Impact of large scale mass trapping of red palm weevil *Rhynchophorus ferrugineus* Olivier in coconut plantations in Kerala using indigenously synthesized aggregation pheromone lures

K. P. Jayanth, M. Thomas Mathew*, G. B. Narabenchi and K. R. M. Bhanu

Bio-Control Research Laboratories, A Division of Pest Control (India) Private Limited 36/2, Sriramanahalli, Nr. Rajankunte, Dodballapur Road, Bangalore-561 203

Traps with highest catches were located mostly along the periphery, rather than the middle of the demonstration area. Most of the pheromone traps that caught the lowest numbers of adults were noticed to be located in the northern half of the study plots, particularly in the north-west quadrangle. Moreover, traps installed in the middle of the study area were generally observed to catch less numbers of weevils.

Abstract

The red palm weevil (RPW), *Rhynchophorus ferrugineus* Olivier, causes death of coconut palms in India mainly due to the difficulty in detecting infestations in the early stages on account of the insidious nature of its feeding. The present paper reports results of large scale mass trapping studies carried out in Kerala, using indigenously synthesized pheromone, under a Technology Mission on Coconut Project sanctioned by Coconut Development Board. A total of 9370 adults were caught in pheromone traps installed over 50 acres each in Muthukulam (Alappuzha District) and Pullad (Pathanamthitta District) during the 10 month study period from May 2006 to February 2007. More numbers of adults were caught in traps installed along the periphery, particularly in the south and south-easterly directions. The pheromone traps were observed to catch significantly more numbers of females (sex ratio 1: 1.99) and majority of them were found to be virgins (45%), followed by gravid females (29%) that had not started laying eggs, indicating the potential of area-wide adoption of mass trapping in bringing down the population density of RPW.

Introduction

The red palm weevil (RPW) *Rhynchophorus ferrugineus* Olivier (Coleoptera: Curculionidae) is a ubiquitous pest of coconut (*Cocos nucifera* L.) that completes all stages of its life within the palm. Although palms of all ages are prone to the attack of this pest, young palms up to the age of 20 years are preferred. Continuous feeding by the grubs inside the stem, for more than one generation, causes breaking of the stem and toppling of the affected

* CCDO, Coconut Development Board, Kera Bhavan, Kochi 682 011, Kerala

palm. Due to the concealed nature of feeding it is difficult to detect RPW infestation in the early stages and farmers become aware of the problem only when the tree is about to die. Considering the fact that adult weevils, which are reported to survive up to 120 days, are capable of flying long distances and can find their host plants in widely separated areas (Abraham *et al.*, 2002) the pest poses a serious threat to coconut plantations. Chemical methods, including spraying of the palms with high pressure sprayers, stem injection of infested palms and spot application of fumigant tablets were only moderately successful in containing the infestation and dispersal of the pest (Vidhyasagar *et al.*, 2000).

The male produced aggregation pheromone of RPW (4-methyl-5-nonanol) was first identified by Hallet *et al.* (1993) while Ochlschlager *et al.* (1993) designed a pheromone based trapping system. Bucket traps baited with pheromone lures can be used for detecting early infestation, trapping floating populations of adults and also for mass trapping as a key component of integrated pest management. Pheromone trapping is adopted widely for management of RPW in date palms in Saudi Arabia (Abraham *et al.*, 2000). Nevertheless, the technology is yet to be validated on a large scale in coconut plantations in India. Area wide adoption of pheromone technology for management of coconut pests in India is also hampered by the high cost of imported pheromone lures.

Pest Control (India) Pvt. Ltd. (PCI), which established the country's first commercial pheromone synthesis facility, has indigenously produced aggregation pheromone lures of the red palm weevil. The present studies were carried out to determine the efficacy of lures produced using indigenously synthesized pheromone and the impact of large scale mass trapping on the population density of RPW adults, as part of a project sanctioned by Coconut Development Board under its Technology Mission on Coconut.

Materials and Methods

The studies were carried out in two contiguous areas at Muthukulam (50 acres, 177 farmers) and Pullad (50 acres, 58 farmers) totaling 100 acres, located about 60 km from each other in the adjoining districts of Alappuzha and Pathanamthitta districts, in Kerala, between May 2006 and March 2007. A total of 100 bucket traps, each baited with red palm weevil pheromone lure, synthesized and manufactured by PCI were installed on coconut trees over 20 years of age @ 1/ acre, about 5 feet from ground level, in the two study plots during the third week of May 2006 (**Figure 1**). Two liters of water were poured into each of the buckets, to which coconut shavings were added as food bait and ½ tea spoon of detergent as wetting agent to kill the trapped adults. The bucket traps were cleaned at fortnightly intervals, while topping of water and replacement of food bait were undertaken at weekly intervals. The same lures were used for the entire study period.

