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Red palm weevil incidence: Spatial pattern and implications in technology adoption

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Abstract

Red palm weevil (RPW) is one of the major fatal pests of coconut. Conventional extension approaches need to be refined for achieving the desired outcome on adoption of integrated pest management (IPM) strategies against RPW, especially among small and marginal farming communities. The pattern of incidence, severity of infestation and age of palms are the factors motivating farmers for adoption of IPM practices. Taking these into account, a technology delivery approach for RPW management was evolved and implemented in the entire geographical extent of 520 ha area of Edava grama panchayat in Thiruvananthapuram district of Kerala state, India. This approach involves farmer participatory surveillance and monitoring with technical facilitation from research institutions which is a paradigm shift to community based area wide management strategies. Besides holdings' profile, number of RPW infested/lost palms and GPS (*i.e.*, latlong) coordinates of infested palms were recorded. The spatial distribution pattern was analyzed using Indices of Dispersion (ID), Patchiness (IP) Cluster Frequency (ICF) and Mean Crowding (IMC) at different cluster levels (*i.e.*, holdings, administrative segments and grids). ESRI GIS software was used to depict geospatial patterns of RPW infestation. Among 5410 coconut holdings, 18.7 per cent were having RPW infested palms. The pest incidence in juvenile palms was significantly higher compared to adult palms. The distribution pattern of infested palms was observed to be aggregated. Knowledge level of farmers regarding aspects of pest and management was below 10 per cent. The proposed methodology of participatory data documentation resulted in rapid and reliable collection of data from large area with an additional benefit of experiential learning for farmers in the locality.

Keywords: Coconut, GIS, knowledge, red palm weevil, technology adoption

Introduction

One of the major fatal pests of coconut in India is the red palm weevil (RPW), *Rhynchophorus ferrugineus* Oliv. Its incidence is increasing in many coconut-growing areas in the country as indicated from the responses and feedback of farmer communities and extension officials (Chandrika Mohan and Rajkumar, 2017). High level incidence of RPW and difficulty in identification of its infestation at an early stage are the major constraints for coconut production as perceived by farmers in root (wilt) disease affected area of Kerala state (Anithakumari *et al.,* 2012a). The situation is further aggravated owing to very low-level adoption of integrated pest management (IPM) practices for red palm weevil, particularly in root (wilt) affected areas. Surveillance in the coconut garden for RPW infestation symptoms, *viz.* presence of chewed-up fiber and cocoons in the trunk; bore holes in the crown region and trunk with brownish fluid oozing out, is an important component of its management practice. Once advanced, the infested palm would topple. Following phyto-sanitation measures and destroying RPWs from the infested palms would reduce the pest population. However, it was stated that adopting any single measure for controlling RPW did not provide full control under field conditions (Abid Hussain *et al.*, 2013). Further, limitations in physical resources such as device for early detection of incidence, skilled palm climbers

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at affordable cost and lack of adequate knowledge on plant protection technologies among coconut farmers (Anithakumari *et al.,* 2012b) render the farmers to perceive field level management of RPW as a difficult task. An integrated approach is needed for managing the pest in farmers' fields considering the perennial nature of the crop and the climate conditions. Further decisions on management tactics should be based on the spatial distribution of pest in the field (Kao, 1984; Taylor, 1984). Besides the pattern of incidence, severity of infestation and age of palms are the factors influencing farmers for adoption of control measures against the pest. Current extension approaches, with a focus on individual farmers, are not taking into account factors which had resulted in less effectiveness of IPM strategies against RPW infestation. In this context, a technology delivery approach for RPW management has been evolved which involves farmer participatory surveillance and monitoring with technical facilitation from research institution. Results on implementation of this community based area wide management approach against RPW in a geographical extent of 520 ha is presented in this study.

