Advances in Semiochemical mediated technologies against Red Palm Weevil

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What is Red Palm Weevil

- There are several species of palm weevils distributed throughout the world.
- *Rhynchophorus ferrugineus* Olivier is the most important species causing severe damage.
- Order: Coleoptera
- Super Family: Curculionidea
- Family: Dryophthoridae
- Subfamily: Rhynchophorinae
- Genus: *Rhynchophorus*

Pheromone Kinds

- “The term "pheromone" was introduced by Peter Karlson and Martin Lüscher in 1959, based on the Greek word *pherein* (to transport) and *hormone* (to stimulate). They are also sometimes classified as ecto-hormones.”
- **Aggregation** 2. Alarm 3. Epideictc 4. Releaser 5. Signal 6. Primer 7. Territorial 8. Trail 9. **Sex** (Most sex pheromones are produced by the females; only a small percentage of sex attractants are produced by males.)
- Semiochemicals
- Pheromone: A pheromone is a secreted or excreted chemical factor that triggers a social response in members of the same species. Pheromones are chemicals capable of acting outside the body of the secreting individual to impact the behavior of the receiving individual
-
- Allomone: An allomone is any chemical substance produced and released by an individual of one species that affects the behaviour of a member of another species to the benefit of the originator but not the receiver.
-
- Kairomone: A kairomone is a semiochemical, emitted by an organism, which mediates interspecific interactions in a way that benefits an individual of another species which receives it, without benefitting the emitter. Two main ecological cues are provided by kairomones; they generally either indicate a food source for the receiver, or give warning of the presence of a predator

Mass trapping with pheromone traps

Advances in pheromone technologies

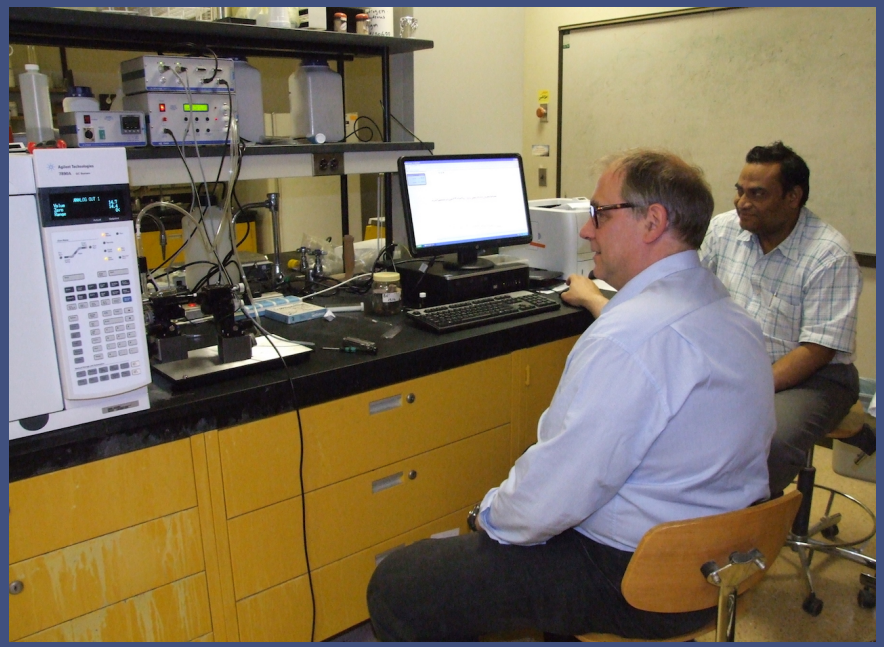
- Only food baits were used as trapping methods in India and other Asian countries against the RPW in coconut farms.
- In early 1990's two groups working in France and Canada isolated and identified the major and minor components of *Rhynchophorus* sp.
- In the beginning the trapping systems was developed for *R. palmarum* in oil palm plantations of Costa Rica.
- Subsequently the trapping systems against *R. ferrugineus* tested and applied in the field in Middle East especially Saudi Arabia.
- Since then several improvements and refinements have been made for trapping.

Log Trapping in Saudi Arabia

(without pheromone)

First traps in 1992

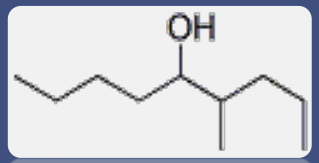
GC-EAD with MS



MALE AGGREGATION PHEROMONE

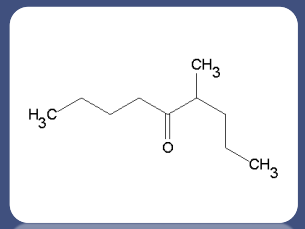
(4S,5S) 4-methyl-5-nonanol

major component $C_{10}H_{22}O$



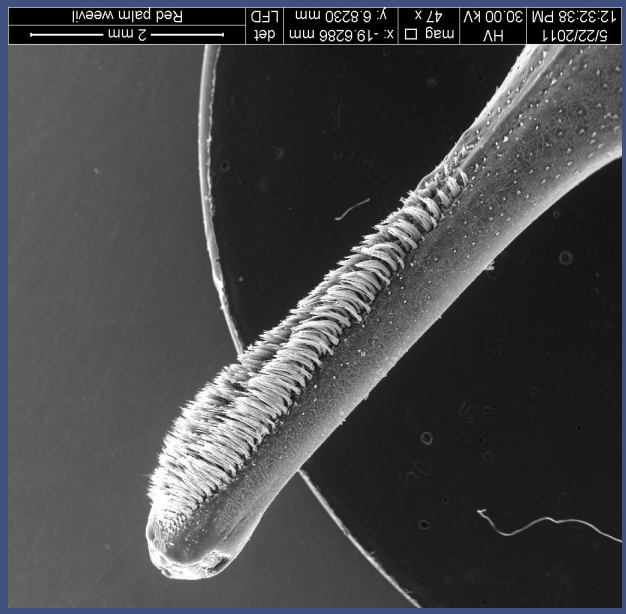
4-methyl-5-nonanone

$C_{10}H_{20}O$



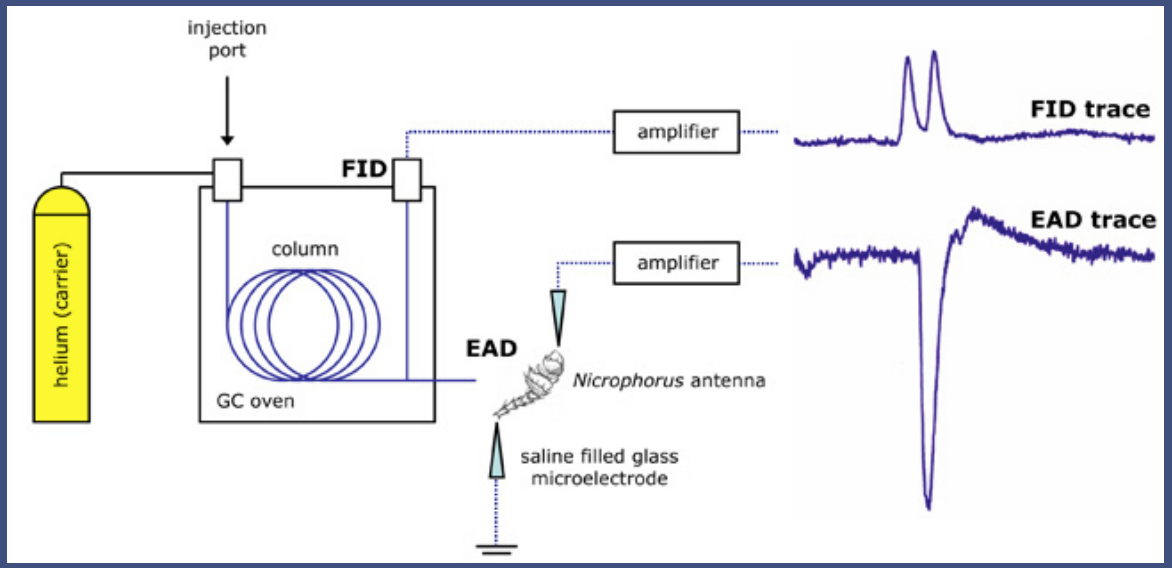
History and discovery of Pheromones in RPW

Aggregation: Male-produced sex attractants have been called aggregation pheromones, because they usually result in the arrival of both sexes at a calling site and increase the density of conspecifics surrounding the pheromone source. Aggregation pheromones are among the most ecologically selective pest suppression methods. They are nontoxic and effective at very low concentrations.



Low resolution SEM of RPW male snout with hairs

Schematic diagram showing GC-EAD and out put



(Blanka Kalinová, Michal Hoskovec, Jan Rùžièka, Hana Podskalská 2010)