Simultaneously release rate studies were carried out under laboratory and open field conditions at Bio-Control Research Laboratories, Bangalore (BCRL) to

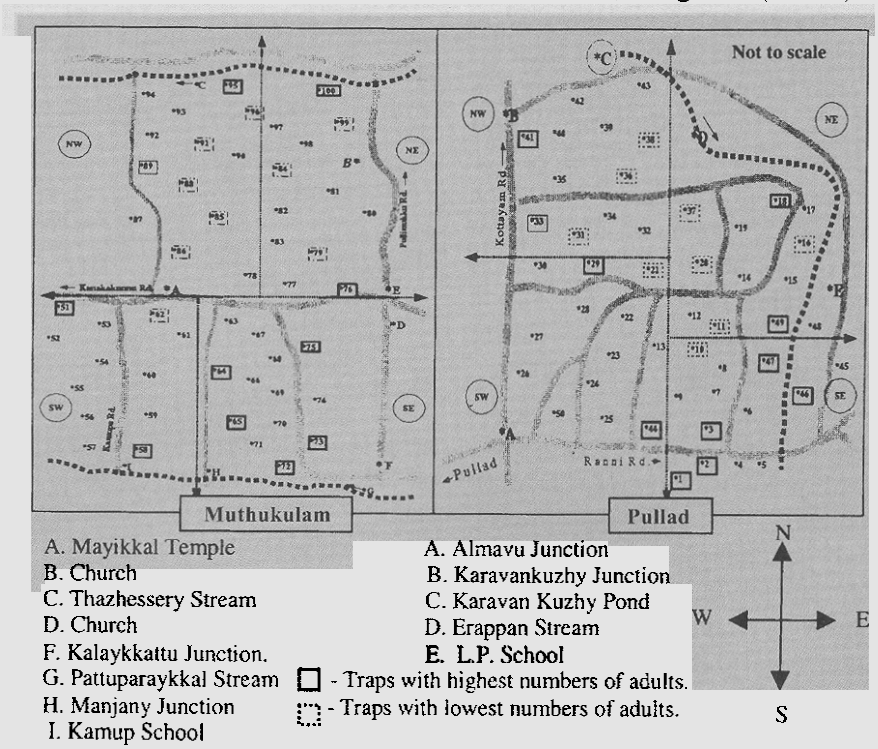


Figure 1. Plot map of the project demonstration areas at Muthukulam (Alappuzha Dist.) and Pullad (Pathanamthitta Dist.), Kerala, indicating location of the pheromone traps in different quadrangles.

determine the field viability of the lures. Studies under field conditions were carried out by installing 2 bucket traps with lures at 2 locations at the BCRL campus. The total weight of each lure, loaded with 800 mg of pheromone, was taken before commencement of studies and at weekly intervals thereafter, throughout the study period. Laboratory studies were carried by hanging 2 RPW lures within a wind tunnel maintained at room temperature. The exhaust fan within the wind tunnel was operated continuously, except for a break of 6 hrs during the night. Observations, as indicated above, were recorded for a period of 6 weeks.

RPW adults caught in pheromone traps were collected, sexed and their numbers recorded trap-wise at weekly intervals. A total of 65 females, caught during different months in pheromone traps, were dissected and examined under a stereo binocular microscope at BCRL to determine their reproductive status. The dissected females were categorized based on ovarian development, numbers of eggs in lateral and common oviducts and accumulation of fat globules in the abdominal cavity (Kalleshwaraswamy *et al.*, 2005).

Observations on adult catches were recorded from the fourth week of May 2006 till the last week of February 2007. After the 40 week study period the lures were removed from all the bucket traps, but the traps were retained in the field at the same locations and serviced as earlier. Observations on adults captured in these traps were recorded at weekly intervals for 4 weeks to determine attraction of adults to pheromone residue present in the traps.

During the course of the studies a total of 91 farmers holding 100.40 acres under coconut in Alappuzha and Pathanamthitta districts, located about 3 and 6 km away from the project demonstration areas respectively, were interviewed to determine their awareness about RPW and understand their perception on death of coconut palms caused by it over the last 5 years, with the help of a questionnaire designed specifically for this purpose.

