Research Article

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Spatial and social dimensions of community extension approach in management of coconut red palm weevil

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Abstract

The killer pest of coconut *Rhynchophorus ferrugineus* Olivier poses, a threat of crop loss to small and marginal farmers. The participatory area-wide study was conducted from 2014-15 in Bharanikkavu grama panchayat in an area of 2100 hectares involving 6249 households with 174667 coconut palms of various age categories. The interventions included assessment of RPW infestation through combing survey involving stakeholder teams, extension interventions, area-wide surveillance, removal of infested palms, adoption of bio management in associated pest rhinoceros beetle and leaf rot disease, weekly coconut clinics, advisory support, technology backstopping and area-wide adoption of management practices. The implementation area was mapped with remote sensing and GIS and the reduction in RPW was mapped comparatively in pre and post-intervention period as a tool to assess the results. The infestation reduced to 0.38 from 2.98 percent in the study area. Cheap and simple, early detection tools and biological control measures are badly needed for the small-scale grower community for managing red palm weevil. The Community Extension Approach was evolved for marginal land holdings of coconut with the threat of red palm weevil infestation. Sustaining the interest, motivation, and support of relevant stakeholders is the challenge in area-wide community management which warrants sequential surveillance assessment and participatory social mechanisms.

Keywords: Red palm weevil, GIS mapping, Impact of extension approach

Introduction

Coconut-based systems support the nutritional, income, and ecological services of millions of small and marginal landholder farm families in India. The adoption of scientific technologies, is liable to be influenced by factors such as the diverse demography of the farming community, part-time farmers with highly fragmented holdings, with non farm income sources and low marketable surplus in production, waning social networks and linkages among traditional coconut farming and weaning away from agriculture-based livelihood options. The pest infestation in coconut palms, gradually evolving as one of the most critical problems causing yield reduction and loss of palms, which reduce the livelihood of homestead and small farmers depending on coconut. The field-level concerns recorded include the hidden and aggregated nature of the pest infestation and its spread, loss of young palms in bearing and pre-bearing stages, posing the social challenges in terms of 'Tragedy of commons' (Hardin, 1968), and 'biosecurity' as a common goods resource. The framework of high subtractability and low excludability (Hinkel*et.al.,* 2015, Gardner, 1990), is relevant to coconut Red Palm Weevil (RPW) (*Rhynchophorus ferrugineus* Olivier) management, requiring a social set of work as a common pool resource since land holdings of coconut are in contiguous manner. Here an individual farmer's resource use subtracts from the common pool available to other farmers, hence high subtractability. Low excludability exists, since it may be difficult to prevent non-adopters from

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imposing management practices leading to the spread of the pest infestation which could not be managed at individual levels. Red palm weevil infestation patterns and area spread is in an aggregate manner (Anithakumari *et al*, 2017) put forth the management and governance challenges or collective action problems, which could occur when the farming community level interests diverge from the individual farmer level negligence or interests. Extension strategies need customization according to the field problem situation and the nature of pests in perennial crops. Some potential solutions to the management and governance challenges posed by the RPW infestation could include collective action of adopting control measures, area-wide surveillance mechanisms, and participation of stakeholders. Reorientation of field level extension programs and methodologies along with shifting paradigm from individual farmers to spatial mode of diffusion and technology adoption is asked for better technology use in field situations. The resources in terms of social institutions, farmers' landholding and investment potential for the technology adoption need to be considered. Several reports from research studies conducted during the past two decades, the knowledge of farmers and field adoption of integrated management of coconut pests were below 10 per cent coupled with a lack of skill in identifying early symptoms of pest infestation. The major constraint perceived by the coconut farmers of root (wilt) disease-affected areas was the widespread nature of RPW infestation and the inability to identify symptoms of the early stage of the pest infestation. (Anithakumari *et al.,* 2012). The low level of adoption of RPW-IPM among coconut farmers in their gardens aggravated the aggregated spread of the pest creating loss of palm. Spatial management demands for coordination among farming communities and cooperation for landscape based management. This approach was emphasized in the report by Epanchin-Neill *et al*. (2010). Another observation was that in field situations with varied level of awareness and practice of RPW_IPM, multiple social and technological interventions needed. (Hussain, A. *et al.*, 2013). Enhancing knowledge and identification skills of coconut farmers, affordable and quick early detection tools would bridge the existing gaps in pest management. (Anithakumari *et al.,* 2012b). The crucial factors in RPW management are the physiological and growth characteristics of the host palms and the climate conditions prevailing. Collective decisions on the implementation of management choices for controlling RPW spatial assessment of incidence and spread in the fields. (Taylor, 1984), the extent and severity of pest infestation in bearing and non-bearing palms and the nature of spread decide on the strategies for managing for realizing effective results. The extension approach for red palm weevil management appropriately should combine ecological, and socio-personal variables. This study had objectives for the assessment of farmer and palm profiles in evolving spatial and social dimension-based approach, for the diffusion of knowledge and managing the pest with stakeholder participation.