Responses of potential kairomones and synthetic pheromone

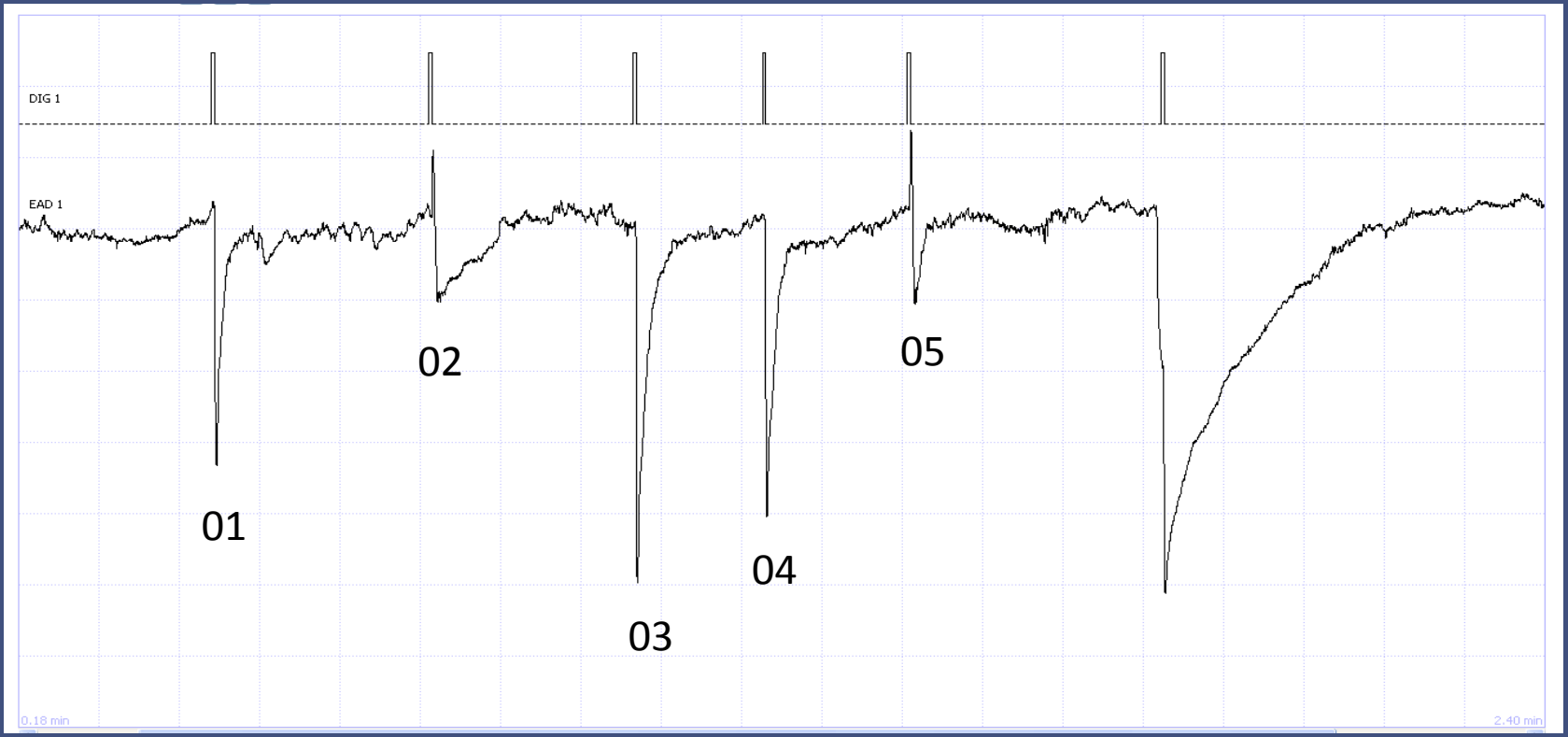


Fig. 08: EAD responses of manual puffs with corresponding DIG timing indications: Peak 01 - *Sukkary* Cultivar; Peak 02 – *Barhy* Cultivar; Peak 03 – Sugarcane; Peak 04 – Pineapple; Peak 05: *Rotana* Cultivar; Peak 06: Commercial pheromone (ChemTica International).

Comparison of pheromone and potential attractants (kairomone)

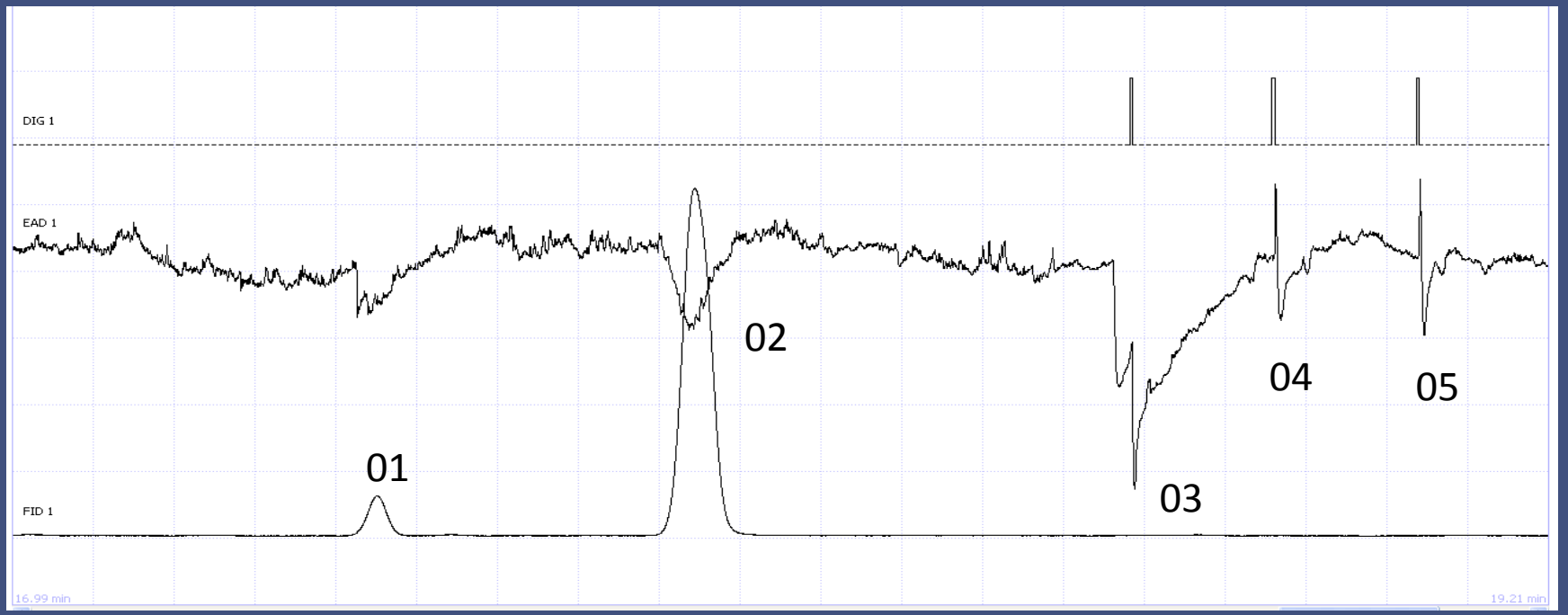


Fig. 09: GC-FID-EAD spectrum of Commercial Pheromone (ChemTica International) with manual puffs of sugarcane and pineapple volatiles: Peak 01 - FID peak of 4-methyl-5-nonanone with a corresponding EAD peak; Peak 02 – FID peak of 4-methyl-5-nonanol with a coincident EAD response; Peak 03 – EAD response to manual puff of commercial pheromone; Peak 04 – sugarcane volatiles; Peak 05: pineapple volatiles. DIG peaks denote the timing of the puffs for EAD responses.

Male-produced aggregation pheromones (AP) and minor components of palm-associated weevils in the Dryophthoridae

Genus	Common	*Rhynchophorus*	*R.*	*R.*	*R.*	*R.*
Species	Chemical	*bilneatus*	*cruentatus*	*ferrugineus*	*palmarum*	*phoenicis*
Distribution	Name	New Guinea	North America	Asia (expanded)	Neotropics	Central Africa
Common name		New Guinea palm weevil	palmetto weevil	Red or Asian palm weevil	American palm weevil	African palm weevil
3-pentanol						
3-pentanone						
(4*S*, 2E)-6-methyl-2-hepten-4-ol	rhynchophorol				AP	
2-methyl-4-heptanol						
2-methyl-4-heptanone						
2,3-epoxy-6-methyl-4-heptanol					minor	
2-methyl-4-octanol						
2-methyl-4-octanone						
(3*S*, 4*S*)-3-methyl-4-octanol	phoenicol			minor		AP
(5*S*, 4*S*)-5-methyl-4-octanol	cruentol		AP			
5-nonanol						
(4*S*, 5*S*)-4-methyl-5-nonanol	ferrugineol	AP		AP	minor	
4-methyl-5-nonanone				AP		