The compiled data was subjected to suitable transformation before analysing statistically and the results are presented below.

Results and Discussion

A total of 9370 adults of red palm weevil were caught in aggregation pheromone traps installed in the 100 acre project demonstration area, over the 10 month study period from May 2006 to February 2007 (Table 1). Two adult catch peaks were recorded during May (Mean 421) and November 2006 (Mean 302.5), with the lowest numbers being recorded in February 2007. The mean number of adults caught on weekly basis was found to decline steadily over the previous months up to August, increased marginally over the next 3 months and declined steadily thereafter. The population density of RPW adults in the project demonstration area was found to decline by 54.39 per cent during the study period, indicating the potential of mass trapping technology in bringing down population density of red palm weevil adults.

Influence of weather

Analysis of correlation of weather factors indicated a positive and highly significant linear relationship between rainfall and adult catches, as evidenced by high "R" value (R= 0.754) (Table 2). Thus the marginal increase in

Table 1. Numbers of Male and Female Red Palm Weevil adults caught, monthly means and mean percentage reduction in the 100 acre study area in Kerala using aggregation pheromone lures during May 2006 to February 2007

Particulars	Male	Female	Sex Ratio (B&:@&)	Total	Mean/ month (Weekly basis)	Mean % reduction over 1st month
May 06	151	270	1: 1.79	421	421.00	—
Jun 06	317	882	1: 2.78	1199	299.75	28.80
Jul 06	348	652	1: 1.87	1000	250.00	40.61
Aug 06	353	723	1: 2.05	1076	215.20	48.93
Sep 06	319	585	1: 1.83	904	226.00	46.31
Oct 06	394	693	1: 1.76	1087	271.75	35.45
Nov 06	410	800	1: 1.95	1210	302.50	28.14
Dec 06	276	608	1: 2.20	884	221.50	47.50
Jan 07	303	518	1: 1.71	821	205.25	51.30
Feb 07	268	500	1: 1.87	768	192.00	54.39
Total	3139	6231	1: 1.99	9370	—	—
Mean	31.39	62.31**	—	—	—	—
t_a (5%) N=100	26.15	—	—	—	—	

** Significant at P= 0.01

numbers recorded during September to November 2006 was probably influenced by rainfall (Figure 2). The first peak of adult catches recorded in May (Mean 421) coincided with the peak rainfall during this month (655.3 mm), while the second adult catch peak (Mean 302.50), noticed during November 2006, was found to follow the second rainfall peak recorded in October (613.5 mm). However, the mean number of adults captured during the second peak (302.5 adults in November 2006) was found to be 28.14 per cnt lower than that recorded during the first peak (421 in May 2006), which in turn was probably influenced by mass trapping of 5687 adults during the intervening period from the study areas.

The studies also showed a significant and positive influence of relative humidity (R= 0.511) and sunshine hours (R= 0.541), while wind velocity (R= 0.170) and temperature (R= 0.003) were not noticed to influence trap catches. The estimated linear regression between pheromone trap catches and different weather factors such as rainfall, relative humidity and sunshine hours, as indicated in equations Y=13.04+0.174X, Y=3.02 + 0.157X and Y=21.019+0.719X, respectively, could be used for predicting the adult weevil catches (Y) in the pheromone traps using different weather factors (X) (Table 2).

Table 2. Influence of weather factors on Red Palm Weevil adult catches in pheromone traps installed in the project demonstration areas in Kerala

Weather Parameters	Correlation coefficients (R)	Regression equation	F test
Rainfall	0.754**	Y=13.04+0.174x	10.572
Temperature	0.003	Y=15.21+0.18x	0.007
Relative Humidity	0.511*	Y=3.02+0.157x	2.82
Wind Velocity	0.170	Y=16.44+0.501x	0.239
Sunshine hours	0.541*	Y=21.019+0.719x	3.315