Materials and methods

The locale of the study is the entire geographical extent of 520 ha area of Edava grama panchayat in Thiruvananthapuram district of Kerala state. It belongs to the agro-ecological unit of southern coastal plain. Coconut is the principal crop in the panchayat and is being cultivated by small and marginal farmers in all the 17 wards (the smallest administrative units in a panchayat). The panchayat had coconut community clusters in every ward for coordinating and supporting coconut cultivation which are facilitated by the Department of Agriculture Development and Farmers' Welfare, Government of Kerala. To gather the information on RPW infestation in the farmers' garden, a participatory survey was conducted. At every ward, a team, comprising of two coconut farmers of respective coconut clusters and two women self-help group (SHG) members, was formed for data collection. Data collection schedule in vernacular language (Malayalam) included socio-economic profile of farmers, stage-wise distribution of coconut palms in the holdings *i.e.,* seedling (up to one year after planting); juvenile (>1 year to start of bearing; 4 to 6 years after planting); and adult palms infested/lost due to RPW and incidence of other pests and diseases. Besides, the geographic coordinates (*i.e.,* latlong) of the RPW infested palms were also recorded using GPS (GS5+, Leica system). A total of 23 on-farm training sessions, 10 to15 field visits every month to cover each wards (17), which is the lowest administrative unit of a local panchayath, and 17 hands-on experience sessions collaborating with the local extension officials and peoples representatives were organized for the survey team and farmers were trained on identification of RPW infestation, recording of data and integrated pests/diseases management (IP/DM) practices. Further, the data documented were triangulated with peoples' representatives and farming community. Field observations were recorded during the period 2012-2014.

The spatial distribution pattern of RPW of coconut was analyzed using Index of Dispersion (ID), Index of Cluster Frequency (ICF), Index of Mean Crowding (IMC), and Index of Patchiness (IP). These indices primary examine the deviation from a random (Poisson) distribution: ID is the variance to mean ratio $S^2/\bar{x}$, which will be 1 for Poisson distribution. ICF $\{\bar{x}/(\text{ID-1})\}$, measures the mean number of clusters per quadrant and IMC, ($\bar{x}$ + $S^2/\bar{x}$ -1), is the average number of points contained in the quadrant except a randomly selected point. Lyod's (1967) index of patchiness (IMC/$\bar{x}$), is to measure the level of aggregation, which is independent of the quadrant size: IP will be more than 1 when the pattern is aggregated and as IP increases, the degree of aggregation also increases. Since RPW population in the field is difficult to identify and count, as an indirect measure, number of infested palms in the holdings was used. Difference between percentage incidence in juvenile and bearing palms was tested using Mann-Whitney U Statistics and Chi-square analysis for ward wise incidence.

ESRI GIS software was used to depict the geospatial pattern of RPW incidence. The source map as well as the geo-referenced map of Edava panchayat as reported in Anithakumari *et al*. (2016) was made use of for this purpose. As the boundaries of many wards criss-cross, a layer of grids of equal size was created on the map to analyze and depict the geo-spatial distribution of the pest.

A standard test was developed to assess the knowledge of farmers regarding the pest RPW, infestation symptoms and integrated management practices of RPW. The methodology followed by Jaganathan *et al.* (2013) was used for its development. Based on available literature and opinion of experts, 18 multiple-choice questions related to RPW were first prepared. Of which, 12 items that discriminate knowledgeable and poor-informed respondents were administered to the respondents. A score of 'one' was given to correct answers and 'zero' for wrong answers. The correct answers for each knowledge items before and after the training sessions given by the farmers were recorded and percentage calculated.

Results and discussion

Incidence of red palm weevil

Incidence of RPW was observed in 8226 out of 91040 palms in Edava panchayat at the time of field survey conducted during the study period (2012-2014). Out of the infected palms, 1354 palms were with toppled crown due to RPW infestation (585 juvenile and 769 bearing palms). Percentage of palms detected with symptoms of RPW infestation during the course of survey was 7 per cent (2063 juvenile and 4809 bearing palms). Incidence of RPW of this order was reported earlier by Rajan and Nair (1997) while conducting studies on integrated pest control strategies against *Rhynchophorus ferrugineus* Oliv. in Kerala during 1970-82.

Percentage incidence of RPW in the 17 administrative segments (wards) of Edava grama panchayat is shown in Table 1. Lowest incidence was noticed in ward 4 (1.5%). In seven wards, incidence of RPW was more than 10 per cent. Faleiro and Kumar (2008) recommended area wide management of RPW if six out of a cluster of 150 palms were found infested under the assumption that the threshold for action is one per cent infested palms in the population. The results of the study clearly indicated the need for formulating area wide management of RPW in all wards of the Panchayat. Percentage of RPW incidence in date palm was

Table 1. Percentage incidence of RPW in Edava Panchayat (2010- 2012)

