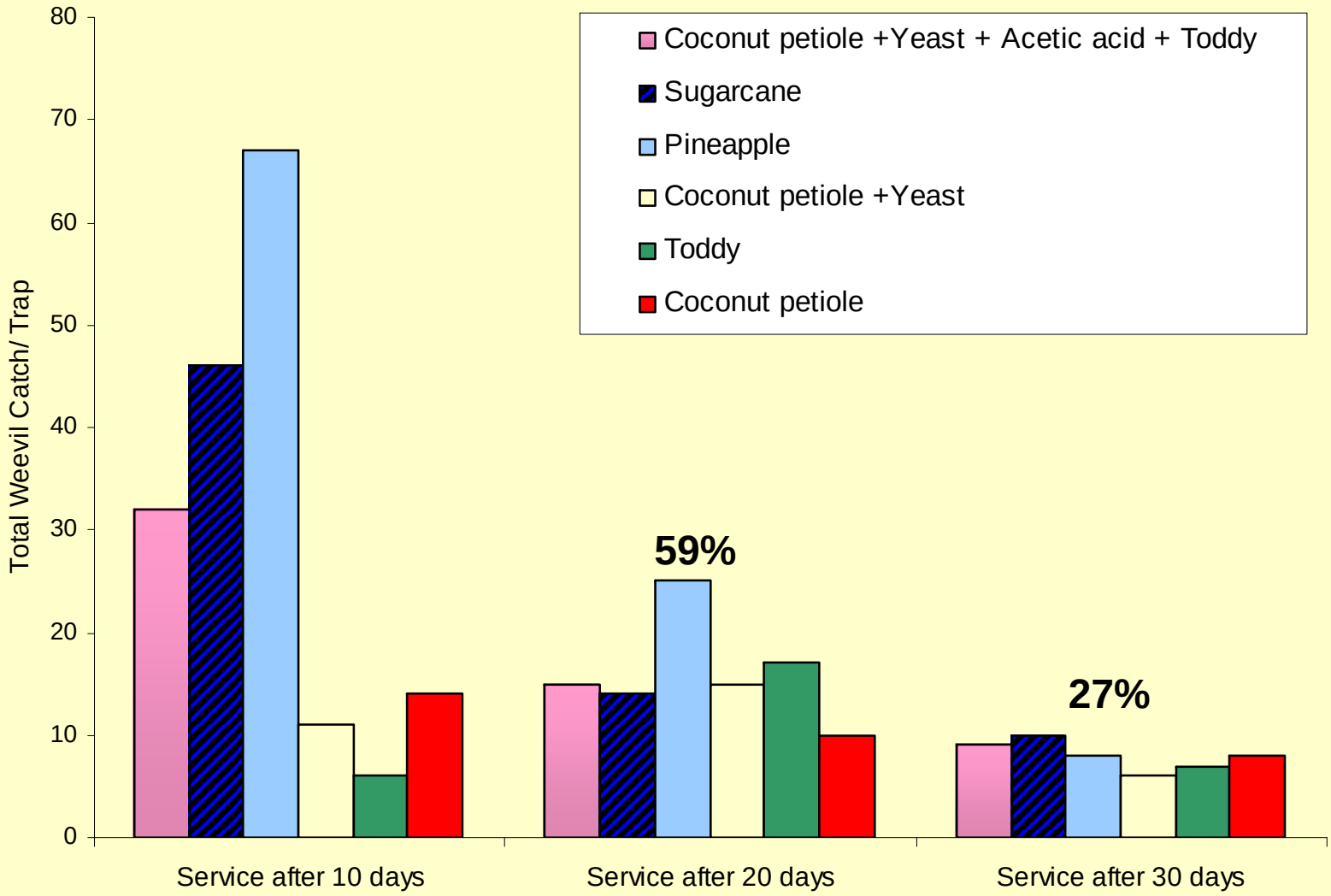

SUGARCANE
COCONUT
PETIOLE

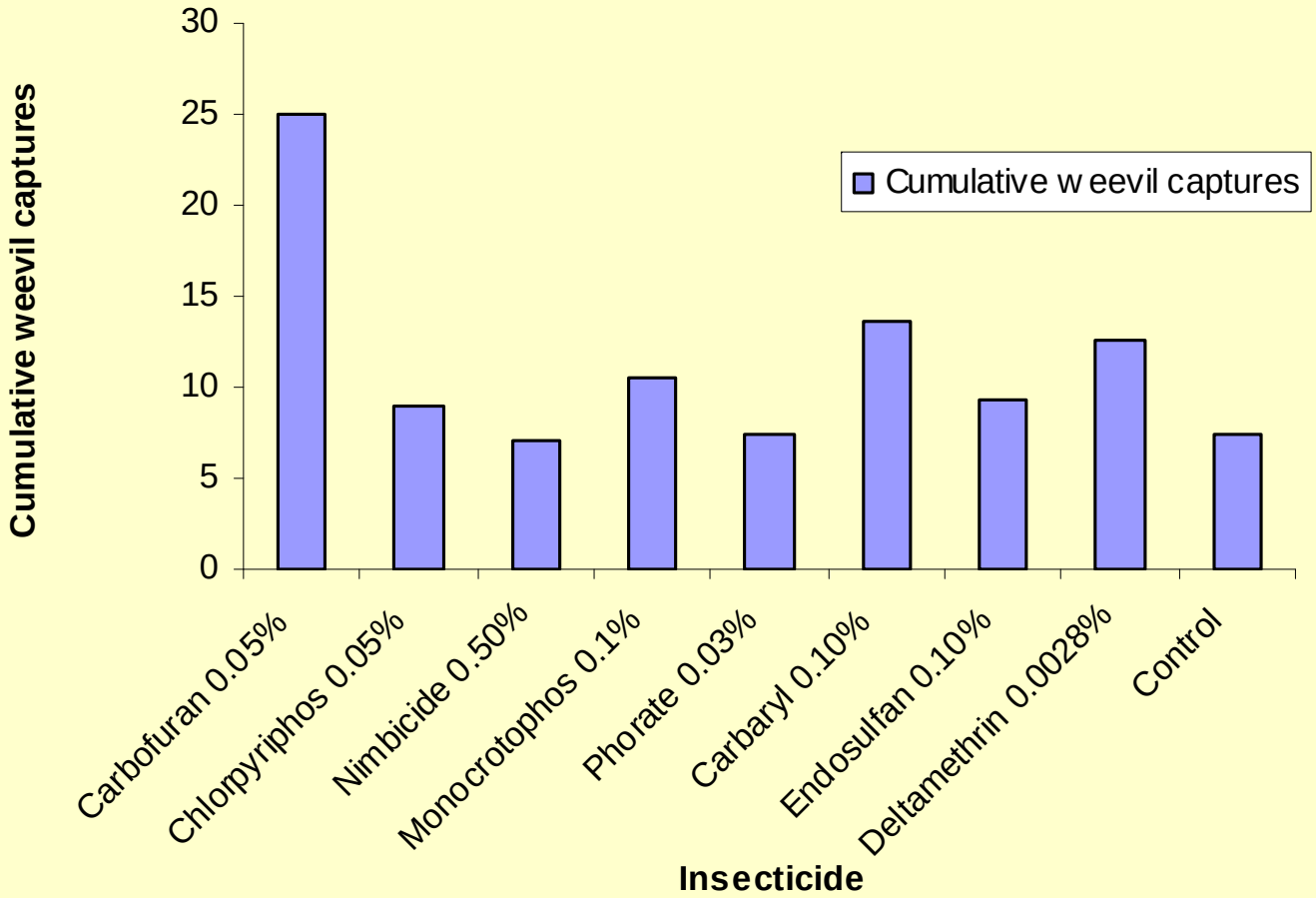


Influence of ethyl acetate on *R.ferrugineus* captures in food baited pheromone traps (Goa, 30/12/2006 and 13/1/2007)


Influence of Ethyl Acetate in RPW Pheromone Traps: Al-Hassa, 2008
EA Dispenser
Tube + Ph + Food
Ph + Food
Block + Ph + Food
3.8
1.27
2.27
p= 0.05 : 0.45
0
1
2
3
4
5
Mean weevil captures

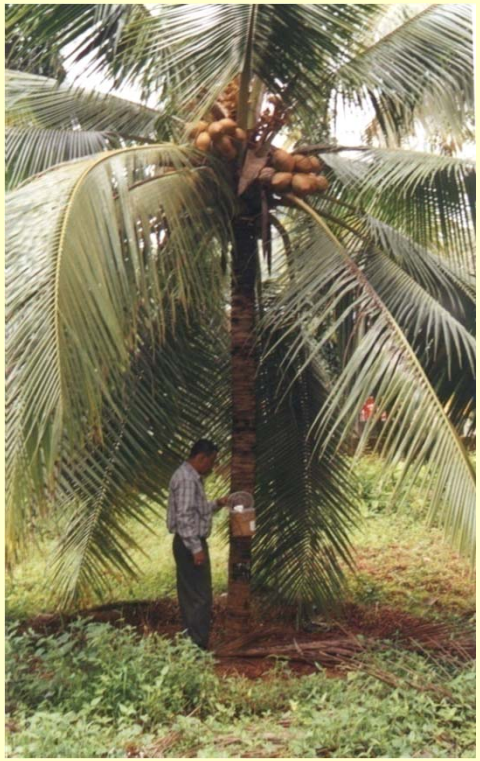
Effect of trap servicing (replacement of food bait) on weevil captures in RPW pheromone traps (March, 2002)





Screening insecticides for use in RPW pheromone traps (12-10-2001 to 17-11-2001)