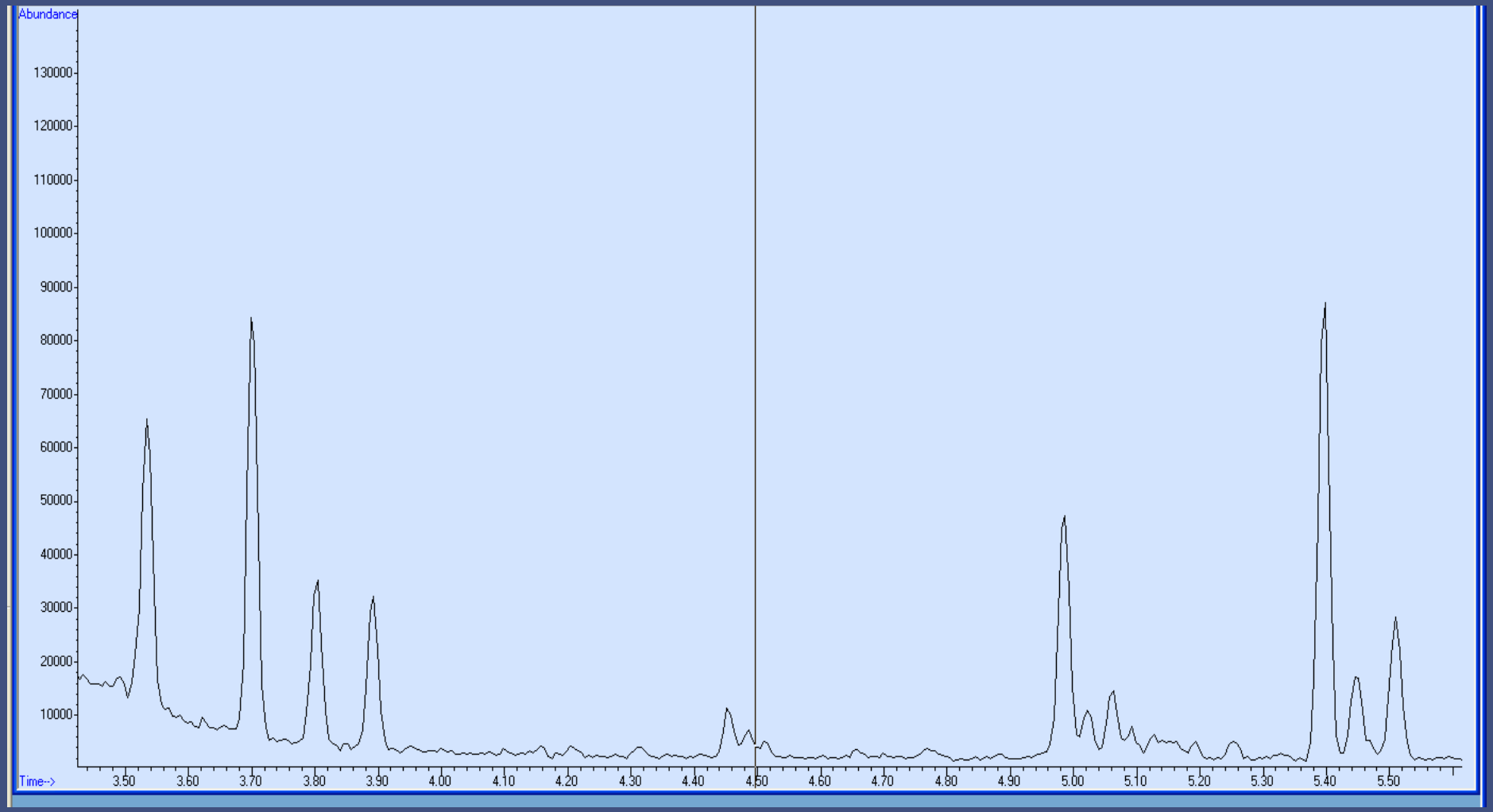
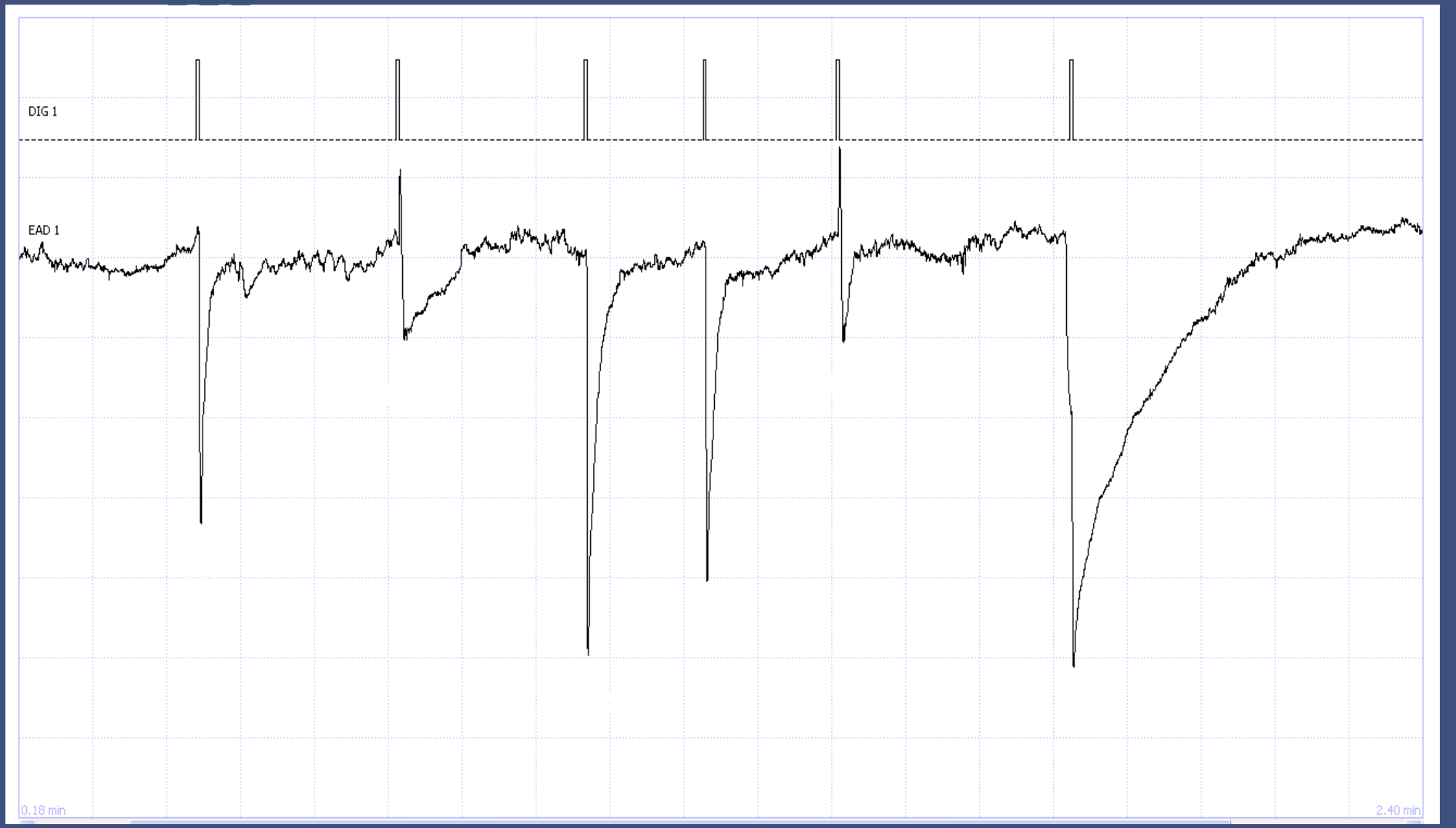


Fig. 02: GC-MS profile of volatile compounds trapped from SUKKARI Cultivar of Date Palm



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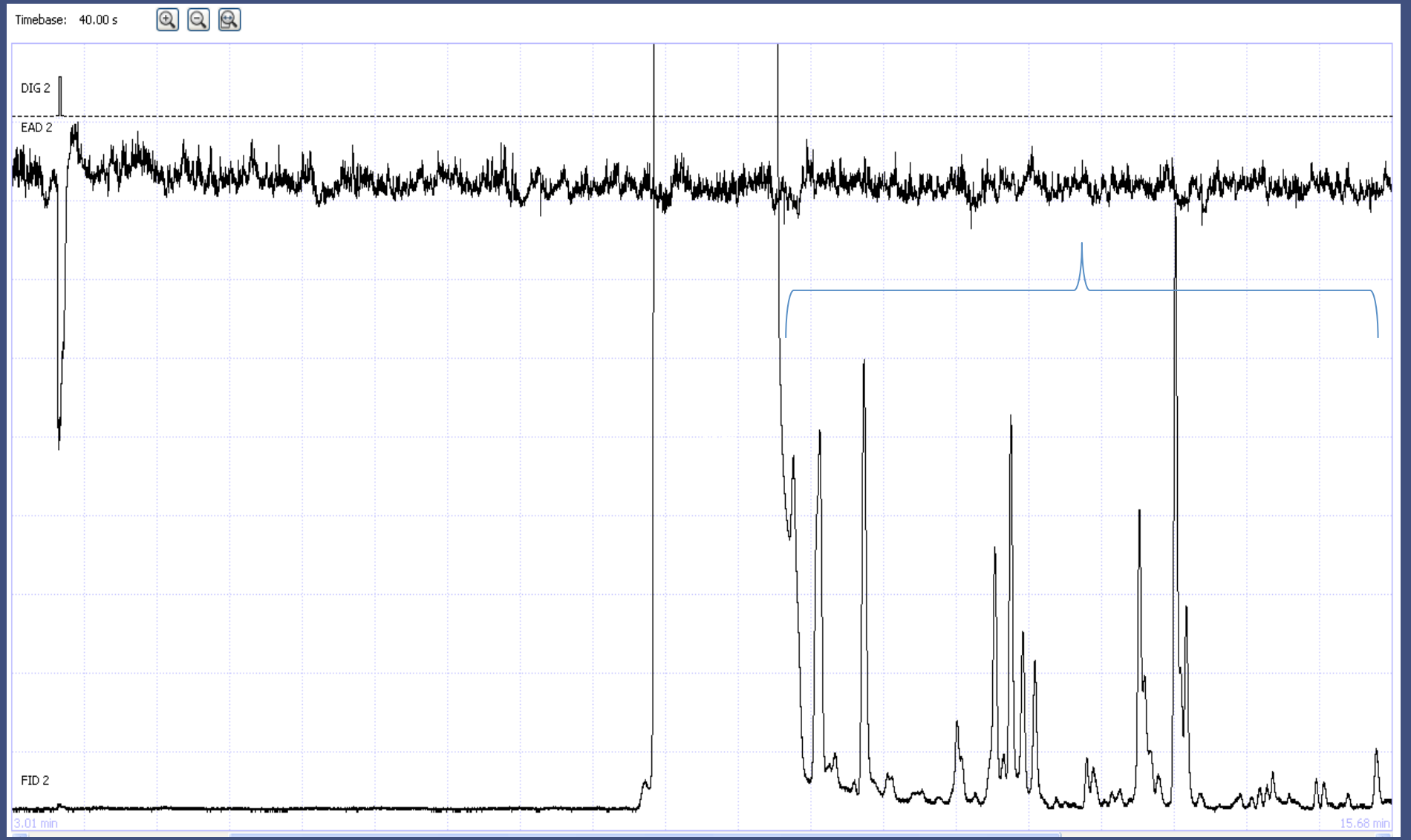


Fig. 06: GC-FID-EAD run of Sugarcane volatiles: Peak 01 – Manual puff of Commercial pheromone (ChemTica International) with corresponding DIG timing indicator; Peak 02 – Broad peak of solvent (CH_2Cl_2) with no corresponding EAD response; Peak Range 03: FID peaks of sugarcane volatiles with no corresponding EAD responses.