Ward	Total no. of palms	% juvenile palms	Coconut holdings*	Incidence of red palm weevil (%)#		
				Juvenile	Adult	Overall
1	6559	9.91	298 (34.2)	21.9	4.0	5.8
2	7514	11.9	395 (17.2)	15.1	4.6	5.8
3	5509	8.0	324 (8.3)	12.5	1.9	2.8
4	4729	18.6	382 (3.9)	5.0	0.8	1.5
5	5544	12.6	326 (4.0)	7.3	2.2	2.8
6	6358	12.5	381 (15.5)	20.4	8.5	12.5
7	5515	34.5	383 (21.7)	7.7	13.1	11.2
8	5423	33.3	387 (37.5)	13.3	23.2	19.9
9	3178	38.0	289 (10.0)	5.3	8.8	7.5
10	4183	29.9	366 (7.9)	5.8	5.5	5.6
11	6952	20.6	260 (8.5)	2.8	2.2	2.3
12	3366	16.3	252 (15.9)	28.3	18.0	22.9
13	7308	8.0	352 (37.5)	30.1	13.0	18.1
14	4206	8.6	209 (42.6)	29.5	12.3	17.5
15	5764	8.0	352 (24.7)	91.9	10.7	13.2
16	4122	5.9	323 (15.8)	23.0	2.3	5.0
17	4810	7.1	229 (16.2)	16.9	1.2	2.4

*Values in the parenthesis are percentage holdings having RPW infested palms # Difference between percentage incidence in juvenile and bearing palms was tested using Mann-Whitney U statistics: It was significant in all wards except wards 7 and 9 observed to be in a similar manner. For instance, Vidyasagar (1997) reported that infestation levels decreased from 6.6 to 2.5 per cent on keeping traps. Baloch *et al.* (1994) reported the incidence and abundance of RPW on various cultivars of date palm in Pakistan ranging from 6.2 to 21.4 per cent.

Compared to bearing palms, the infestation seemed to be more in juvenile palms. On testing the difference between percentage incidence in juvenile and bearing palms using Mann-Whitney U statistic, it was significant (at 5%) in 15 wards (*i.e.*, except ward 7 and 9). Ward-wise chi-square analysis to test association between pest incidence and growth stage of the crop also led to similar inference. The percentage of juvenile palms in the wards varied from 7.1 to 38.0. Juvenile palms were only less than 10 per cent in 7 wards; and in 5 wards, it was 20 per cent. Low percentage of juvenile palms in the holdings testimony the farmers' perception that juvenile palms were more prone to RPW infestation. It may be further observed from Table 1 that percentage juvenile palms were less in wards where RPW incidence was more. This was further confirmed with the significant (at 5% level) negative correlation between percentage juvenile palms and percentage RPW incidence in juvenile palms. Higher incidence of RPW in juvenile palms was reported in the case of date palm (Abdel-Wahed *et al.*, 2014). In date palm, 18.2 per cent of the infestation occurred in trees aged between 2 and 6 years; 67 per cent of infestation in trees aged between 7 and 10 years, and only 15.1 per cent in trees aged between 11 and 14 years. In coconut plantations of 5 to 10 year old coconut trees, infestation of RPW to the tune of 12 per cent, in India (Sekhar, 2000). This indicated the destructive nature of the pest causing loss to coconut farmers. Muralidharan *et al.* (2000) mentioned that date palms in the age group 2 to 5 years are more prone to RPW infestation. As in the case of date palm (Massoud *et al.,* 2011), protection of young trees should be a priority in the case of coconut as seen from the results of the present study.

There are other studies of various periods supporting the field level scenario reported in this study. Lever (1979) stated that in Kerala, nearly 5 per cent of coconut palms below age of 10 years were killed annually by RPW. Abraham *et al.* (1989) reported that when they started a field level experiment for management of RPW in 1970, 69 out of 1005 palms (6.9%) were found to be infested by this pest. By 1982, they could reduce the RPW infestation to zero and free from fresh incidence. Gailce *et al.* (2008) reported that 5 to 10 per cent of coconut palms in the age group of 5-10 years were attacked by RPW. A study by Ge *et al.* (2015) documented that in Hainan province, the RPW affected coconut trees to a large extent. It was reported that nearly 10,000 kilometre square were damaged and almost 20,000 palms destroyed by this killer pest.