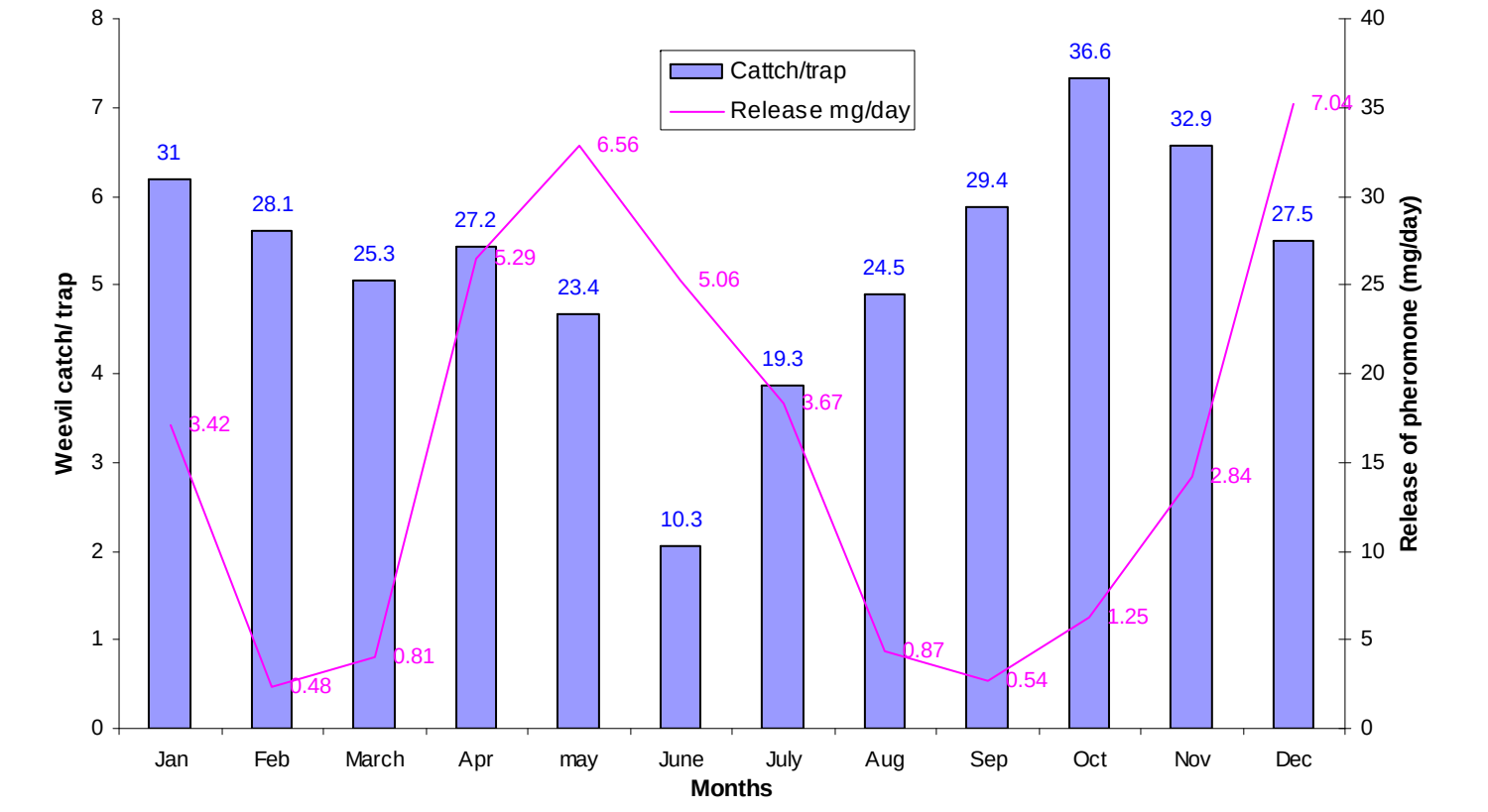
Trap setting in the field



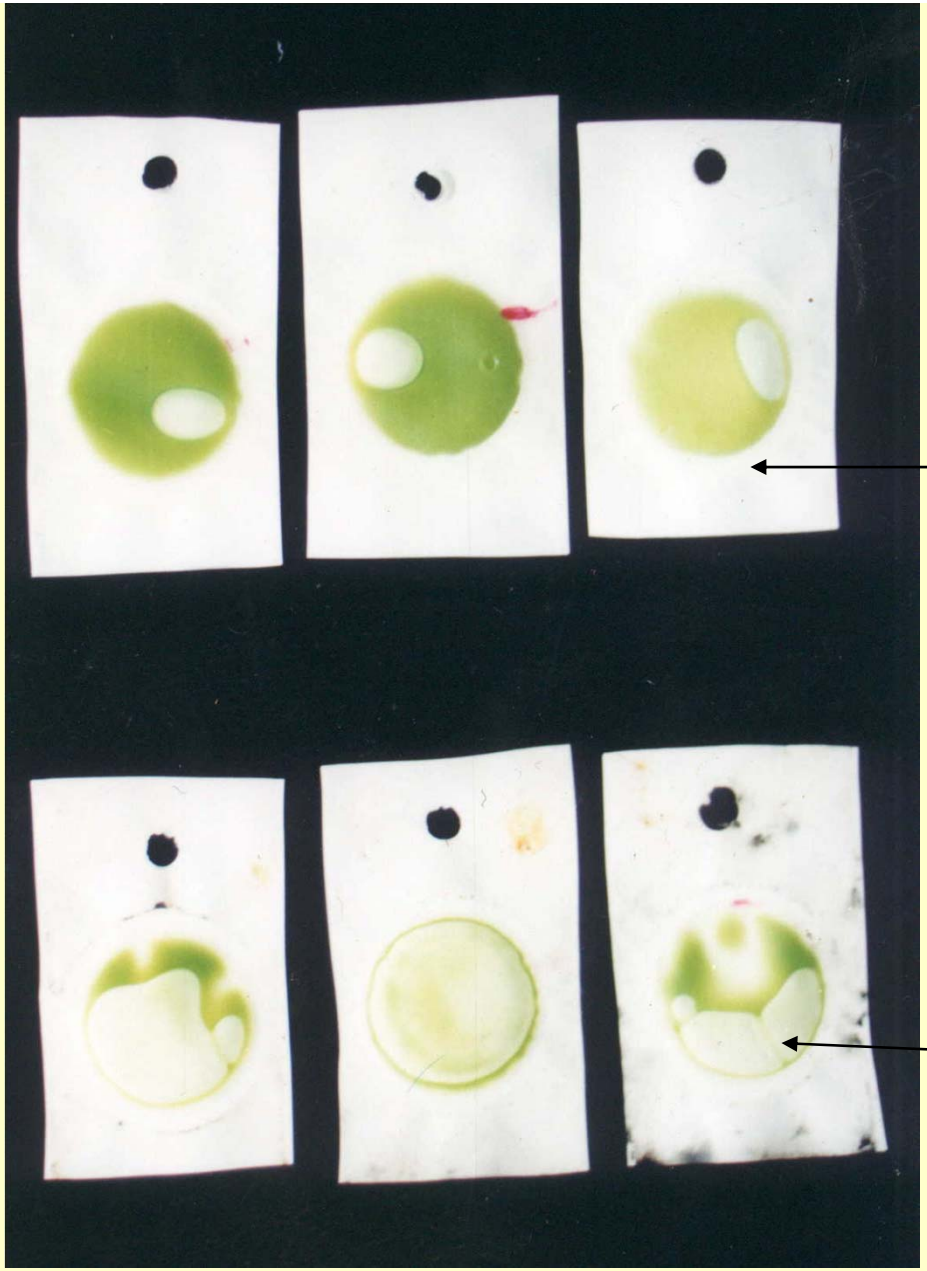
Shade ✓

Exposed to sun ✗

Traps near young palms ✗



Mean monthly weevil catch per trap and release of pheromone (mg/day) in Goa, India - January, 2000 to December, 2001.