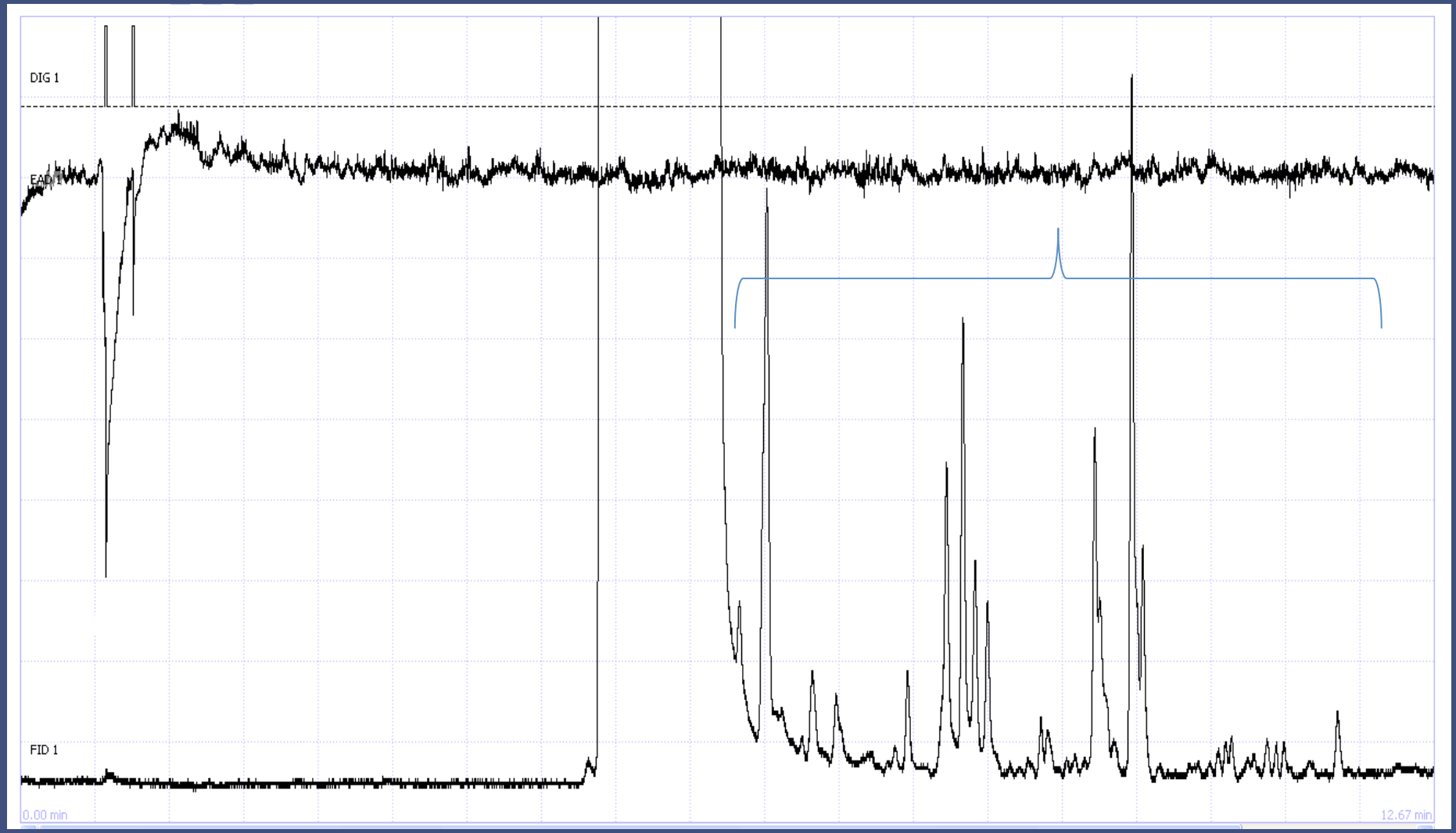
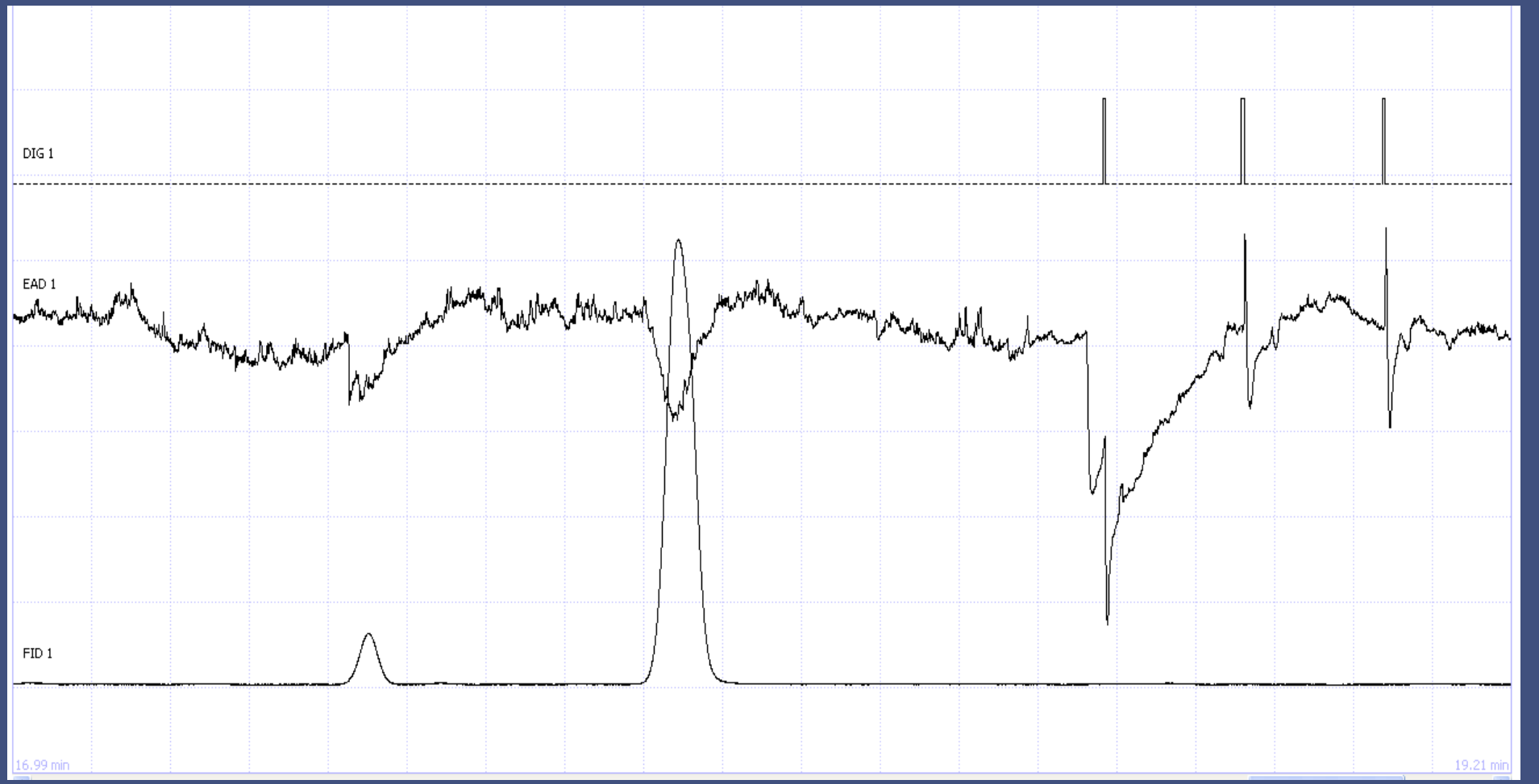


Fig. 07: GC-FID-EAD run of Pineapple volatiles: Peak 01 – Manual puff of Commercial pheromone (ChemTica International) with corresponding DIG timing indicator; Peak 02 – Manual puff of pineapple volatile mixture (same as injected into GC) with DIG timing indicator; Peak 03 - Broad peak of solvent (CH_2Cl_2) with no corresponding EAD response; Peak Range 04: FID peaks of pineapple volatiles with no corresponding EAD responses



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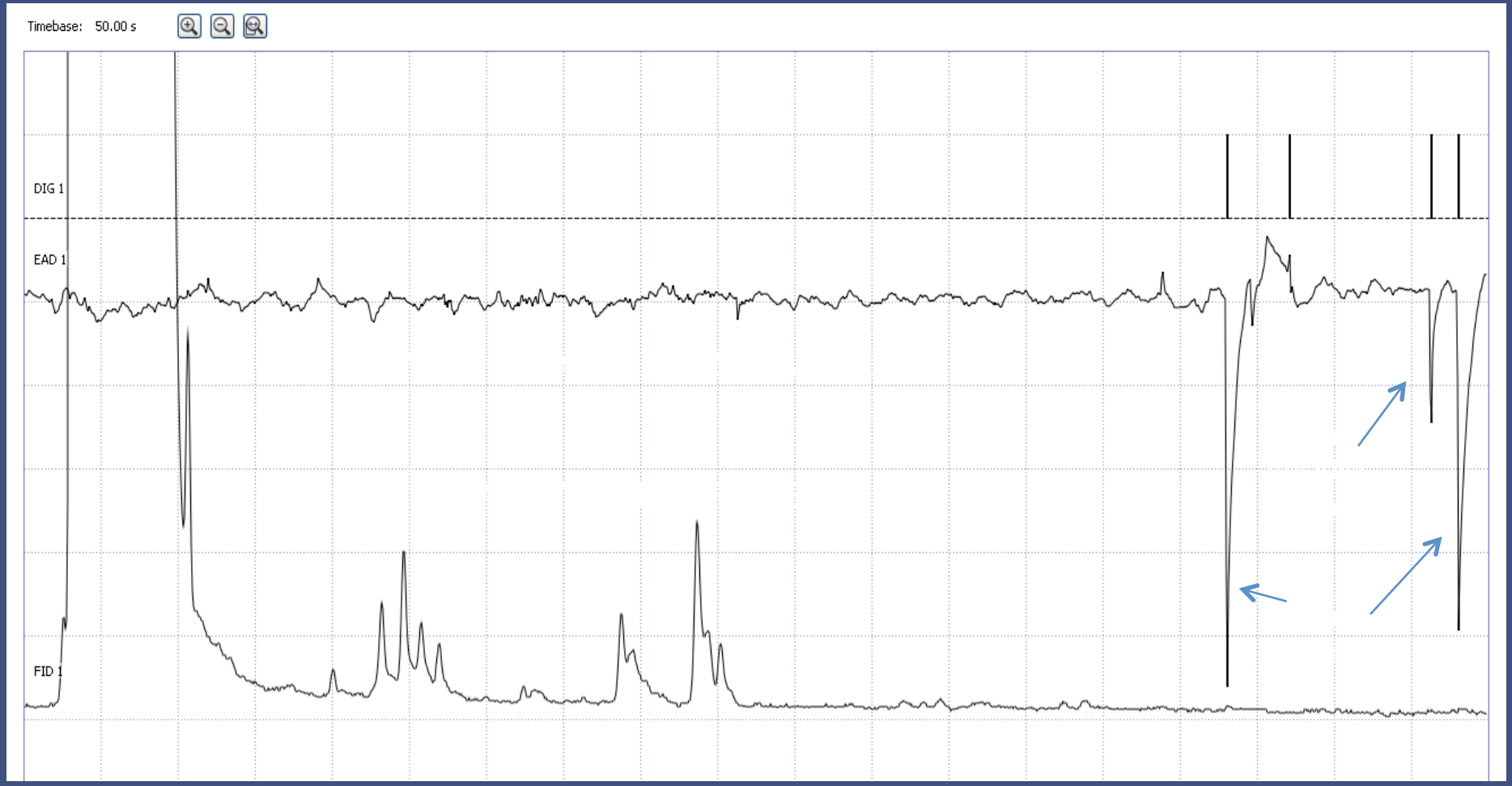
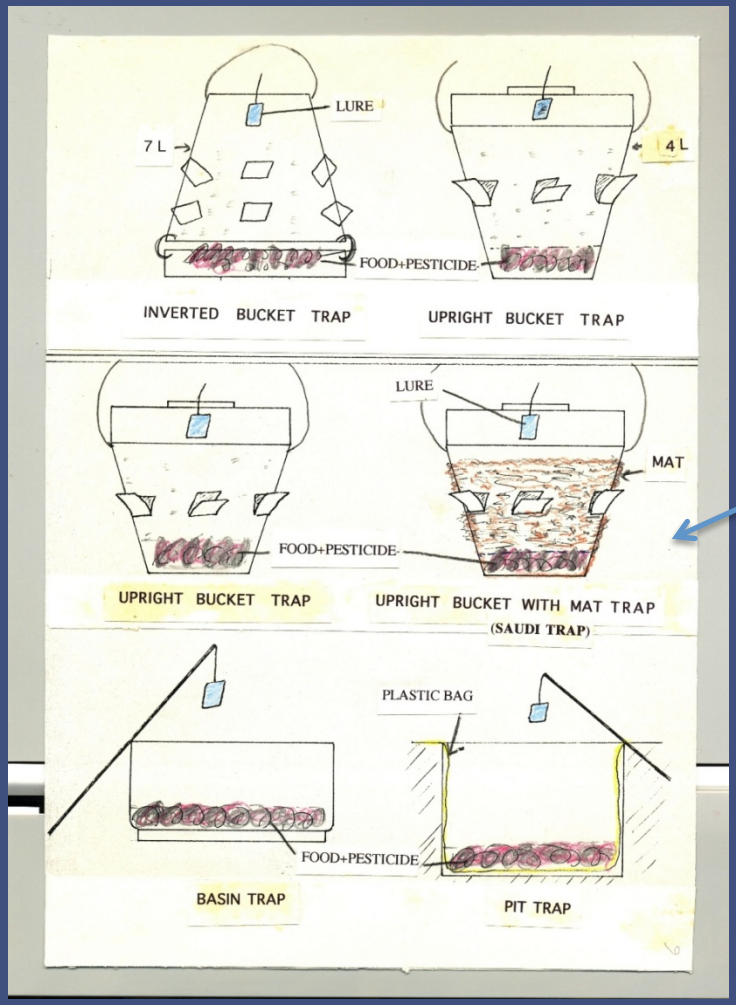