Materials and Methods

The study was conducted in linkage with the Department of Agriculture and Farmers Welfare, Kerala state, local self-governments in 2000 hectares of coconut area of Bharanikkavu Grama panchayat in Alleppey district. Coconut is the major crop in homestead-based systems and linkages with coconut clusters formed in 21 wards, which is the basic strata of administration facilitated by an elected member, of the panchayat.

A participatory survey on RPW infestation, was conducted in 6249 coconut homesteads, before and after the interventions. Individual palm profile such as age, status and pattern of RPW infestation was recorded for 174667 palms in coconut gardens. The survey was conducted during 2018-19 onwards. A data collection questionnaire was prepared in Malayalam and face-to-face interviews were conducted in the fields. Age-wise distribution of RPW-infested or killed coconut palms was recorded with geographic coordinates (i.e., lat long) and GS5+Leica system GPS. The survey elucidated the spatial information of the pest in coconut plots which was mapped using ArcGIS software before and after interventions.

The Mapping of RPW in coconut land cover for spatial pattern analysis was done using IRS-1C, LISS 3 data with 23.5 m spatial resolution (acquired during March 2013) prepared the land cover map of coconut gardens in Bharanikavu panchayath. The base mapping was done with support information from Survey of India (SOI) and the panchayat basic information map.

GPS (Global Positioning System) was used for collecting and collating ground truth data for this purpose. IRC LISS 3 data was used for image classification of the land cover coconut map. (Fig. 1).

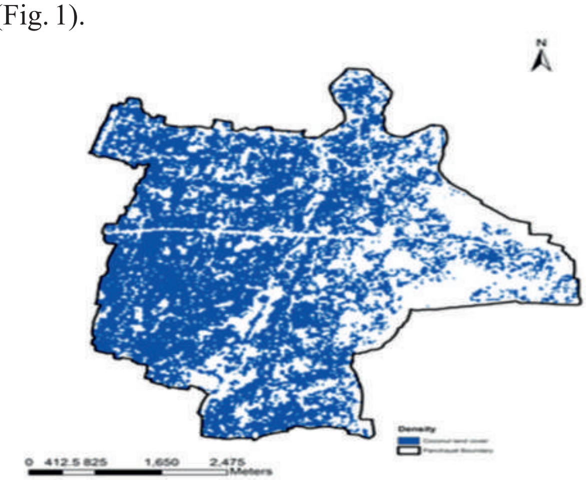


Fig. 1. Coconut land cover map of RPW intervention area (Bharanikkavu Grama Panchayat)

The geo-coordinates of the coconut RPW palms in farmers' gardens were collected using GPS during field surveys. ArcGIS software was utilized for mapping and analysis of the spatial incidence, distribution pattern and intensity of red palm weevil infestation in the panchayat, before and after the interventions.

The participatory survey team consisted of ward-wise collectives of relevant stakeholders and evolved convergence for implementing the social experiment. The involvement and participation of Coconut Producers Societies (CPS), grama panchayat unit, Kerala State Department of Agriculture and farmers Welfare, progressive farmers and women farmers self-help groups were ensured facilitated by team ICAR CPCRI. This socio-ecological approach is imperative based on the study report by Anithakumari *et al.* (2017) that the clumping variance (*K*) and the index of aggregation arrived based on the mean and variance ratio of incidence of RPW in coconut palms, was more than the mean (in the majority of 21 wards of Bharanikkavu grama panchayat where the social experimentation imposed) indicating the clumped or aggregate pattern of RPW distribution. The clumping variance showing the dispersion of the pest confirmed the contagious pattern since *K* was less than the value of eight in all the wards. Besides aggregate nature of RPW was also confirmed with David and Moore's Index in homestead farming systems.