* Significant at P =0.05 **** Significant at P =0.01**

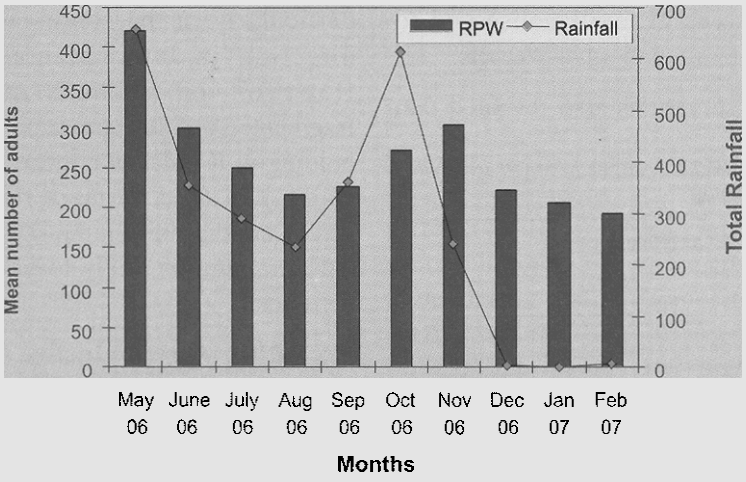


Figure 2. Impact of rainfall on RPW adult catches in the study area in Kerala

Influence of trap placement

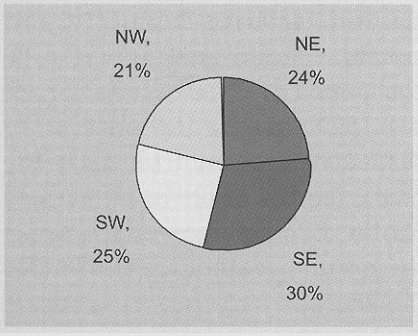
More RPW adults were captured at Muthukulam in Alappuzha district (4773) as compared to Pullad in Pathanamthitta district (4597), but the differences in number were not significant (Table 3). Comparison of adult catches recorded between the 4 quadrangles in both study areas indicated that location of the trap influenced adult catches. Thus, significantly more numbers of adults were captured from the south-east quadrangle over other locations, which in turn was on par with catches recorded in the south-west quadrangle (Fig. 3). Further analysis revealed that significantly more numbers of adults were captured from the southern part of the study area as against the northern part (Table 4). Although more numbers of adults were recorded from the eastern part of the study plot as against the west, the differences were not found to be significant

Table 3. Numbers of RPW adults caught in different quadrangles in the two 50 acre study plots at Muthukulam (Alappuzha Dist.) and Pullad (Pathanamthitta Dist.), Kerala

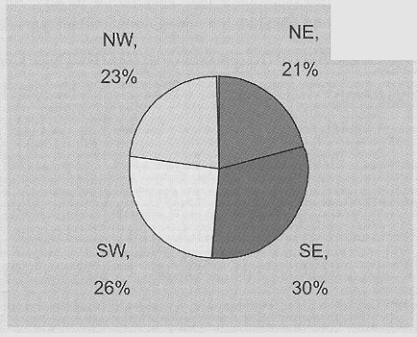
Quadrangle	Numbers of weevils/ quadrangle/ locality					
	Pullad		Muthukulam		Both	
	Total	Mean/trap	Total	Mean/trap	Total	Mean/trap
NE	1009	84.08(9.10)^{b}	1126	88.62(9.11)^{b}	2135	85.40(9.19)^{b}
NW	1078	89.83(9.40) ^{ab}	953	79.41(8.86)^{b}	2031	84.62(9.25)^{b}
SE	1438	110.62(10.37)^{a}	1368	105.23(10.21)^{a}	2806	107.92(10.29)^{a}
SW	1248	96.00(9.74)^{ab}	1150	95.83(9.27)^{ab}	2398	95.92(9.75)^{ab}
Mean/ Total	**4773**	**95.46**	**4597**	**91.94**	**9370**	**93.70**

* Figures in the parenthesis are square root (ÖX+0.5) transformed values

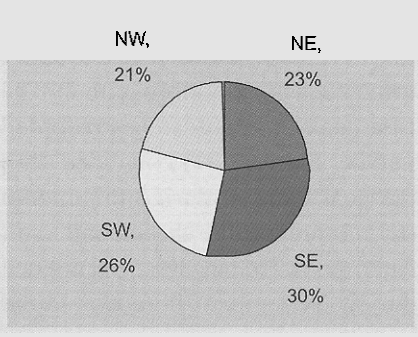
** In a column, means followed by similar letters are not significantly different statistically (p = 0.05) by DMRT



Muthukulam



Pullad



Both

Figure 3: Percentage of red palm weevil adults caught in different quadrangles in the two 50 acre study plots at Muthukulam and Pullad and both areas together during the 10 month study period

(Table 5). These studies indicate the possibility of wind direction influencing adult catches by dispersing the pheromone plume in a south-easterly direction to attract more adults in traps installed in the south-east quadrangle.