New Lure

Six months old lure

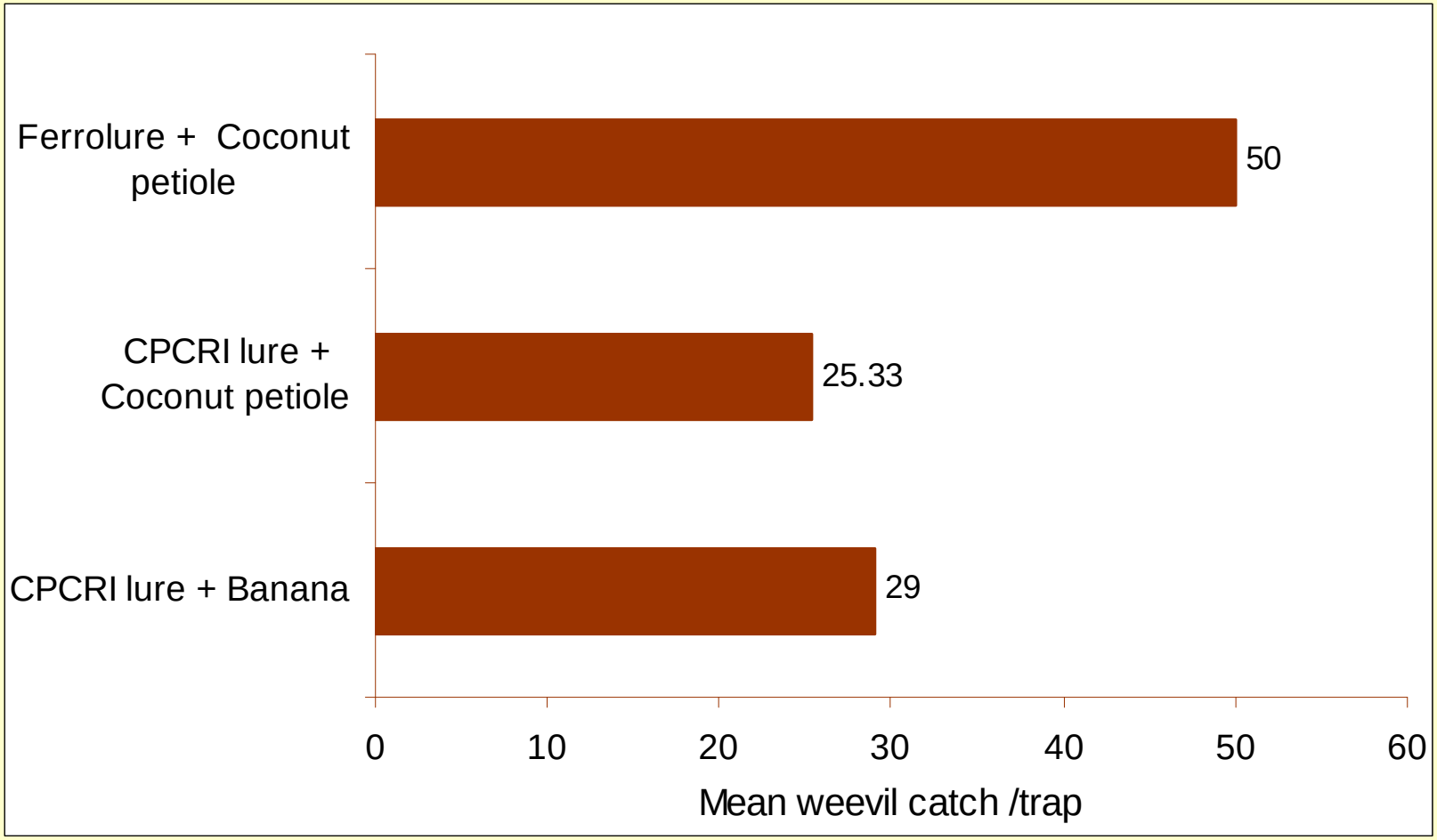
Different dispensers for ferrugineol based lures

Testing RPW pheromone lures

Sr.No	Treatments	Strength of lure	Mean weevil catch per trap			
			Trial I (23/12/02 to 24/1/03)	Trial II (25/1/03 to 26/2/03)	Cumulative	Sex ratio
1	Pherobank RPW lure (Holland)	400mg	3.52 (12.0)	2.90 (8.3)	3.26 (10.1)	1: 2.05
2	Pherobank RPW lure	700 mg	2.70 (7.0)	2.41 (5.6)	2.57 (6.3)	1: 2.8
3	Pherobank RPW lure	1000 mg	3.02 (8.7)	2.41 (5.6)	2.76 (7.1)	1: 1.39
4	Ferrolure+ (Costa Rica)	800 mg	2.88 (8.0)	2.66 (7.6)	2.79 (7.8)	1: 1.35
5	ISCA Technology (USA)	900 mg	2.76 (7.3)	2.22 (4.6)	2.55 (6.0)	1: 1.25
6	CPCRI lure (India)	0.157 g	1.56 (2.0)	1.26 (1.3)	1.47 (1.6)	1: 2.00
7	Ferrolure+ only (no food)	800 mg	2.18 (4.3)	1.74 (2.6)	2.00 (3.5)	1: 1.63
8	Food only (coconut petiole)	----	0.88 (0.3)	0.71 (0.0)	0.81(0.1)	1: 0.00
CD (P = 0.05)			0.49	NS	0.46	---

Figure in Parenthesis are the original values NS = Non significant

Imported / Indian lure



Impact and Success Stories

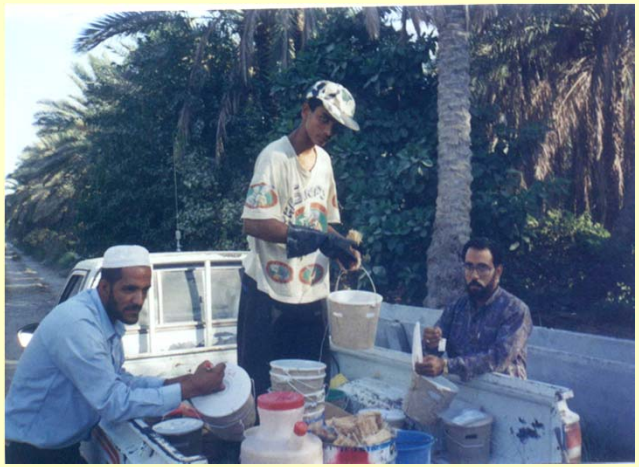
Life span and Reproductive Status Of Pheromone Trap collected **Female Weevils from coconut gardens (Goa, India)**

Parameters	Mean of three trials (July 2000, Dec 2000, May 2001)	
	Solitary females	**Paired females**
Mean life span (days)	75.40 (±3.60)	69.73 (±4.02)
Mean egg lay	163.53 (±21.94)	251.73 (±21.63)
Percent egg hatch	55.05 (±9.22)	78.61 (±2.61)

Figures in parentheses are standard errors

(Females-Young, Gravid & Fertile).