The landscape-based community management of coconut red palm weevil included the conduct of 43 on-farm training sessions for hands-on skill in prophylactic measures, crown cleaning, pesticide preparation, application methods, identification of pest incidence and symptoms well supported with 232 field visits by ICAR CPCRI. The Integrated Pest Management (IPM) for red palm weevil recommended by ICAR CPCRI comprised of periodical crown cleaning, avoidance of physical injury by cutting petiole at least 1.2 m from the trunk, prophylactic leaf axil management of rhinoceros beetle, curative management by spot application of imidacloprid 17.8 SL @1 ml/liter of water or spinosad 45 SC@4 ml/liter of water and installation of pheromone traps with ferrolure plus embedded in nanomatrix @1per ha. The installation of pheromone traps as per recommendation was not agreed upon by coconut community, based on their previous experiences of increased infestation of RPW and negative opinions of farmers on the adoption of RPW pheromone traps, hence not included in this participatory experiment. Innovative field extension mechanisms such as the operation of 18 numbers of integrated coconut field clinics in coconut farmers' fields as per the report of Coconut Plant Protection and Surveillance Groups (CPPSG) consisted of ICAR CPCRI team members, focus group discussions (FGD)with active involvement of local extension officials and peoples' representatives were integrated. Integrated coconut field clinics (ICFC) were conducted regularly every month in 21 locations for field visits to diagnose field problems and provide advisory services on management aspects. These clinics were linked with the CPPSG for mapping the RPW incidence in coconut palms in the households. The trained surveillance team consisted of 7 members, from women SHG, coconut producers, extension officials, local self-government representatives, and ICAR CPCRI project team members.

The household survey was conducted, and recorded farm and palm profiles, knowledge and adoption about red palm weevil, and general management of coconut crops. For assessing the knowledge on RPW and the symptoms a total of

18 multiple-choice questions related to RPW were prepared incorporating expert opinions and available literature. Among them thirteen knowledge items that differentiate respondents who are well informed or not were selected for the knowledge test. The correct answers were given a score of one and the wrong zero. The tests were conducted sequentially to arrive at the gain in knowledge of the participant farmer of the program interventions. The obtained results were further triangulated with other stakeholders and field visit during 2014 -15 and 2018-19.

Results and Discussion

The study area consisted of 6249 coconut-based households of marginal land holdings with 17,4667 coconut palms of various age categories. The average number of coconut palms per household was 28, with inter-crops and other farm components with diverse resource bases and attitudes. The study location is in the hot spot of the debilitating root (wilt) disease-affected coconut area, Kerala, rendering the palms more vulnerable to biotic stress, adding risk to the farmers. As indicated in Fig.2 among the total palms, 60.74 per cent were bearing coconut palms, 20.48 per cent non-bearing juvenile palms, and 18.78 per cent were in the seedling stage (up to three years of age). A total of 2.08 per cent were infested by the pest, across age categories, and 2.56 per cent when the number of seedlings (not generally infested by red palm weevil) is not considered.

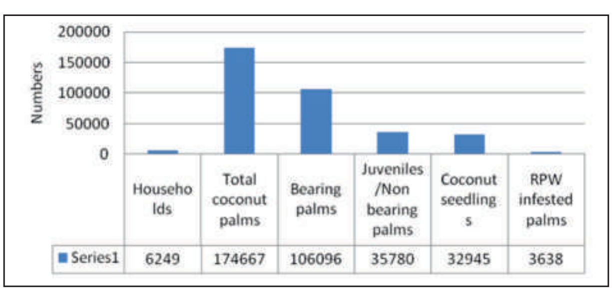
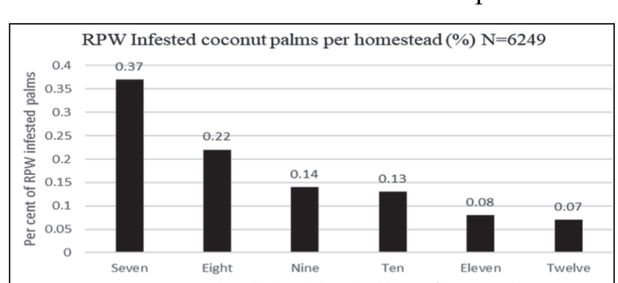


Fig. 2. Study area profile (Households and coconut palms)