Further evidence on the impact of placement of traps was obtained by marking out pheromone traps that captured the 10 highest and lowest numbers of adults, among the 50 traps installed in each of the study areas, in the plot map. It is clearly evident from Fig. 1 that majority of the traps that captured the highest numbers of adults were located in the southern half of the plot, particularly the south-east quadrangle. The above analysis also revealed that traps with highest catches were located mostly along the periphery, rather than the middle of the demonstration area. On the other hand most of the pheromone traps that caught the lowest numbers of adults were noticed to be located in the northern half of the study plots, particularly in the north-west quadrangle. Moreover, traps installed in the middle of the study area were generally observed to catch less numbers of weevils.

Observations also revealed that majority of the traps with least adult catches were located near houses, indicating the need for installing traps in areas without any physical barriers that hinder free movement of air. The present studies thus indicate that mass trapping can be made more effective by installing more traps along the periphery, particularly in the south-easterly direction in large plantations. However, on account of the fragmented and low per capita land holding in Kerala, as noticed in the study area (235 farmers for 100 acres), large-scale community based mass trapping is likely to be more beneficial.

Table 4. Numbers of RPW adults caught in the northern and southern parts in the two 50 acre study plots at Muthukulam and Pullad

Direction	Numbers of weevils/ direction/ locality					
	Pullad		Muthukulam		Both	
	Total	Mean/trap	Total	Mean/trap	Total	Mean/trap$$
North	2087	83.48(9.36)	2079	83.16(9.07)	4166	83.32(9.21)
South	2686	107.44(10.04)*	2518	100.72(9.99)*	5204	104.08(10.01)*
Total/ Mean	4773	95.46	4597	91.94	9370	93.70
t_a (5%)		2.12		3.28		3.69

Note: Figures in parentheses are square root (ÖX+0.5) transformed values
$ Mean of 25 replications
$$ Mean of 50 replications
* Significant

Sex ratio and reproductive status of females captured in pheromone traps

Pheromone trap catches during the study period was found to be

Table 5. Number of RPW adults caught in the eastern and western parts in the two 50 acre study plots at Muthukulam and Pullad

Direction	Numbers of weevils/ direction/ locality					
	Pullad		Muthukulam		Both	
	Total	Mean/trap$	Total	Mean/trap	Total	Mean/trap$$
East	2447	97.88(9.81)	2494	99.76(9.72)	4941	98.82(9.76)
West	2326	93.04(9.59)	2103	84.12(9.35)	4429	88.58(9.47)
Total/ Mean	4773	95.46	4597	91.94	9370	93.37
t_a (5%)		0.57NS		1.22NS		1.11NS

Note: Figures in parentheses are square root (ÖX+0.5) transformed values
$ Mean of 25 replications
$$ Mean of 50 replications
NS- Non-significant

female biased, with 6231 females as against 3139 males, which in turn was highly significant (P=0.01) as determined by student't' test (Table 1). The sex ratio was found to range from 1: 1.71 to 1: 2.78 (male: female) during the different months, with a mean of 1: 1.99 (B&: @&) for the entire study period. These observations are in conformity with earlier studies (Abraham *et al.*, 2002; Faleiro and Rangnekar, 2000; Faleiro and Satarkar, 2003), which reported predominance of females in pheromone traps.

4). However, higher percentage of gravid females as compared to virgins was reported by Kalleshwarasway *et al*, (2005) during the studies carried out over a period of one year in Tumkur, Karnataka. The preponderance of virgins recorded during the present studies was probably on account of large area mass trapping, which resulted in mopping up of the freshly emerged adults on a continuous basis. Based on the results of the present studies it can be concluded that pheromone traps are more

Table 6. Release rate of RPW pheromone under laboratory (wind tunnel) and field conditions at Bangalore

Particulars	Release Rate	
	Wind tunnel	Open field
Date of commencement of studies	Feb 13, 2006	Oct 31, 2006
Date completed	April 22, 2006	Feb 07, 2007
Weight of pheromone loaded per lure	800 mg	800 mg
Initial mean weight of lure including blister	3.0665 gm	3.4840 gm
Final mean weight of lure including blister	3.0350 gm	3.3264 gm
Total pheromone released during study period	31.5 mg	157.6 mg
Pheromone remaining in the lure	768.50 mg	642.4 mg
Release rate (Weight/ Day)	0.75 mg	1.6 mg