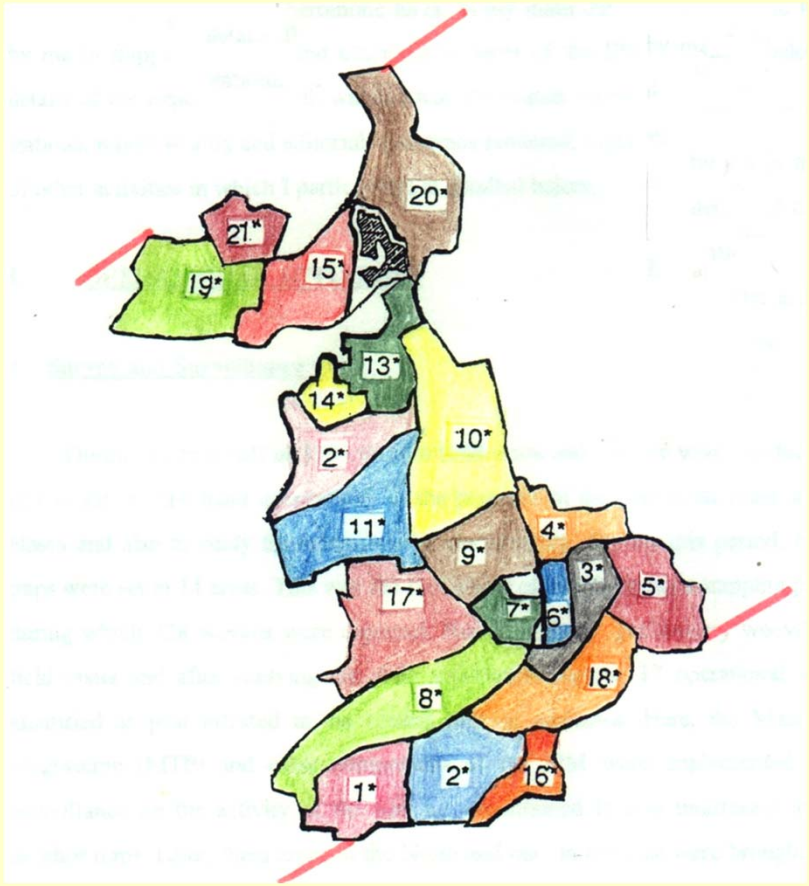
Preparing pheromone traps for mass trapping



Mortality of coconut palms and estimated loss before implementing pheromone based IPM programme

Sr. No.	Name of the Farmer	Area of farm (ha)	Total number of palms	Number of palms lost due to RPW	Per cent mortality	Estimated loss @ Rs. 2,000/ palm
1	Shri Vidyadhar Mallya	10	1,200	10	0.83	20,000
2	Shri Agnelo Barretto	5	700	06	0.86	12,000
3	Shri J. G. Xavier	8	1,100	50	4.54	1,00,000
4	Shri Auduth A. Prabhudesai	8	1,200	07	0.58	14,000
5	Shri Azim Khan	12	1,500	15	1.00	30,000

Mass trapping programme in date palm (Al-Hassa, 1994 to 1998)