During the combing survey of coconut homesteads by the team, the RPW infestation in the intervention area was mapped using GPS tagging and all the wards (the smallest population-wise administrative units of local self-government with an elected member) had more than one per cent of RPW infestation among palms warranting spatial, landscape based management in stakeholder participatory mode extension strategies. In each of the 21 wards, infestation was recorded from 1.12 to 10.52 per cent of palms indicating the uneven but alarming spreading pattern. The infestation was higher in non-bearing palms (3.8 %) compared to bearing coconut palms (2.72 %). Regarding the adoption of management practices for red palm weevil, it was seen that regular surveillance, adhering to precautionary measures, and timely adoption of management were less coupled with a lackluster attitude of the local extension officials in dealing with this pest infestation. Moreover, difficulty in getting climbers and high labor charges posed serious constraints in adopting plant protection practices in the area. Hence awareness building and learning together approaches and outreach activities need intensification shifting paradigms to a landscape framework.

Household-wise RPW infestation status

The household-wide incidence of coconut red palm weevil attains importance in evolving community extension approach to enable social learning and responsibility in arresting the spread by not adopting the surveillance, phyto sanitation and management measures. Fig.3 indicated that 31.60 per cent of homesteads have at least one palm with RPW infestation to a maximum of 20 infested palms per household, whereas 68.60 per cent of households are devoid of RPW-infested palms. These household data play a crucial role in designing, planning, and implementing extension strategies for coconut cultivation in geographical locations/landscapes, involving farmers and stakeholders efficiently and cost-effectively. The spatial and temporal pattern of RPW infestation spread (Anithakumari *et al.* 2017), ascertained that probable risk is prevailing in the coconut farming community, and at the individual level also knowledge and skill empowerment and social level awareness need to be built up.



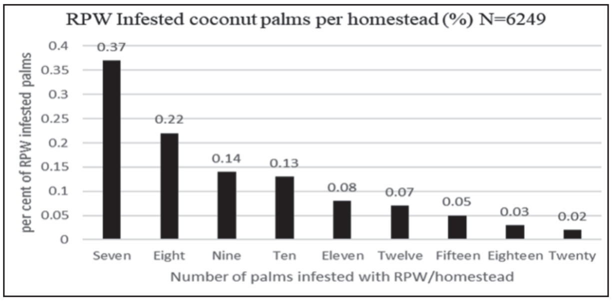


Fig. 3. RPW infestation in coconut palms per homestead (%)

Data also indicated that among the RPW-infested coconut palms, 30.66 per cent of households recorded more than one per cent infestation ranging from one to six infested palms and 1.11 per cent of households had less than one per cent of infested coconut palms ranging from seven to twenty. Progression of infestation is visible in the data indicating slow progression if not done surveillance and managed. MEWA (2020) in their statistical report reported 80,000 RPW-infested palms in 2017 which escalated to 3,82,500 in 2020 (3.78 folds increase) indicating the potential risk and spreading nature.

RPW infestation symptoms- status in coconut homesteads

The field survey and surveillance of RPW in homestead holdings recorded different types of symptoms in varied occurrences in non-bearing and bearing palms in coconut fields. The major types of symptoms were crown toppling of palms, leaf axil entry of pest, bored holes with reddish ooze and entry through the palm bole (ground level). Table.1 shows that 80.05 per cent of adult-bearing palms showed crown toppling and lesser (4.18%) with bored holes with reddish ooze among younger-bearing palms. Among non-bearing juvenile palms,61.46 per cent had crown toppling symptoms and 25 per cent with leaf axil entry symptoms. The need for identification skills of symptoms of pest attacks in the early stage is needed to avoid eventual crop loss. The infestation symptoms vary with the age of bearing palms and, the topography (the spreading nature of infestation in palms differs in flat and undulating topography). The skill of the growers in early identification of the infestation symptoms is critical in satisfactory and effective RPW management and arresting the spatial spread since it was very evident that 60 to 80 per cent of the field-level symptoms were of the advanced stage of crown toppling.