Studies on the reproductive status of females captured in pheromone traps revealed that majority of them were either virgin (45%) or gravid (29%), and together constituted 74% of the females caught in traps (Fig.

attractive to freshly emerged, unmated females, which in turn increased the proportion of virgins over gravid females in the pheromone traps. The present studies clearly demonstrate the beneficial impact of mass trapping, particularly since majority of females (74%) attracted to pheromone traps had not started laying eggs. It has been reported that RPW adults can survive for as long as 120 days and females are capable of laying up to 531 eggs (Abraham *et al.*, 2002). Hence, it may be necessary to undertake sustained mass trapping over large areas on a community based approach to bring about a decline in the population density of this noxious pest.

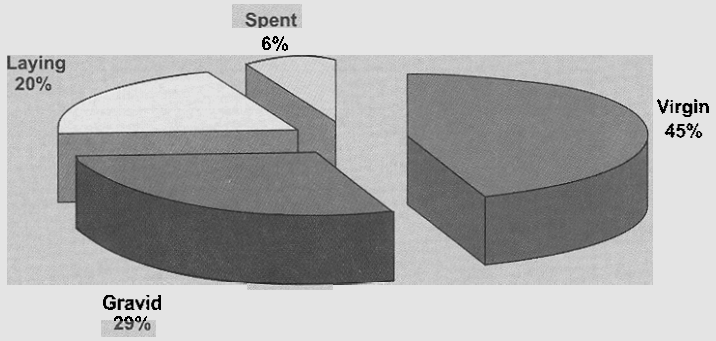
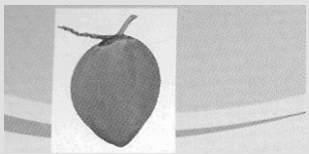


Figure 4: Reproductive status of red palm weevil females caught in pheromone traps

Field viability of pheromone lures

The pheromone lures manufactured by PCI were found to remain viable under field conditions throughout the 10 month study period (Table 1), as confirmed by release rate studies carried out under laboratory and open field conditions at Bangalore. These studies revealed that the rate of release of RPW pheromone from the blister pouch was high during the first 2 weeks, both under laboratory and open field conditions, and declined thereafter (Fig. 5). Although the rate at which pheromone was released remained low after the 4th week under laboratory conditions, fluctuations in release rate were noticed over the different weeks under open field conditions, probably influenced by temperature fluctuations. A total of 157.6 mg of pheromone was released in 14 weeks from the lures installed under open field conditions, indicating a release rate of 1.76 mg per day pre lure (Table 6). Thus, a lure loaded with 800 mg of pheromone is expected to remain viable under field conditions for more than 450 days.



Persistence of pheromone residue

A total of 14 adults were captured in 9 out of the 100 bucket traps over a period of 3 weeks (6, 3 and 5 adults respectively during the first 3 weeks) after removal of the lures, indicating the persistence of pheromone residue as reported earlier (Nair, C. P. R., Central Plantation Crops Research Institute, Kayangulam, Kerala, Personal Communication, 2006). Majority of these adults (11) were captured in traps installed along the periphery of the demonstration plot and only 3 of them were recorded from the middle, with 86% (12) of them being females. However, each of the 9 traps was observed to catch RPW adults only once during the 4 week study period. The present studies highlight the need for exercising caution while undertaking mass trapping studies and the importance of proper servicing of bucket traps, addition of recommended food baits and detergent or insecticide inside the traps and regular cleaning and topping up of water, to prevent the attracted females from causing fresh infestations.