Fig. 05: GC-FID-EAD responses of individual volatile compounds from SUKKARI cultivar's extract along with manually puffed total extract and RPW pheromone

Trap Designs tested



Abozuhairah et al, 1996

Various Trap Designs

Inverted Trap

French Trap & **Lure**

Serial Funnel Trap of Turkey

Pheromone Trapping

Monitoring

- Distribution of Saudi pheromone traps
- Monitoring the traps and checking infestations

Mass pheromone trapping

- Attract and kill the insect to reduce population
- Higher density trapping methods
- Servicing of traps regularly
- Adoption of any new methods

Case study of successful mass trapping in Saudi Arabia

RPW Scenario in SAUDI ARABIA

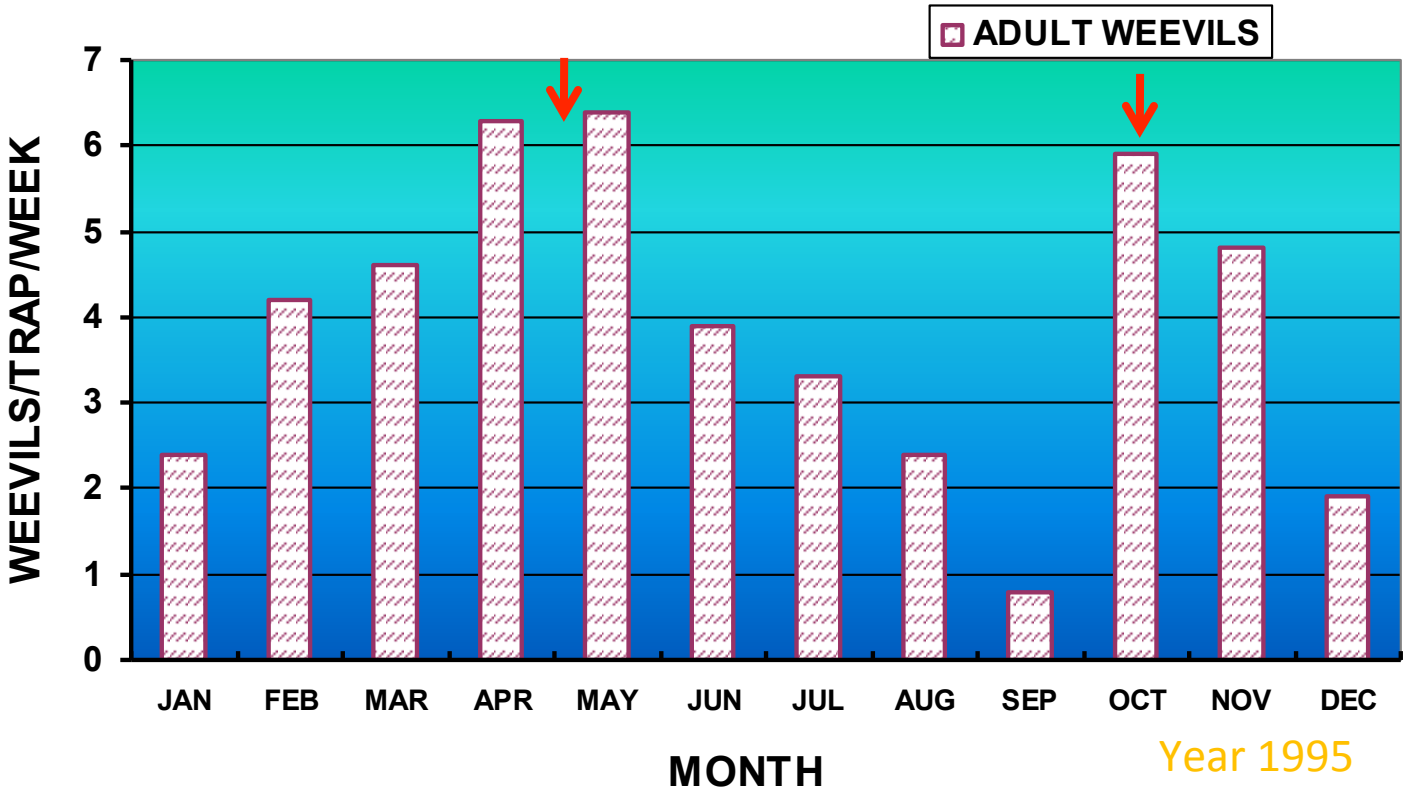
- ✓ RPW known to farmers since 1990s only.
- ✓ Most of the farm operations are carried out by farm labor.
- ✓ Plant protection operations are organized by Agriculture Ministry and/or farmer himself.
- ✓ More awareness about the damage and hence ready to adopt new methods of control.
- ✓ Access to latest methods for management through extension services.
- ✓ Propagation by offshoots or grownup palms and transported and transplanted in other locations.
- ✓ Plant quarantine laws regarding transport or import of planting material in place.

Estimated losses due to RPW

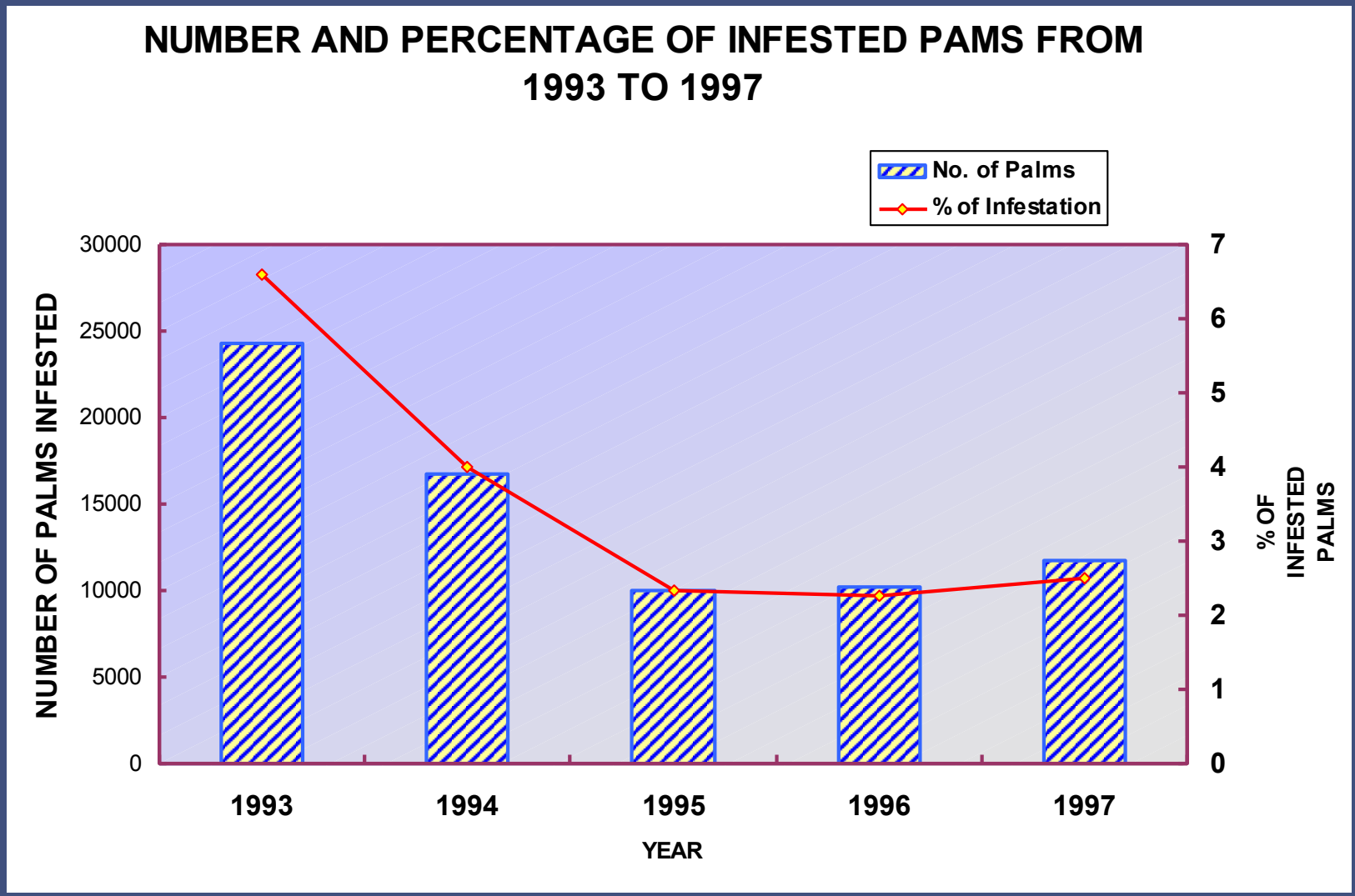
Estimated losses caused by RPW	**(Saudi Riyals)**
1. Cost of treatment	**23,000,000**
2. Cost of removal	**23,000,000**
3. Cost of new offshoots	**46,000,000**
4. Estimated yield loss for 5yr	**129,375,000**
Grand total	**221,375,000**