Table 1. Field level symptoms of RPW infestation in coconut palms (N=3638)

Red Palm Weevil infestation mode in farmers' fields (pre intervention)	Number of palms	Per cent	Category wise (%)
Bearing Coconut Palms			
The toppling of the crown	2015	55.43	80.05
Entry through the leaf axils	266	7.32	10.57
Reddish ooze in the bored holes	105	2.89	4.18
Entry through the palm bole	131	3.60	5.20
Non bearing coconut palms			
The toppling of the crown	689	18.95	61.46
Entry through the leaf axils	281	7.73	25.07
Reddish ooze in the bored holes	99	2.72	8.83
Entry through the palm bole	52	1.43	4.64

It was documented that around 30 per cent of the coconut farmers had correct knowledge of the identification of life stages of the red palm weevil, symptoms, and management practices which are critical in the management of the pest in field situations. The knowledge of advanced symptoms and identification of RPW infestation in palms improved to 96 per cent after interventions from 43 per cent before interventions. The early symptom identification of farmers improved from 10 to 60 per cent indicative of intense programs to be implemented. The urge for management of RPW among farmers was more and the 'Experiential Learning approach' led to the impact. Kaseem *et al.* (2020) reported that the majority of farmers could not visually identify RPW symptoms and the extent of damage. (Grasswitz (2019) opined that small-scale farmers lack adequate information on pest symptoms and their perceptions and practices are crucial in developing participatory IPM in local farming situations and considered in our study and interventions. The same line of results and opinions were reported by Faleiro *et al*. (2018), FAO (2020), and Ferry *et al*. (2018) as well.

Table 2. Knowledge of farmers on coconut red palm weevil (RPW) - Pre and post-interventions

Knowledge items	Per cent	Correct knowledge
	Pre	Post
Destructive stage	58.02	100.00
Life stages	45.57	92.31
Identification of grub (instars)	0.00	11.52
Active season	18.14	90.00
Entry locations in palms	48.35	93.26
The egg size	0.00	73.80
Egg-laying sites	57.38	100.00
Number of legs of RPW grubs	17.30	100.00
Number of wings of RPW	11.39	74.90
Identification of RPW pupa	55.70	100.00
Management practices of RPW	12.38	79.19
Early symptoms of RPW infestation in coconut	10.97	58.60
Advanced symptoms of RPW infestation in coconut	43.00	96.00
Average	29.09	82.27

It is very evident that the average knowledge of red palm weevil and management practices was only 29.09 before the program interventions and it improved to 82.27 per cent of the participant farmers after the extension interventions. The data in table. 2 is also indicative that the tacit knowledge items requiring experience and observation skills such as identification of larval instars required thorough learning skills on the part of the farmers. Aotaibi *et al*. (2022) also reported a low level of knowledge and adoption of preventive, mechanical, and chemical control measures of RPW among farmers. It could also be seen that the direct implication and application of these knowledge items in adoption is very less for tall bearing palms due to the nature of the pest infestation and dependency on skilled climbers for management.

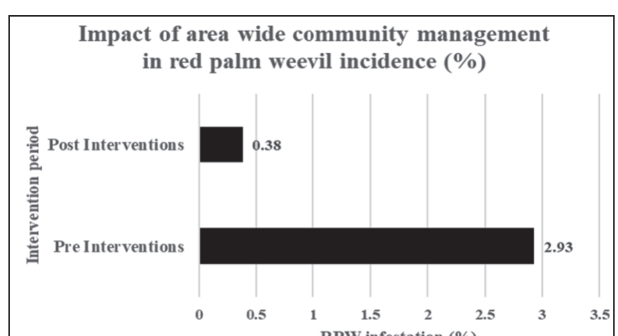


Fig. 4. Impact of area-wide community management in red palm weevil incidence (%)

The incidence of coconut RPW in farmers' gardens on a spatial basis in a contiguous area of 2000 ha in 21 wards, was reduced to 0.38 per cent from 2.03 per cent in pre-intervention period, indicating 87 per cent of reduction in the incidence of RPW (Fig.4). This attains particular importance as per the report of Faleiro and Kumar (2008) wherein, they proposed that coconut farmers can decide against adopting area-wide management of RPW if the cumulative number of RPW infested palms are nil out of a unit of 150 palms and may decide to have the area-wide management if the cumulative infestation number for the similar area is five or six. Sampling in sequence has to continue for assessing the RPW infestation level and also useful in assessing the effectiveness of RPW management among coconut farmers, which is stated in this study clearly, as effective. The project intervention proposes an effective spatial mode for reducing RPW a concerted community manner. The lessons of the program were as follows:

Awareness building through various media and modes, ensuring involvement of community and stakeholders and sequential surveillance are key for successful spatial RPW management. This approach could be up-scaled and out-scaled building up social capital and stakeholder participation. The staggered, but potential source of inoculums will be present in the landscape, which could be managed individually. Integration of group and individual outreach strategies is needed for sustainability. Fajardo *et al*. (2021) also in their study on Canary Island, reported on the control of red palm weevil with interventions over 10 years, and pointed out, that the major challenge is not a lack of technology per se, but an effective and sustainable institutionalized mechanism to prevent and detect early infestation of this pest with due support and motivational interventions among the communities.