Farmers' perception on importance of RPW

The summary of observations recorded during intensive surveys carried out over 100 acres in Alappuzha and Pathanamthitta districts by interviewing 91 farmers is presented in Table 7. Majority of the farmers in the surveyed areas in Alappuzha (93.55%) and Muthukulam (60.00%) districts held less than 1 acre of land. Most of the coconut trees in Alappuzha region were below 20 years of age (68.54%), which probably explained the higher loss of trees (13.33/ acre) in the past 5 years in this region, as against 3.61 in the surveyed area in Pathanamthitta district. Farmers in Alappuzha region appeared to be more aware of the problem posed by RPW, with 67.74 per cent of them identifying RPW (51.61%) or RPW together with rhinoceros beetle (16.13%) being the cause of tree

Table 7. Farmers' perception on problems posed by RPW at Alappuzha and Pathanamthitta districts in Kerala based on information collected using a questionnaire

Particulars	Alappuzha	Pathanamthitta	Total
Number of farmers surveyed	31	60	91
Total land holding (Acres)	16.80	83.60	100.40
Area-wise categorization of farmers in study area (Percent)			
Farmers holding < 0.5 Acres (%)	58.07	43.33	48.35
Farmers holding 0.5 to 1.0 Acres (%)	35.48	16.67	23.08
Farmers holding 1.0 to 2.0 Acres (%)	4.45	30.00	21.98
Farmers holding 2.0 to 4.0 Acres (%)	0.00	8.33	5.49
Farmers holding > 4 Acres (%)	0.00	1.67	1.10
Total number of palms in study area	1157	3908	5065
Age distribution of palms in the study area (Percent)			
< 5 year old palms (%)	36.30	15.56	20.30
5-10 year old palms (%)	12.36	10.75	11.21
10-15 year old palms (%)	10.11	10.31	10.27
15-20 year old palms (%)	9.77	11.36	11.00
> 20 year old palms (%)	31.46	52.02	47.32
No. of palms reported lost in the last 5 years	224	302	526
No. of palms lost per acre	13.33	3.61	5.24
Cause of death as understood by the farmers			
Red Palm Weevil (RPW) (%)	51.61	31.67	38.46
Rhinoceros Beetle (RB) (%)	16.13	15.00	15.38
RPW + RB (%)	16.13	21.67	19.78
Black headed caterpillar (%)	0.00	6.67	4.40
Mites (%)	3.23	0.00	1.10
Not known (%)	12.90	25.00	20.88

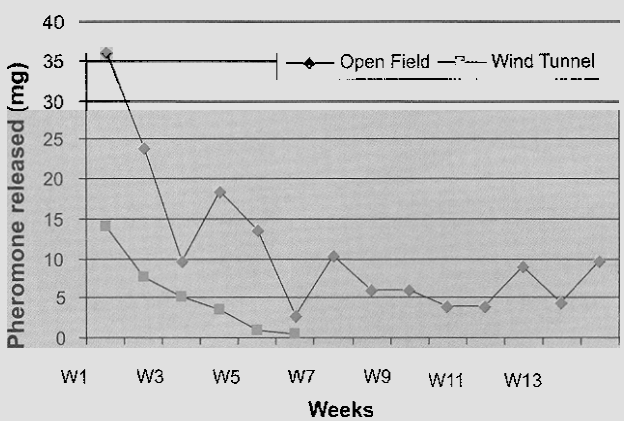


Figure 5: Release rate of RPW pheromone from blister lures under laboratory (wind tunnel) and open field conditions at Bangalore

deaths, as against 46.67 per cent for Pathanamthitta region. It was also noticed that about 25 per cent of the farmers in the surveyed area in Pathanamthitta district were not sure about the reason for tree mortality.

Abraham *et al.* (1989) had reported 6.9 per cent infestation by RPW on coconut in Kerala, while 11.65 per cent infestation of young palms was reported by Sekhar (2000). Coconut palm, which has been described as a "Tree of life" by Nirula (1955), is a means of livelihood for more than 10 million families in India (Nampoothiri *et al.*, 1998). In this context the capture of 9370 adults over a period of 10 months from the 100 acre project demonstration area in Kerala is significant and provides an indication of the high population density of the pest prevalent in the region and the need for taking up concerted efforts to manage the same.

Acknowledgment

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Coconut Crunched

You will go nuts on this : Gram for gram, coconut contains more saturated fat than butter does. As a result, health experts have warned that it will clog your arteries.

Suprisingly despite its bad reputation, coconut appears to have a beneficial effect on heart-disease risk factors. One reason. more than 50 per cent of its saturated-fat content is lauric acid. An analysis of 60 studies published in the American Journal of *Clinical Nutrition* reports that eventhough lauric acid raises LDL (bad) cholesterol, it boosts HDL (good) cholesterol even more. Overall, this means it decreases your risk of cardiovascular disease. The rest of the saturated fat is almost entirly composed of 'medium chain' fatty acids which have little or no effect on cholesterol levels. Even better news, it won't spike your blood sugar.

Source : Health