*Assumption that about 1% of total palms are affected out 0f total 23 million palms and of that 50% is treated and remaining 50% removed

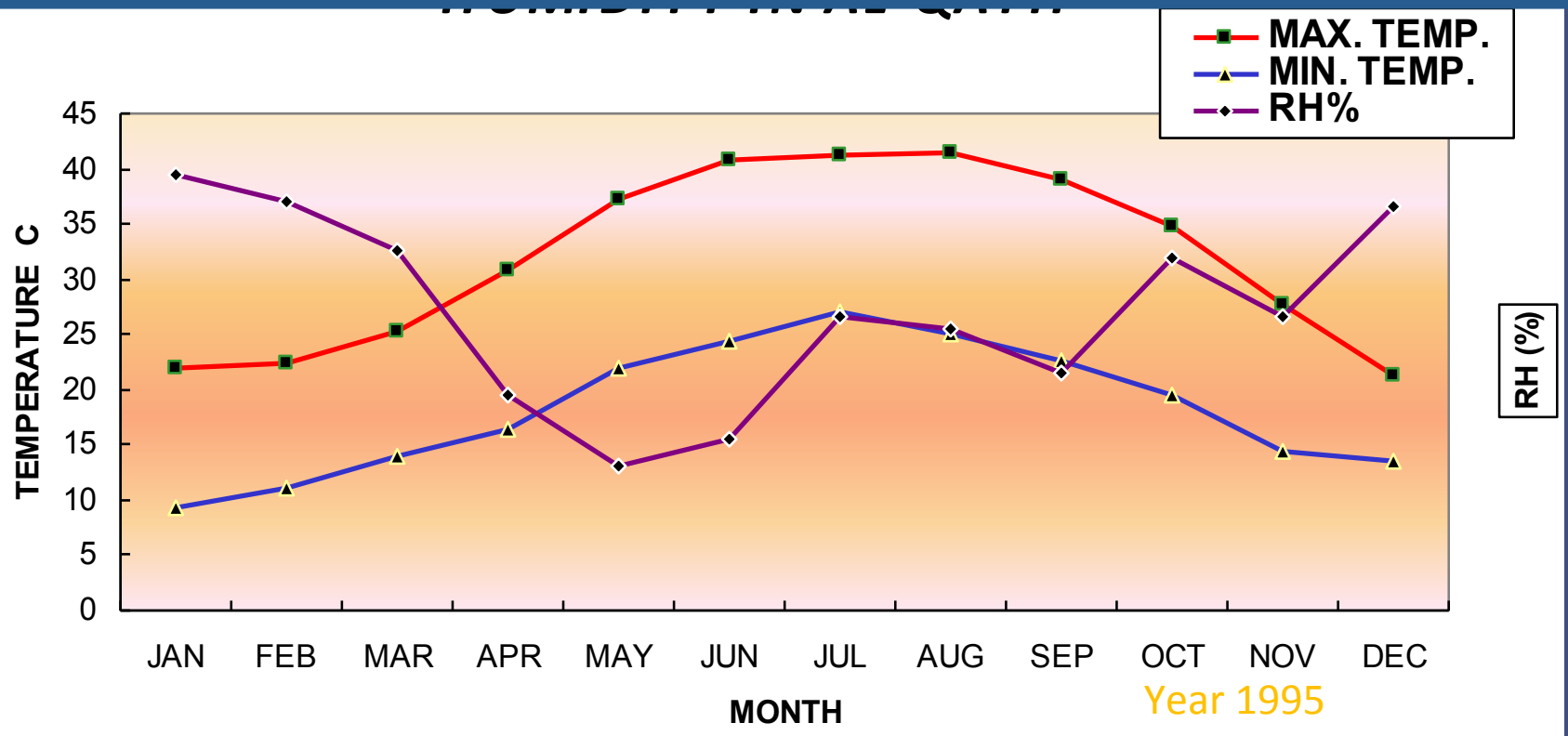
Average Number of Adult Red Palm Weevils Captured in Different Months



Management of RPW in Saudi Arabia



AVERAGE MAXIMUM AND MINIMUM TEMPERATURE AND RELATIVE HUMIDITY



Sustaining Trapping Systems

- **For developing a successful trapping system against a pest, information on the**
- **Type of trap**
- **Height of trap**
- **Kind of food bait and**
- **Most essentially trap density is needed.**
- **More information is required to make a strong program.**

Trap Designs tested in the study (1)

Treatment 1
Saudi Bucket Trap

Treatment 2
Date Stump Trap

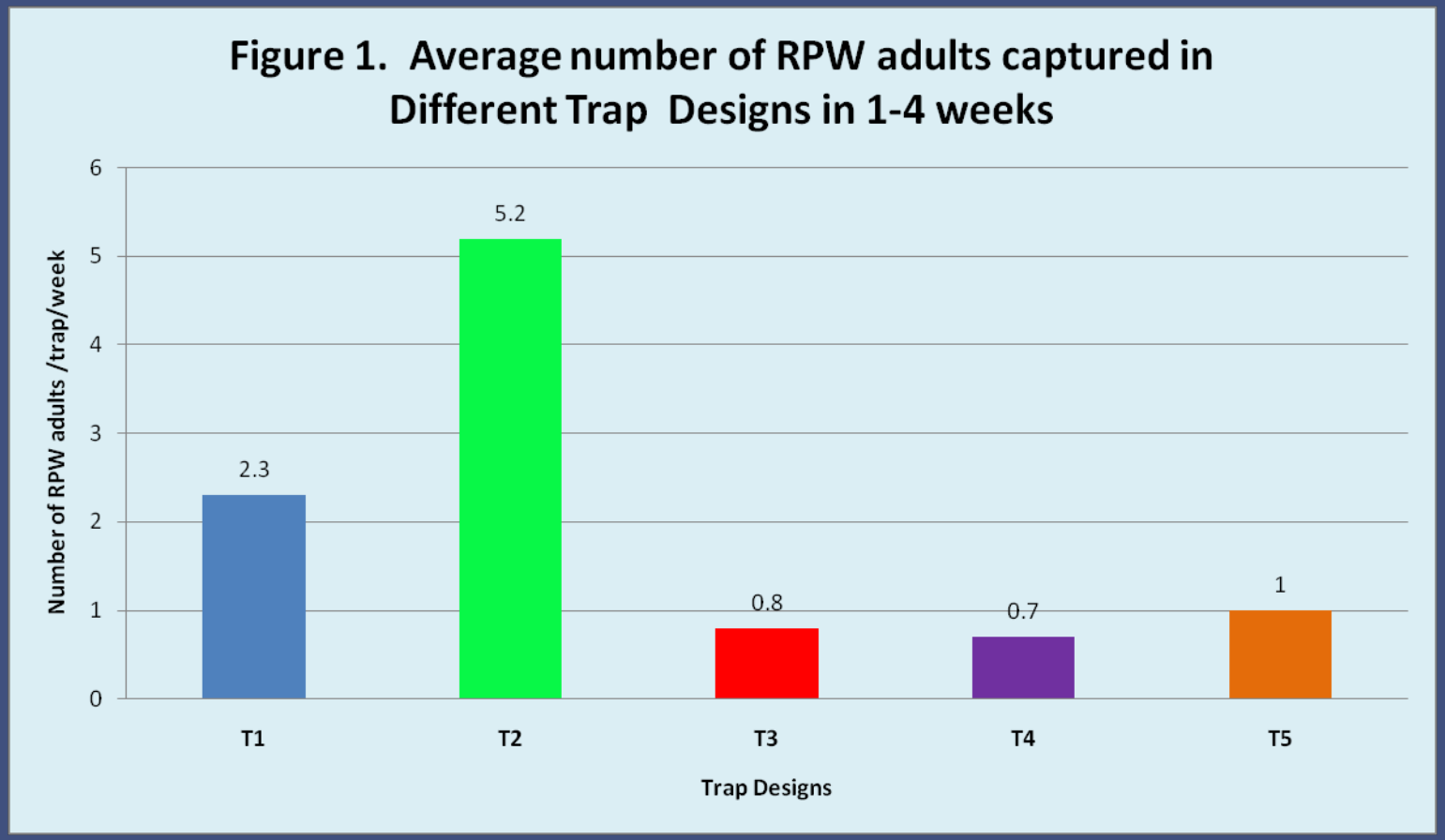
Trap designs tested in the study (2)