Figure 5 and 6, depict the spatial distribution of the infestation before and after interventions. This was analyzed through the kernel diversity function for a 500m radius. The analysis showed and confirmed the patchy or clustered pattern of spread with very high-density zones of infested coconut gardens in pre intervention period and the subsequent reduction in the corresponding areas after interventions. The depictions indicated the reduction in total infestation and patchiness after the interventions but staggered palms infested which could be managed at the individual farmer level.

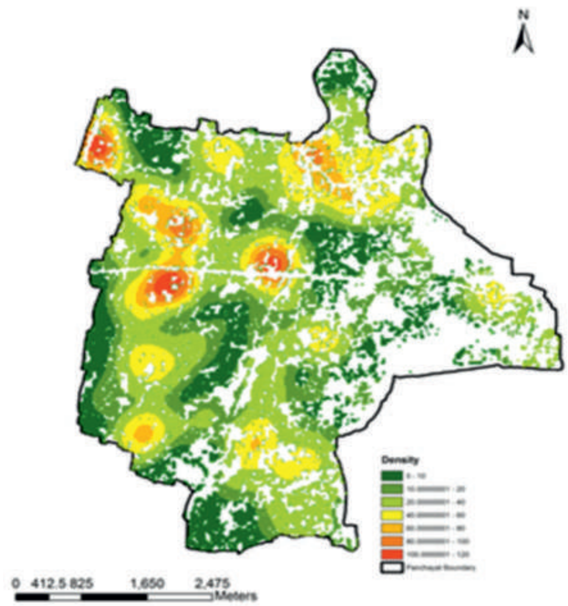


Fig. 5. Pre intervention mapping of RPW infestation in intervention area

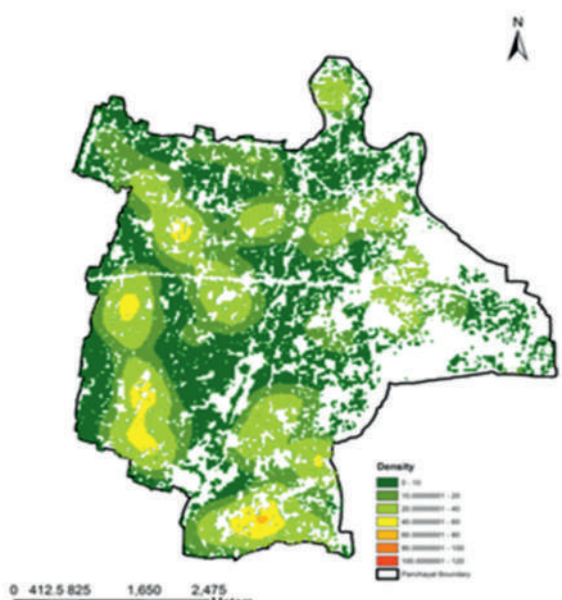


Fig. 6. Post-intervention mapping of RPW infestation in intervention area

Perceptions of the participant farmers

A stakeholder interface meeting and feedback workshop of the participant farmers, extension officials, CPPSG members, Women SHG, ward-wise coconut-clinic group members, and local peoples' representatives was organized after the project completion. More than 90 per cent of the participant farmers of this program indicated that dwarf palms, particularly green dwarfs needed frequent observations and care for managing RPW infestation since it is found to be more susceptible. Farmers also opined that local tall palms (West Coast Tall (WCT) could be saved if the early symptoms of the pest infestation are noted as they could tolerate red palm weevil infestation than dwarf coconut palms. The Chowghat Orange Dwarf (COD) palms were recorded by 84.90 per cent of participants as comparatively of less incidence which could be verified by the ICAR CPCRI project team also in the coconut homesteads during the period of interventions. However, it was documented that there were only 2.34 per cent of dwarf palms out of the total palms in the intervention area. Maximum infestation was recorded in plots with closer planting of coconuts, i.e. less than 5 meters between palms. The irony is that farmers had a notion to plant more seedlings to compensate for the loss of young palms due to RPW, thus forming a vicious circle. The field-level regular surveillance, advisor and diagnostic services and technical facilitation of the 21 Coconut Plant Protection and Surveillance Groups (CPPSG) were perceived by 93.78 per cent of households as very much useful and needed. Participant farmers also recorded their perceptions that more RPW infestation in palms, noticed after rains in coconut gardens and it was moderate during April, May and June months and maximum observed in July, August and September months. Fajardo *et al.* (2021) stated emphatically that human factors such as spatial diffusion and adoption at the community level were crucial for successfully managing RPW in combination with technical and pest aspects.