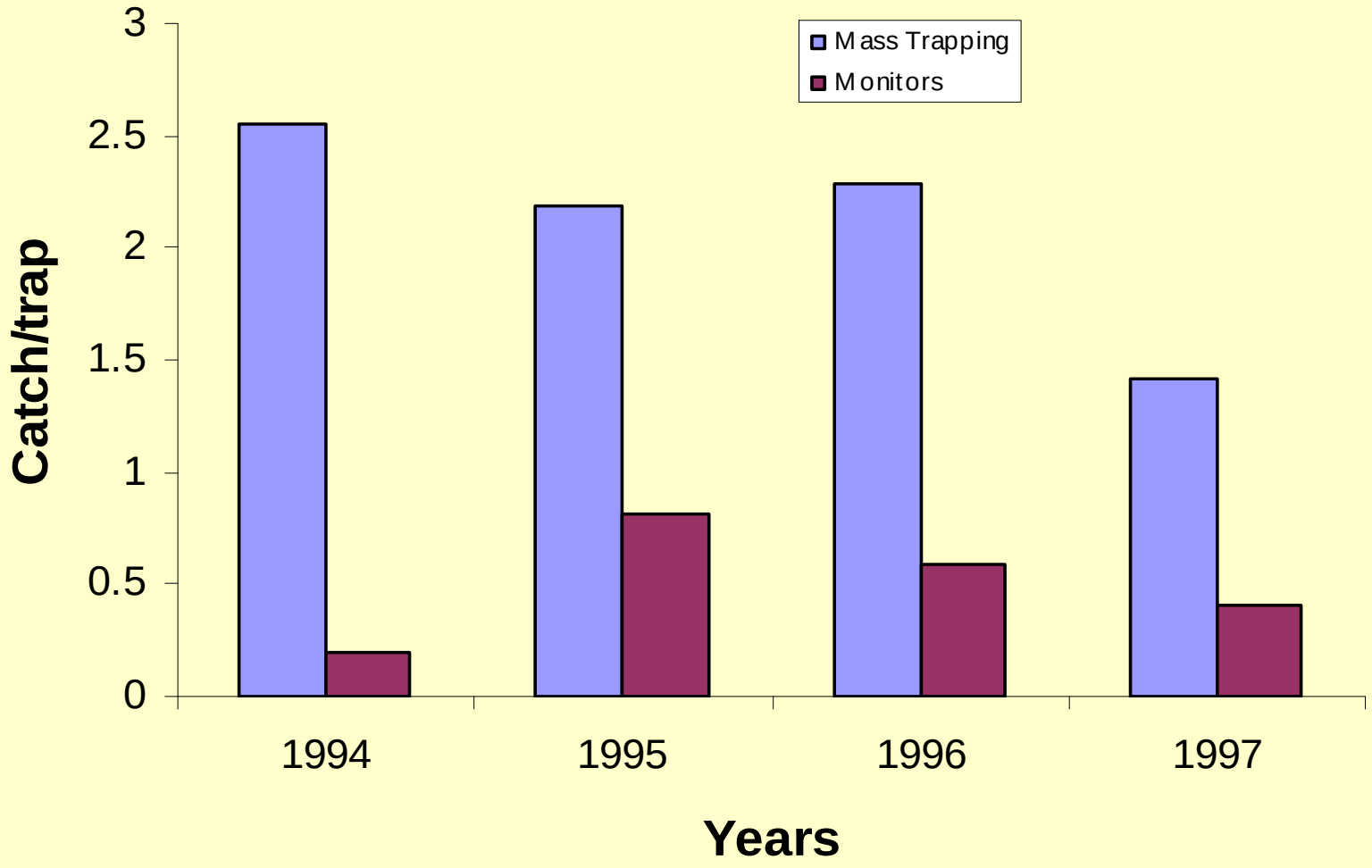
No. of traps = 2650

Area = 4000 ha

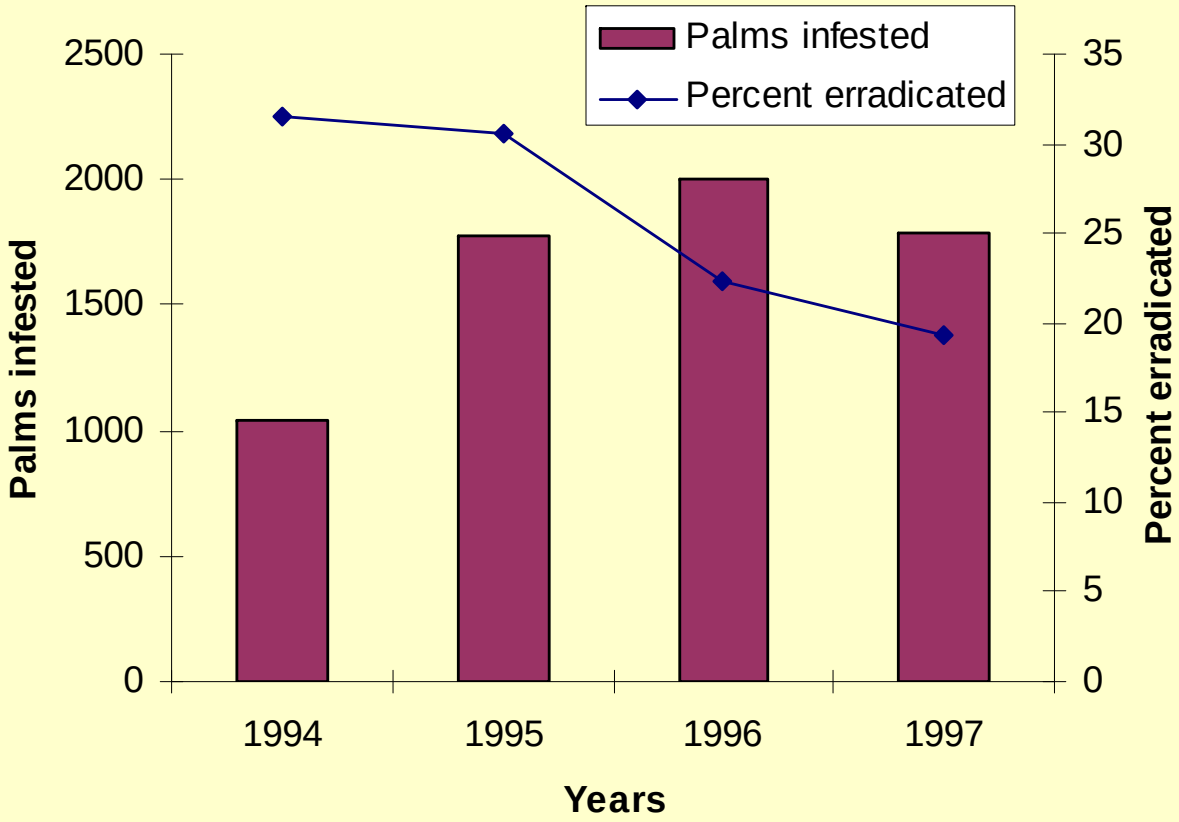
Trapping density = 0.66 trap/ha

No. of palms = 0.7 million

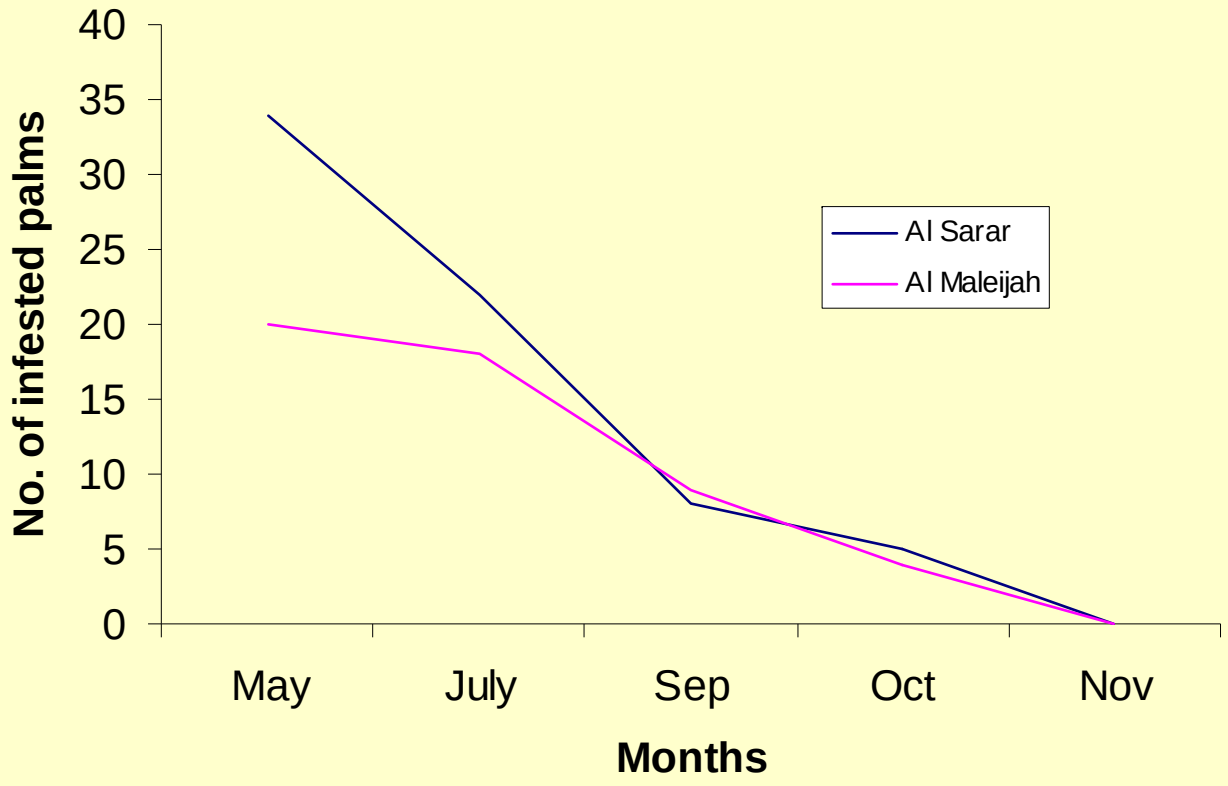
Infested palms = 7000



Weevil captures in mass trapped and monitor areas of Al-Hassa (Mid 1994 - Dec, 1997)



Number of date palms infested and erradicated due to RPW infestation in Al-Hassa (1994 - 1997)



Progressive decline in infestation at isolated date plantations during 1995.