Treatment 3
Prop Trap

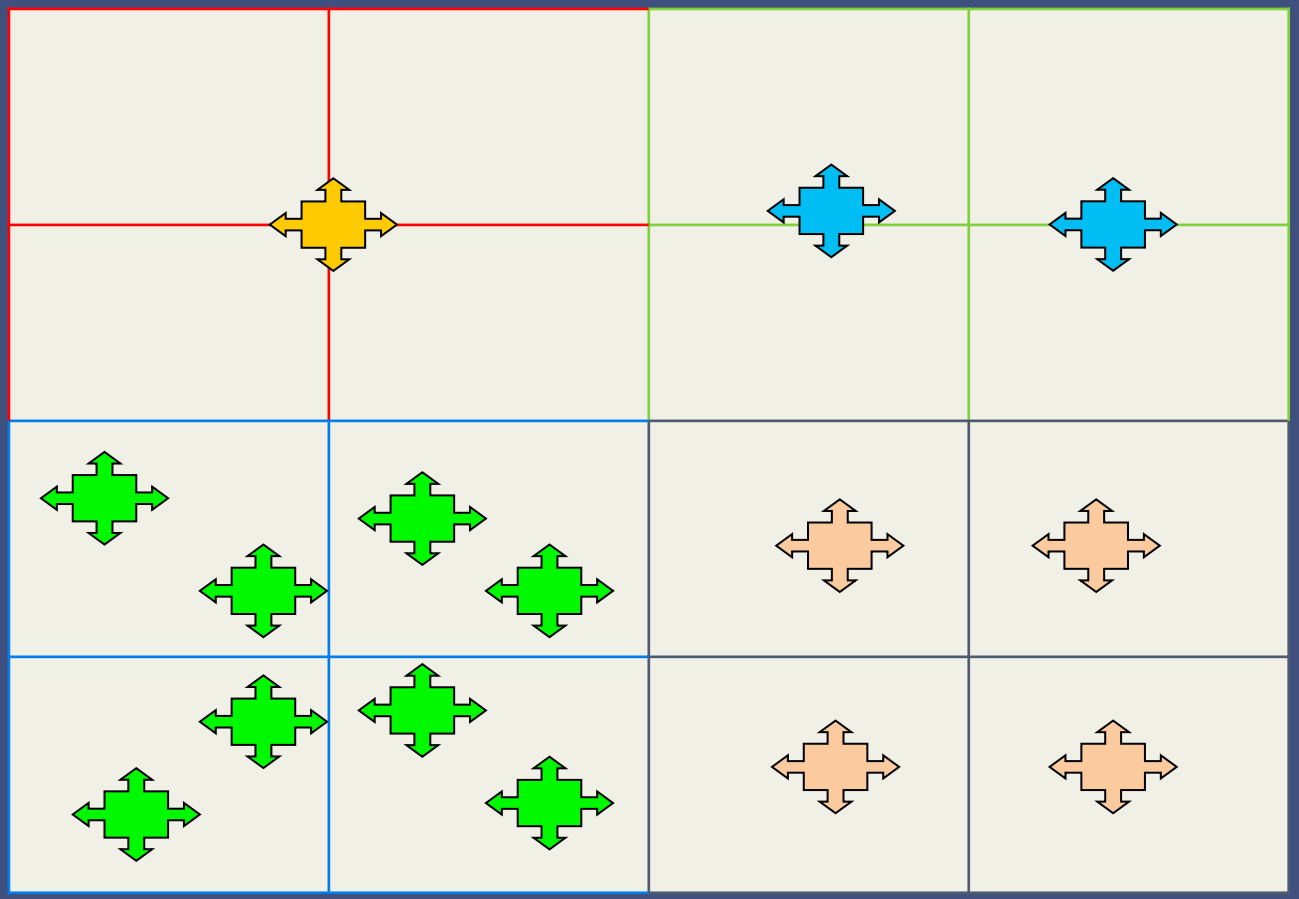
Treatment 4
Ground Trap

Treatment 5
Matwall Trap

EFFICACY OF DIFFERENT TRAP DESIGNS

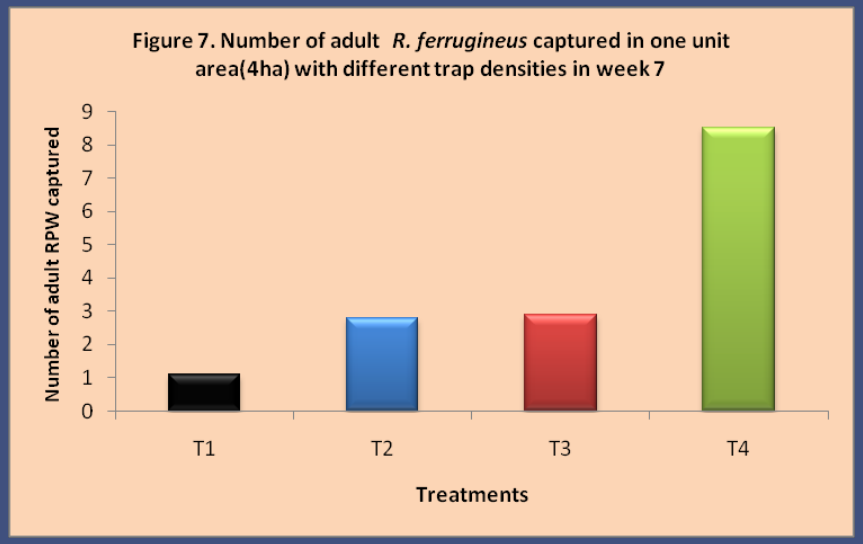


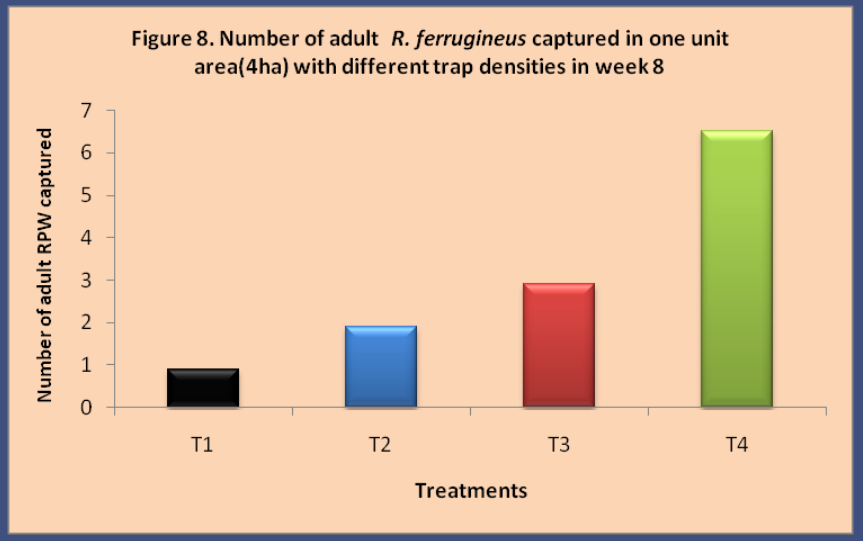
Trap Density Layout and Treatments



T 1 – One trap per one block of 4ha
T2 – Two traps per one block of 4ha
T3 - Four traps per one block of 4
T4 – Eight traps per one block of 4ha

Adult RPW captured at different trap densities in week 7 & 8 in Al Hassa

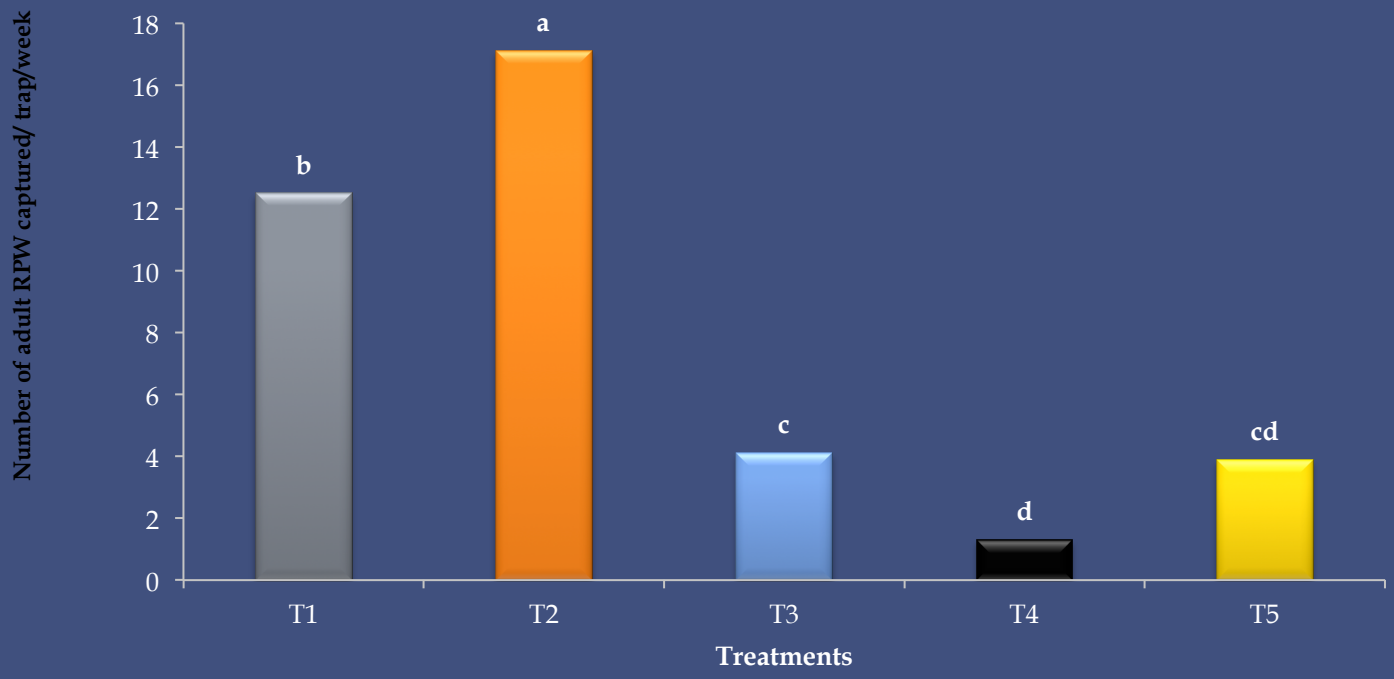




Food baits in pheromone traps

(At Al Kharj)

Figure 1. Adult Red palm weevils captured in different pheromone treatments in the 1st week



T1 – Saudi Trap with (Pheromone lure + Date Fruit + water)
T2 – Saudi Trap with (Pheromone lure +Date Fruit+ Ethyl acetate + Yeast + water)
T3 – Saudi Trap with (Pheromone lure + Date Fruit + Ethyl acetate + Propylene glycol + water)
T4 – Saudi Trap with (Pheromone lure + Date syrup + Propylene glycol + Apple flavor Tobacco+ water
T5 – Saudi Trap with (pheromone lure + Date syrup + Propylene glycol + Pineapple flavor Tobacco + water)