Based on the experiential learning and documentation of the process and impact of the area-wide interventions, evolved the community extension approach for the RPW area-wide management for a contiguous area of 1000 to 2000 hectares of coconut-based homesteads in Kerala, India. (Fig.7). Convergence and linkages to be developed, maintained and sustained with local institutions for mobilizing, conscientization, social auditing of interventions and results and conflict resolutions in community mode is imperative. Technology integration based on field assessment of RPW infestation, nature and extent of infestation assist in evolving and implementing extension strategies for effective implementation, appraisal, refinement, and sustainability. Midingoyi *et al.* (2018), Grasswitz (2019) and Rezaei *et al.* (2020) in their studies indicated that the challenges of RPW management need purposive involvement of stakeholders, training and awareness programs, triangulation and evaluation of existing RPW curative and preventive technologies and the effect of management of RPW infestation, which is agreed by this study conclusions.

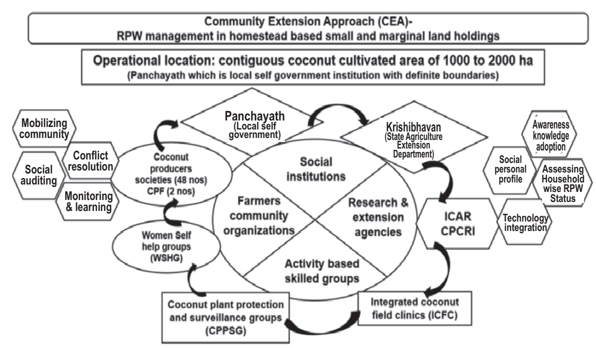


Fig.7. Community Extension Approach for RPW Management in coconut- based homesteads

Conclusion

The study brought to light, the increasing infestation levels of RPW incidence in coconut-based homesteads of southern Kerala, which is also a hot spot area of coconut root (wilt) disease. The nature of the pest, pattern of spread, loss in yield and crop stand due to pest attack, and association of the pest infestation with adoption of management practices, also determine the technology transfer approach to be adopted customized to the locations. The factors of social and economic status, the resource base of farmers, knowledge and skill with the pest and management, farmers' role as community actors in horizontal technology dissemination, institutional budget support and technology backstopping by extension and research institutions are to be considered and converged for sustainable impact on pest management in case of red palm weevil. The pattern of RPW incidence in the study area was non random or clustered and this is also an indication of the potential for creating cumulative loss of palms affecting the confidence and positive attitude towards coconut cultivation. The RPW incidence, if not managed at community level in spatial dimension, could emerge as a community problem with low excludability from the negative impacts to individuals. Each farmer as community members should have the essential knowledge and skill in identification of pest stages, symptoms of infestation, attitude towards coconut and vigilant surveillance owning the responsibility towards welfare of coconut community. GIS supports informed decision making in area-wide integrated RPW management with spatial and temporal data on the spread and severity over time for spatial evaluation of impacts. In general, social and farm resources influence, the efficiency of technologies adopted in a system. The spatial RPW management process involves sequential surveillance and assessing the pattern of the pest infestation, analyzing results of management practices adopted, accelerating extension education efforts to improve tacit and explicit knowledge of RPW of coconut, and mobilizing communities through stakeholder approaches. The challenges to be addressed are feasible, simple and cheap tools for early identification of symptoms, biological control methods, customized extension methods for knowledge and skill enhancement, particularly early visual symptoms and continued technology adoption in a spatial manner for mutual benefits of reducing crop loss. Linkages with line departments and convergence with farmer clusters in participatory mode are the key to managing this difficult pest of coconut.

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