Other pheromone based RPW-IPM success stories

- Vidyasagar *et. al*., 2000 (infestation level brought down from 6.6 % in 1993 to 2.5 % in 1997) – Al Qatif, Saudi Arabia
- Annonymous, 2004 (Jordan and Palestinian Authority)
- Al- Khatri,2004 (Oman- Reduced eradications from 24% in 1998 to only 3% in 2003)
- El-Ezaby *et.al*.,1998,Oehlschlager,2006 (UAE-64% reduction in infestation in 2 years / 71% reduction in one year)
- Faleiro, 2005 (India –From 5% to zero in one year)
- Sujatha *et.al*. 2006(India-From 2.4% to 0.2% in 1.5 year)
- Rajapakse, 1998 (Sri Lanka –Significant reduction in infestation)
- Jayanth *et al*., 2007 (India – 9370 adults captured in 10 months from 100 acres).

Rochat, 2006 (Iran – Infestations increased around traps)

- Improve the trap design and trapping protocols

Adopt the best trapping protocols

How many adults are trapped ?

Males : 22.22 to 38.17 % Females : 43.28 to 51.11 %

M + F : 24.41 to 35.26 %

Will trapping alone do ?

The North African Experience



•Trap captures increased from 10 weevils / trap / month during May ,2009 to over 100 weevils / trap / month during February , 2010



•Trap captures within 2-5 weevils / trap / month (2009-10)

Chemical Control Methods for RPW

Preventive – Based on Trap Capture/ Infestation Reports

- Frond axils filling
- Spraying/ Soaking
- Protecting wounds (tar/cement/insecticide)
- Dipping offshoots in insecticide (quarantine)

Curative – Treating Infested Palms

- Trunk Injection
- Fumigation
- Root feeding

Curative treatment of RPW infested palm

Treat fresh injuries on priority

Eradicating severely infested palms

Removal

Shred / pulverize

Burn ??

Treat palm base with insecticide

Infestation in different age groups of date palm (Al-Hassa, 1995- 1997) – Implications for quarantine

Age group (Years)	Palms infested (%)
0 – 5	15.2
6 - 10	54.8
11 –15	24.6
16 – 20	4.6
>20	1.0

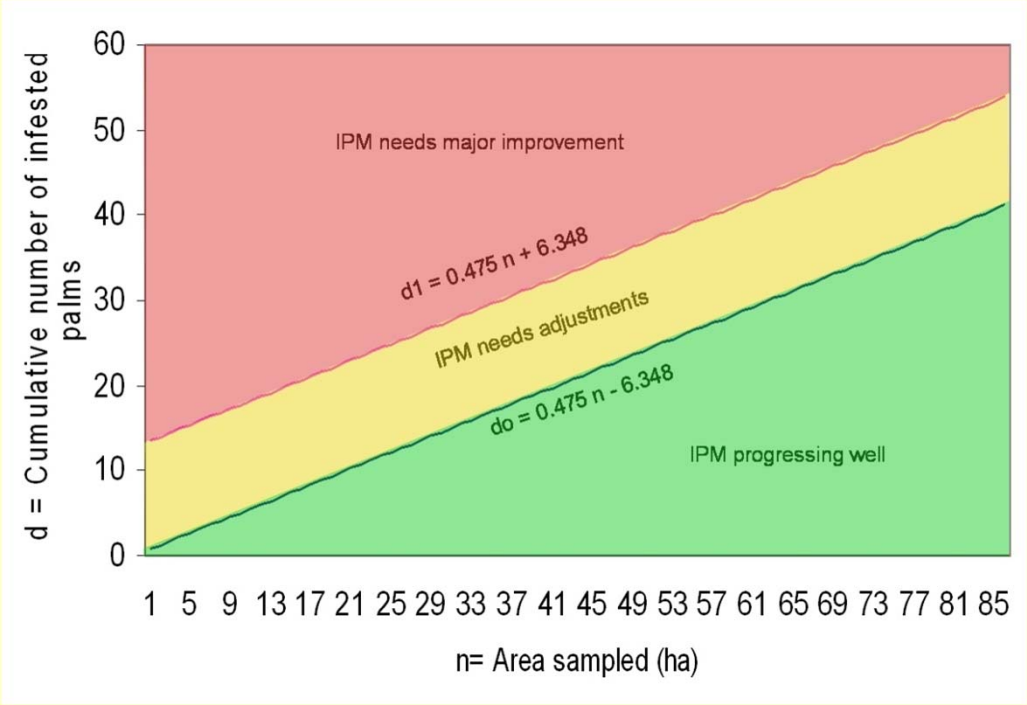
Check escape of RPW through planting material

Dipping off shoots in insecticide

Validating RPW-IPM

- Weevil Captures
- Infestations / Eradications
- Sequential Sampling
- GPS / GIS

RPW-IPM validation plan (Decision lines) in date palm for Al-Hassa, Saudi Arabia



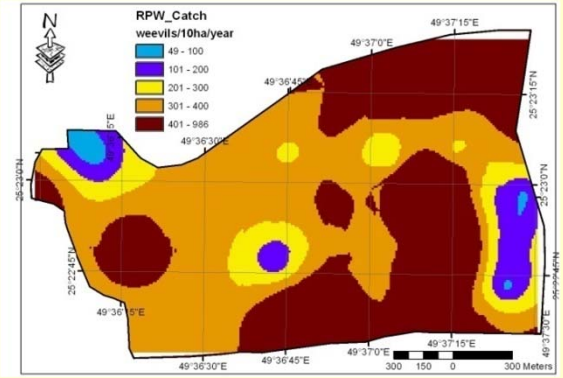
Validating RPW-IPM in Al –Hassa , Saudi Arabia (8 July to 6 August ,2009)