Among the 5410 coconut holdings, 18.7 per cent were having RPW infected palms but varied among wards of the panchayat (Table 1). The lowest incidence was noticed in ward 4 (3.9%) and the highest in ward 14 (42.6%). Among the RPW-infected holdings, 44.5 per cent were only having less than 10 palms. In these holdings, 67.3 per cent palms were observed to be infected. Whereas, in holdings with more than 50 palms (*i.e.*, 6.7 per cent of RPW-infested holdings), the incidence was only in 26.7 per cent. In the middle category *(i.e.,* holdings with 10 to 50 palms), percentage incidence was 44.5 per cent. Analysis of variance of percentage infected palms confirmed significant (at 5% level) difference among holding-size categories. Average number of infested palms in the holding-size categories is shown in Table 2. Infested palms were more in large-holdings. Further, percentage holdings with one or two infested palms were relatively less

Table 2. Distribution of infested palms in holding-categories

Holding category	Average number		% holdings with number of infested palms				
	Infested palms	Dead palms	1 to 2	3 to 4	5 to10	11 to20	>20
Up to 10 palms	3.6	0.6	43.8	29.7	26.5		
11-50 palms	10.1	1.6	12.0	15.8	35.4	27.7	9.1
>50 palms	22.3	3.9	5.8	10.1	24.7	26.1	33.3

Table 3. Estimates of parameters indicating pattern of RPW incidence based on clusters of palms as in holdings, wards, and grids

Aggregation level	Mean	Variance	Index of Dispersion	Index of Cluster Frequency	Index of Mean Crowding	Index of Patchiness
Holding	1.52	28.09	18.518	0.087	19.035	12.55
Ward	482.71	139111.85	288.192	1.681	769.898	1.59
Grid	200.15	49759.48	248.616	0.808	447.762	2.24

in larger holdings (Table 2). On the other hand, substantial number of holdings with RPW infestation had more than 5 infested palms. These observations suggest that the incidence of RPW is in a clustered manner. In a study conducted in Pollachi region, an important coconut growing tract in India, Ganapathy *et al.* (1992) reported that RPW was in 34 per cent of the coconut groves.

One of the reasons for higher incidence of RPW weevil in Edava grama panchayat would be prevalence of absentee landlordism leaving many of the coconut groves neglected without timely plant protection or surveillance. The grama panchayat is surrounded on three sides by Arabian Sea and fresh water Paravur lake and the spread of infestation was thus confined to the geographical area compared to other Panchayats, making it prone to the spread and loss of coconut palms.

Spatial distribution

Spatial pattern of incidence of RPW was analyzed by forming three levels of aggregation of palms: At lowest level, holding was taken as the cluster; next, palms within the administrative segments (wards); and thirdly, geographical extents confined to grids of equal size. Estimates of various parameters concerned with the distribution of RPW incidence are provided in Table 3. It was observed that at all levels, incidence of RPW in Edava panchayat was non-random as the index of dispersion was >1. Values of other indices also indicated the same. Highest value for index of

Table 4. Estimated parameters of pattern of RPW incidence among wards

Aggregation level	Mean	Variance	Index of Dispersion	Index of Cluster Frequency	Index of Mean Crowding	Index of Patchiness
Ward 1	1.27	6.26	4.924	0.324	5.196	4.09
Ward 2	1.11	10.17	9.158	0.136	9.268	8.35
Ward 3	0.47	5.84	12.445	0.041	11.914	25.40
Ward 4	0.19	1.12	5.846	0.039	5.037	26.36
Ward 5	0.48	11.92	24.911	0.020	24.389	50.98
Ward 6	2.09	39.85	19.099	0.115	20.186	9.67
Ward 7	1.57	15.06	9.582	0.183	10.153	6.46
Ward 8	2.79	65.68	23.578	0.123	25.363	9.11
Ward 9	0.82	21.77	26.421	0.032	26.245	31.86
Ward 10	0.64	7.85	12.280	0.057	11.919	18.64
Ward 11	0.61	6.19	10.120	0.067	9.732	15.91
Ward 12	3.06	110.10	35.939	0.088	38.003	12.41
Ward 13	3.75	65.91	17.590	0.226	20.338	5.43
Ward 14	3.51	59.97	17.100	0.218	19.607	5.59
Ward 15	2.15	31.56	14.655	0.158	15.808	7.34
Ward 16	0.63	4.22	6.644	0.112	6.279	9.89
Ward 17	0.49	7.33	14.857	0.036	14.350	29.09