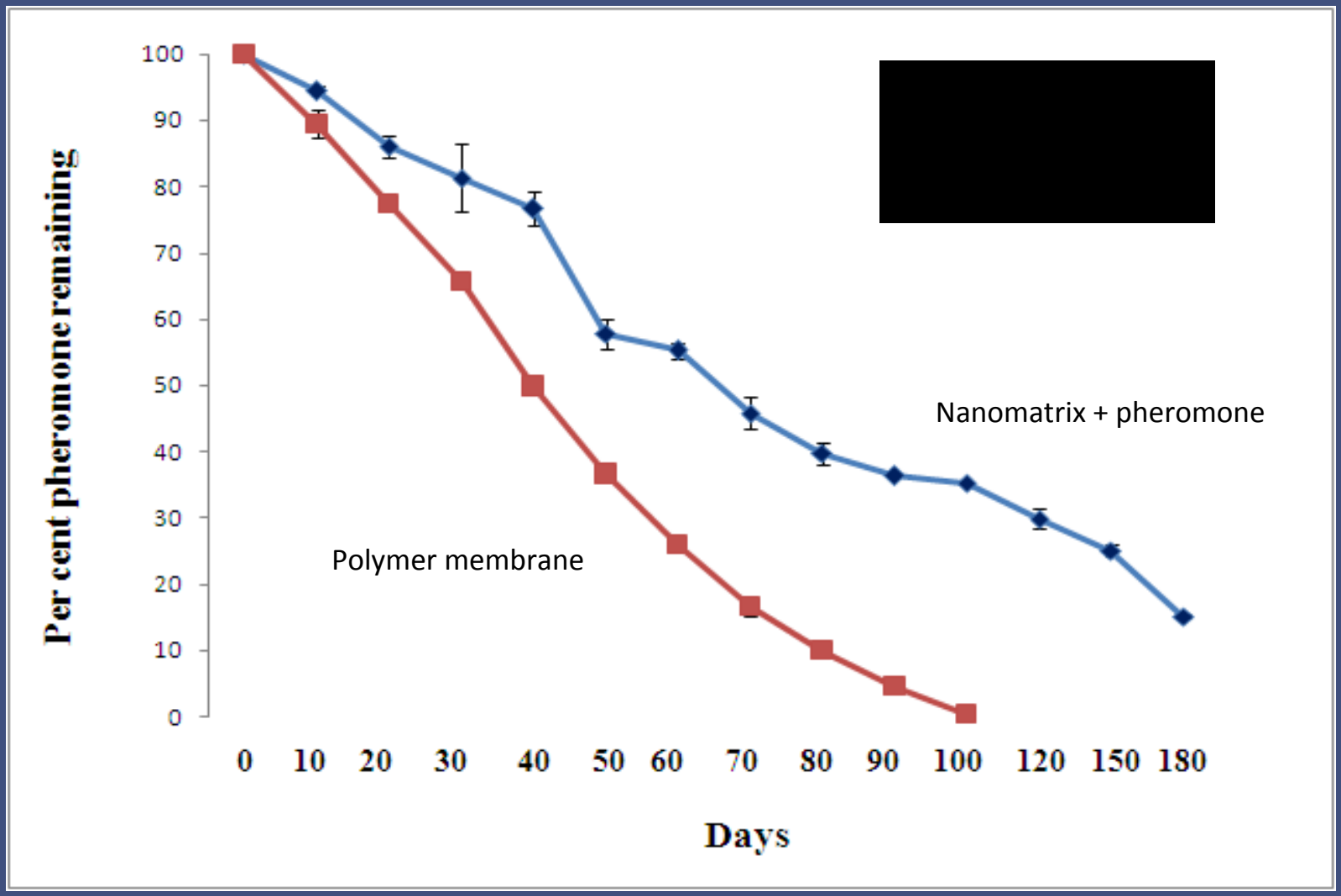
Specifications of the red palm weevil pheromone lures

Brand	Dispenser type	Pheromone	Quantity (mg)
ICAR - JNCASR	**Nanoporous matrix** 	4 methyl 5 nonanol + 4 methyl 5 nonanone (9:1)	**65**
Chemtica (Costa Rica)	**Polymer membrane** 	4 methyl 5 nonanol + 4 methyl 5 nonanone (9:1)	**700**

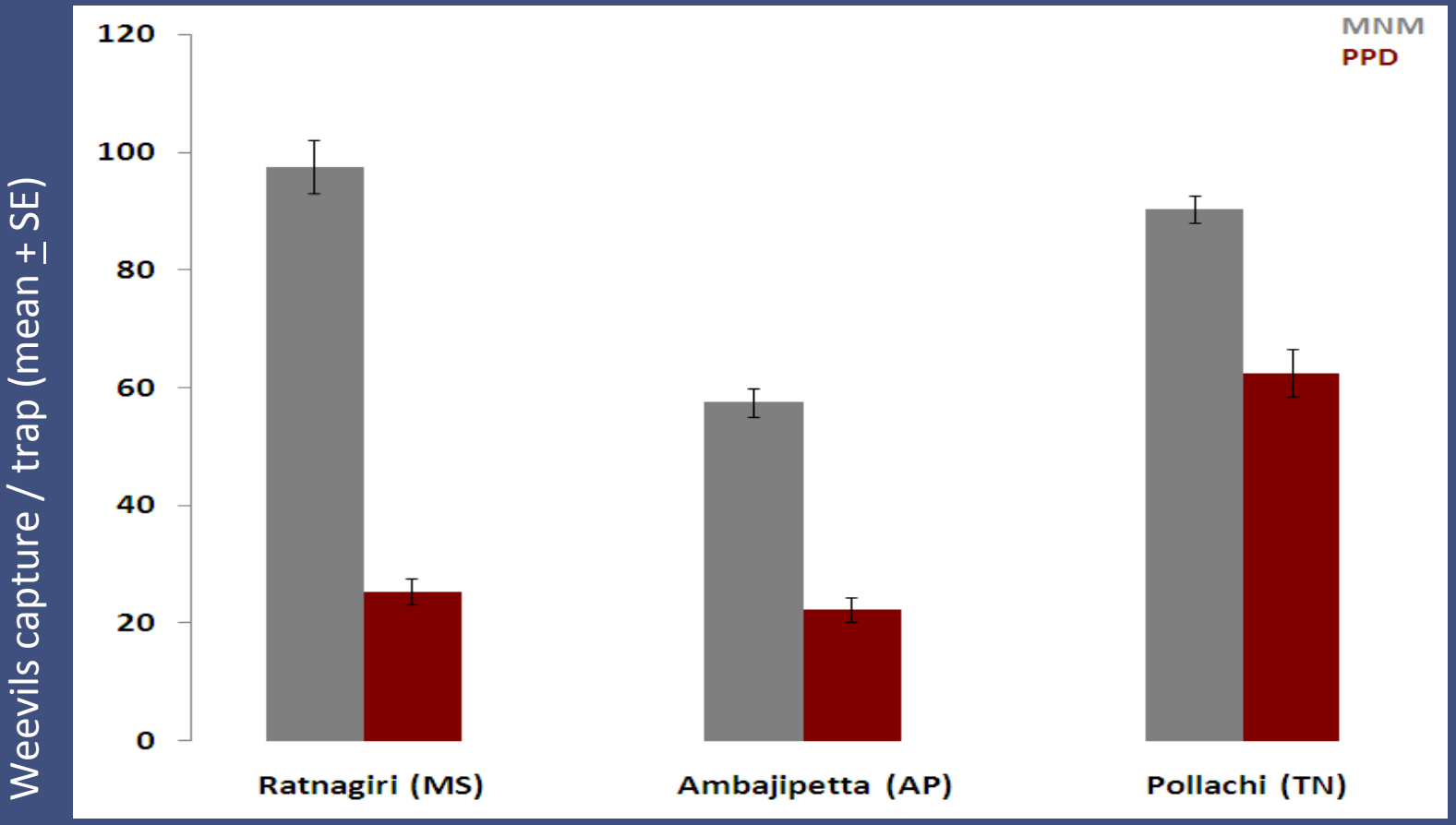
"**A composition and methods thereof**" 5156/CHE/2013 filed on 12.November 2014.

Dissipation pattern of pheromone loaded into nanomatrix

(Gravimetric)



Multi location trial to assess the performance of lure loaded in nanomatrix



X^2 = 11.93 2 df p=0.01 X^2 = 12.93 2 df p=0.01 X^2 = 12.98 2 df p=0.01

Kruskal Wallis test

MNM – Nanomtrix PPD – Polypropylene dispense

Monitoring with Pheromone traps

- Pheromone traps can be used for surveillance of invasive pests.
- The traps are also useful for monitoring the population dynamics of a particular species in a specific region or location.
- Caution must be taken to stick to the protocols recommended.
- If not properly used these traps may bring in or spread of the pest.

Scenario in India about pheromone trapping for RPW management

- In India coconut is a major plantation crop with an area of 10.20 lakh hectares and produces about 5911 million nuts annually. The value of produce is Rs. 7000 crores that is contributed to the country's GDP. The four Southern states account for the 90% production.
- Regarding date palms, it was estimated to be around 1.9 million palms in the Gujarat and Rajasthan states.
- Oil palm is in an area of about 2.09 lakh hectares and the area is expanding.
- All these palms are attacked by RPW. In India RPW management is done with pheromone trapping in coconut farms and also to some extent in date gardens in Gujarat and Rajasthan states. For coconut the coconut Development Board provides subsidy to the farmers under several schemes to encourage the use of pheromone trapping as a tool in the control of RPW in coconut growing states mainly Kerala, Karnataka, Tamil Nadu and Andhra Pradesh.

Chemical Ecology of the insect – future trends

Present status	Future research
Aggregation pheromone blends in mass trapping are used (4 methyl 5 nonanol + 4 methyl 5 nonanone) (9:1)	Are there other groups of behavior modifying chemicals in RPW ?
Aggregation pheromone + Kairomone also used	Are there other host volatiles to increase attraction?
Food baiting is a must?	Any substitute for Food available ? Sustainability of new Dry trap.

Clean Date Farm with Pheromone loaded bucket traps on stems

Conclusions

- The chemical ecology research demonstrated the value of intensive basic research on the physiological and behavioral aspects of the insect RPW.
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- Synthetic Pheromones as a component in the management of RPW has been successfully used in many countries.
-
- For enhancing the attraction of pheromone traps, kairomones are added as supplements.
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- These methods of control are non-toxic, eco-friendly, cost effective, do not develop resistance, sustainable, besides many more advantages.
-
- Hence it can safely be said that all RPW insect management programs should have a pheromone/kairomone as a major component.

Thanks

- King Saudi University
- ICAR
- Farmers
- All collaborators