Sr. No.	Palms checked	Infestations reported/Palms eradicated	Per cent infestation /eradication	Estimated infestations /100ha	Weevil catch /trap/week
Central Zone					
1	22335	77/12	0.34/15.58	34	0.89 (107)
2	34300	91/24	0.27/26.37	27	0.41 (177)
3	38772	100/39	0.26/39.00	26	1.24 (197)
4	10910	13/0	0.12/0.00	12	0.65 (130)
5	30140	64/25	0.21/39.06	21	1.53 (212)
6	6175	41/6	0.66/14.63	66 *	0.87 (85)
7	10027	26/7	0.26/26.92	26	0.87 (60)
8	16595	62/19	0.37/30.65	37	1.06 (177)
9	26830	118/26	0.44/22.03	44	0.94 (252)
10	11580	21/5	0.18/23.81	18	0.88 (68)
11	28560	48/14	0.17/29.17	17	0.56 (90)
12	37270	147/56	0.39/38.09	39	0.57 (239)
13	20013	117/60	0.58/51.28	58 *	1.71 (142)
14	25793	213/68	0.83/31.92	83*	2.97 (135)
15	15910	27/4	0.17/14.81	17	1.25 (73)
16	10585	18/0	0.17/0.00	17	1.48 (33)
17	13188	85/25	0.64/29.41	64 *	1.12 (83)
TOTAL	**358,983**	**1268/390**	**0.35/30.75**	**35**	**1.10 (2260)**

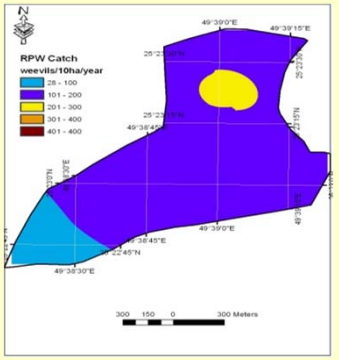
*Infestation above the assumed action threshold of 1% infested palms.
Figures in parentheses denote number of pheromone traps.

GIS Simulated Spatial Models for RPW Trap Captures and Infestations in Al-Khadoud and Al- Sodah, Saudi Arabia (2008)

Weevil Captures

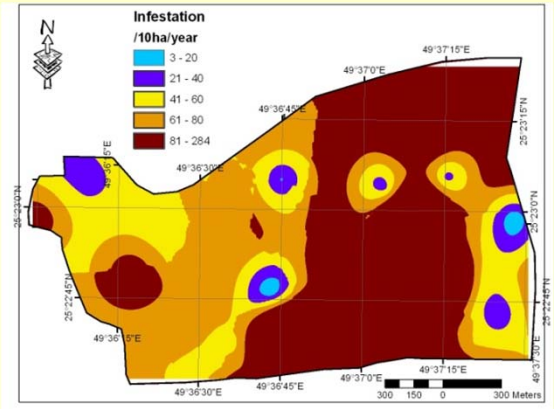


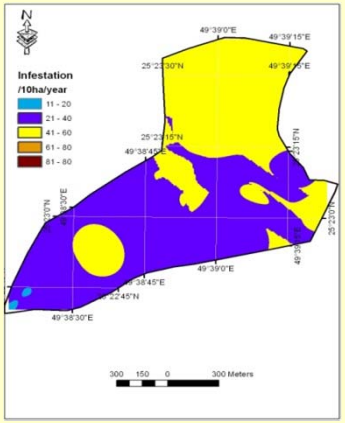
Al-Khadoud



Al-Sodah

Infestation





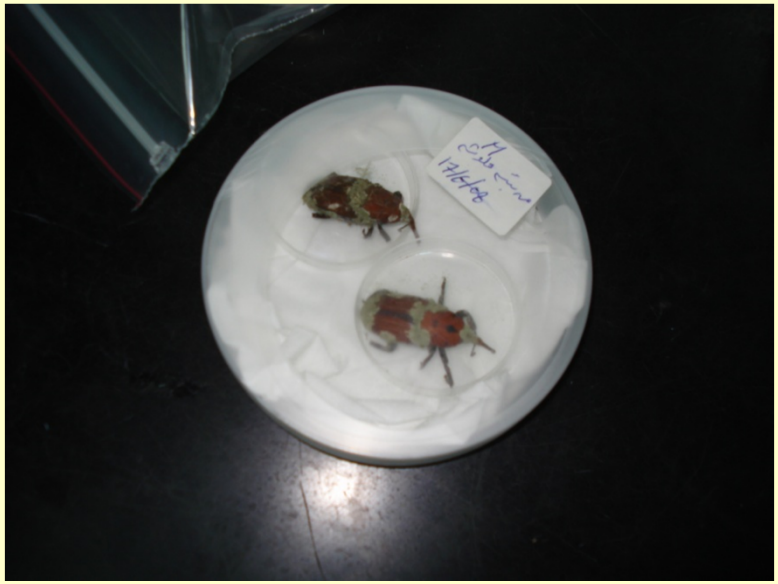
Other IPM Possibilities

Identifying effective Bio-control agents

Incorporating host plant resistance

Potential Natural Enemies of RPW

Sr. No.	Potential Biocontrol Agents	Scientific Name
1	Insects (Wasp, Earwig)	*Scolia erratica* , *Sarcophaga fuscicauda*, *Chelisoches moris*
2	Bacteria	*Pseudomonas aeruginosa*, *Bacillus* sp., *Serratia* sp. *B. sphaericus*, *B. mgaterium*, *B. laterosporus*, and *B. thuringinsis*,
3	Fungus	*Beauveria bassiana*, *Metarhizium anisoplieae*
4	Virus	Cytoplasmic Polyhedrosis Virus (CPV),
5	Yeast	------
6	Entomo-Pathogenic Nematodes (EPN)	*Heterorbhabditis* spp., *Steinernema abbasi*, *Heterorbhabditis indicus*, *Teratorhabditis palmarum*, *Steinerema* sp., *H. indica*, and *Rhabditis* sp.
7	Birds (Indian tree pie bird and Crow pheasant bird)	*Dendrocitta vagabunda parvula*



Metarhizium anisoplieae
infected adults

Beauveria bassiana
infected adults

Host Plant Resistance

IRAN - Calcium inhibited RPW growth while, date palm varieties with high sugar levels enhanced oviposition and growth while reducing mortality of RPW (Farazmand, 2002)

SPAIN- *Washingtonia filifera* : Antibiotic mechanism

Chamaerops humilis : Antixenotic mechanism

Phoenix canariensis : Highly preferred (Dembilio et. al.,2009)

INDIA – The coconut cultivar Chowghat Dwarf Green most preferred for egg laying while, Malyan Dwarf was least preferred (Faleiro and Rangnekar ,2001)

Male Sterile Technique

Gamma –ray dose of 1.5 Krad induced about 90% sterility in males

Large scale field trials in India -70% viability of eggs from females collected where sterile males were released.

- Rahalkar, *et. al*., 1977,1982 (India)

Future Research Priorities

- Early detection
- Quarantine protocols
- RPW repellants

Thank you