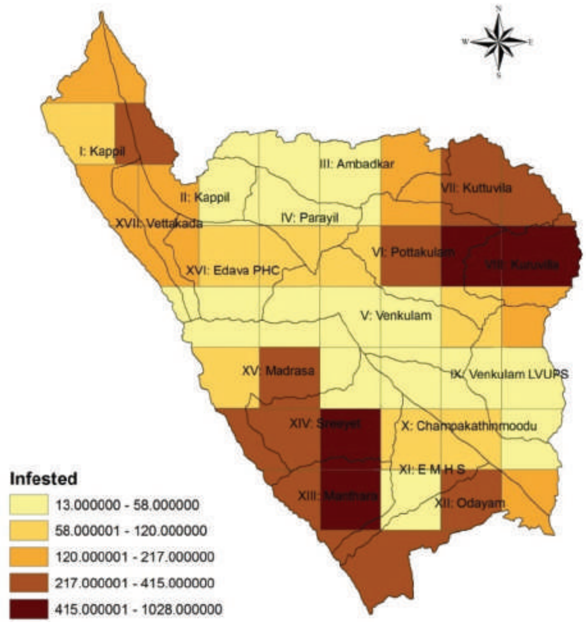

Fig. 1. GIS-derived map showing distribution of RPW infested palms in Edava panchayat

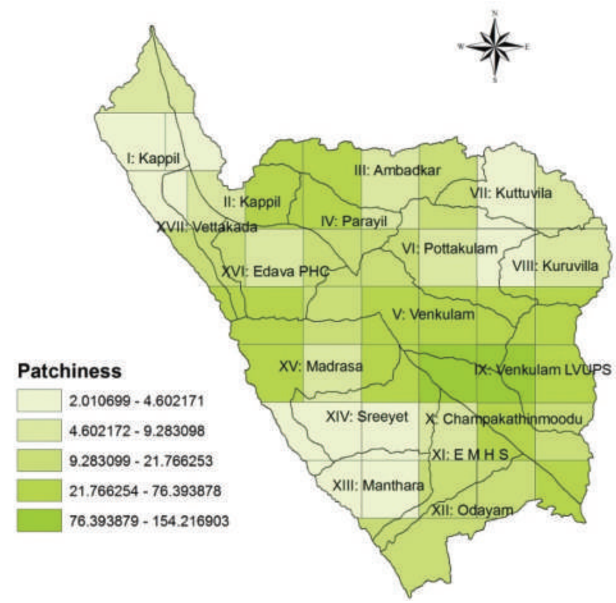

Fig. 2. Index of patchiness of RPW incidence among grids created on the map of Edava panchayat

patchiness was observed when palms aggregated at holding-level. It was lowest at ward-level. It may be noted here that there was a slight reduction in CV (86%) when clusters of palms as wards was considered compared with other two levels of aggregation.

Distribution of RPW incidence among wards showed variation but in all wards it followed a cluster pattern rather random (Table 4). Among wards, the index of dispersion varied between 4.92 (ward 1) to 35.93 (ward 12); index of cluster frequency between 0.02 (ward 5) to 0.324 (ward 1); index of mean crowding between 5.037 (ward 4) and 38.003 (ward 12); and index of patchiness between 4.09 (ward 1) and 50.98 (ward 5). It was observed that CV for number of palms per holding varied between 72 (ward 6) and 142 per cent (ward 17). It was 118 per cent for the panchayat as a whole.

Incidence of RPW within the grids was also analyzed. The variation of number of palms in the holdings among grids was relatively less as revealed from the CV. The CV was less than 72 per cent in 40 per cent of the grids, while in 24 per cent grids; it was more than 100 per cent. Distribution of RPW incidence in all the 41 grids was non-random as indicated by the estimates of parameters. Among grids, the index of dispersion varied between 2.47 and 40.44; index of cluster frequency between 0.007 and 0.989; index of mean crowding between 1.78 an 40.68; and index of patchiness between 2.01 and 154.2. Number of RPW infected palms in the grids and index of patchiness are shown in Fig. 1 and 2. When number of infected palms was less, index of patchiness showed larger values. When incidence was less, the clustered behavior of infection could be seen easily. On the other hand, in grids with large number of palms infected, the index of patchiness was relatively less but following non-random distribution. It also indicated occurrence of RPW infection in large number of holdings in that grid. This situation was quite alarming as substantial number of palms in that grid (location) was already infected and if weevils inside them are not destroyed, will act as a potential source to infest nearby palms. It may also be observed from Fig. 1 that incidence of RPW within a ward varies which justifies subjecting data from grids for analysis. However, optimization of grid size was not attempted in this study.

The aggregated distribution pattern of RPW in coconut gardens had been reported by Faleiro *et al.* (2002) based on number of trapped weevils using pheromone baited traps. Instead of number of weevils trapped, the present study used infested palms for analysis which has an additional advantage of implementing field management strategies with a wider perspective. Moreover, substantial proportion of weevils resides inside the infested palms that were not available for trapping. Thus spatial distribution of RPW infested palms attains particular importance in area where the crop is cultivated in a contiguous manner as in Edava panchayat. Wide spread of coconut in the area provides a stable habitat for the pest and could have lead to clustered nature of infestation as in the case of oil palm kernel borer (*Pachymerus cardo*) reported by Onwuteaka and Ogbalu (2015).

Linking spatial and temporal information of pests to GIS would also enhance the scope of plant protection strategies as suggested by Papadopoulos *et al.* (2003), Hetzroni *et al.* (2009) and Faleiro (2008). For instance, in severely affected areas prophylactic measures to prevent further spread of incidence could be included in the IPM strategies. Similarly in sparsely infected areas, awareness creation could be a priority. Another application of GIS interface is grouping of farmers according to infection level in their holdings for enhancing effectiveness of training/ demonstration. Further, while assessing the impact, better insight on effectiveness of interventions on pest/disease management could be drawn once GIS interface is made.

Table 5. Percentage of farmers having knowledge on identified attributes discriminating the poor-informed

Attribute	Percentage
Differentiating of male and female RPW	0.7
Egg laying location	3.2
Average number of eggs laid by a female	15.2
Life stages of the pest	49.0
Life stage of RPW inside palm	75.6
Differentiating larvae of RPW and rhinoceros beetle	4.7
Early symptoms of RPW infestation	4.4
Severe attack of RPW will lead to crown toppling	52.5
Age class of palms that is more prone to RPW infestation	79.2
Chemical recommended for curative measure	6.9
Need for phytosanitation	60.4
Pests and diseases that augment RPW infestation	64.2

Knowledge of coconut farmers on RPW

Farmers of Edava panchayat were poorly informed about RPW as could be seen from the very low knowledge-score obtained based on the 12 identified attributes that were observed to be discriminating the poor-informed on the pest, pattern of incidence and management. Percentage farmers having knowledge on these attributes are shown in Table 5. These knowledge items are very crucial in the decision making for timely management and surveillance. It could be noted that the knowledge regarding the pest *per se* is very low and understanding the pest enables the farmers to keenly observe and take logical decisions. The knowledge level of the farmers regarding various aspects of RPW strongly indicated, need for intensive awareness programmes, use of extension methods including ICT among coconut farming communities for bridging the wide knowledge gap.

Socio-economic implications

The present study has clearly brought out the increasing rate of RPW incidence in southern parts of Kerala where the crop is cultivated in contiguous extends by small and marginal farmers. The idea and strategies of pest management need changes considering the severity and nature of the pest damage. Equally important is the socio-economic status, resource base, knowledge and skill of the farmers as community actors for sustainable impact on pest management. The pattern of incidence of RPW in Edava was observed to be non-random (clustered) which also implies clustered distribution of the pest. This fact also indicating cumulative loss for affected farmers due to loss of palms which in turn affects their confidence and interest in coconut farming and the whole issue become a community problem. The knowledge level of the coconut farmers regarding the RPW, symptoms of infestation, prophylactic and integrated management practices are relatively low. Hence, for area-wide community adoption strategies, the individual farmer's knowledge, skill and attitude are critical in managing a pest spatially. GIS can support as a decision making tool in integrated pest management over a wider area, since it serves to store vast amount of spatial and temporal data on pest spread, farmers characteristics and social evaluation on impact. The effectiveness of technology developed depends on the social resources hand in hand with the individual farmer resource base. Extension education and appropriate approaches could aid coconut communities in a range of activities such as plotting the pattern of prevailing position as well as potential fresh attacks of RPW, analyzing impact of interventions and planning for adoption of management practices in large area with community participation to avoid crop loss. The present study involving farmer participatory action research emphasizes the need for problem specific appropriate technology utilization strategies for enhancing knowledge dissemination and adoption.

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