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Distribution of *Aedes aegypti* and *Aedes albopictus* in different eco zones of Thiruvananthapuram city with special reference to dengue viremia in humans

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ABSTRACT: Mosquito index study of three ecologically different ecozones of the Thiruvananthapuram district, Kerala showed sharp difference on the proportionate distribution of *Aedes aegypti* and *Aedes albopictus*. Human dengue viremia (HDV) was very high in those ecozones where *A.aegypti* density was high and HDV was low where *A.albopictus* was high. In a coastal zone of Thiruvananthapuram city, *A. aegypti* was the most abundant vector and in a hilly, arid sub urban zone, *A.albopictus* was the abundant vector. In the urban zone both species of mosquitoes showed equal distribution. Study on the circulating serotypes in the serum of HDV by Single step single tube Multiplex PCR showed all the four serotypes *viz* DENV1, DENV2, DENV3 and DENV4 in patients of Thiruvananthapuram city, which indicated the possibility of Dengue Shock Syndrome, unless there is efficient vector management. Among the four dengue serotypes, Type 1 was the most abundant virus. Abundance of microhabitats in Thiruvananthapuram city, which support *A. aegypti* may be the reason for high prevalence of dengue fever in the urban zone.

KEY WORDS: *Aedes aegypti, A. albopictus*, dengue, serotypes, microhabitat specificity

INTRODUCTION

Dengue Fever (DF) is one of the most wide spread infectious disease globally and its transmission now occurs in 128 countries (Mahalingam *et al.,* 2013). Dengue Hemorrhagic Fever (DHF) and Dengue Shock Syndrome(DSS) are major public health problems with almost one half of the global human population may occur epidemically and endemically in any area where susceptible Aedes mosquitoes *(Aedes aegypti, A. albopictus*) breed (Farrar *et al.,* 2007). In tropics, DF occurs most frequently after rainy seasons.. After biting an infected human the mosquito becomes infective after an incubation period of 8 to 22 days with a mean duration of 11 days. In India first report of dengue was from

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Chennai in 1780 and the authentic report was available from Kolkata in 1963 (Gupta *et al*., 2012). In India severe attack of DF was reported during 1970s from various states such as Karnataka (George and Soman, 1975) , Uttar Pradesh (Chadurvedi *et al.,*1974), Maharashtra (Prasada Rao *et al.,*1981) and Rajastan (Ghosh and Sheikh, 1973) and in all these states the primary vector was *A.aegypti.*

After an epidemic in Kerala during 2003, numerous cases of DF were reported from several districts, including those in sylvian environs of Western Ghats such as Idukki and Kottayam districts (Tyagi *et al.,* 2006; Tyagi *et al.,* 2003; Tyagi and Dash, 2006). During the year 2006, a scanty distribution of DF was reported from various parts of Kerala and among the human viremia cases 65% of the total cases were reported from Thiruvananthapuram district. During 2017 a wide spread infection of DF with many DSS and accompanied deaths were reported from various districts of Kerala and in this instance also the Thiruvananthapuram district was the worst affected place in the state (Kumar *et al.,* 2013). Kerala, with an average population density of 819/sq.km provide ample survival chances for vector mosquitoes. Dengue infections are caused by four closely related virus strains named DENV1-4. The mosquito borne flavivirus is a single stranded RNA virus and are antigenically distinct from one another and have 60-80% homology. Infections result in long term protection against a particular serotype but no resistance against other serotypes (Gupta *et al.,*2014). During an outbreak of dengue fever in Delhi in 2003, serological studies of patients proved that DENV1, DENV2 and DENV3 were equally distributed but DENV4 couldn't be located (Lalith Dhar *et al.,* 2006). After a lag of three years the disease once again lashed on the population of Delhi, but that time DENV3 was the prominent serotype observed (Gupta *et al.,* 2006; Preethi *et al.,* 2008). The present study was undertaken to know the dynamics of dengue transmission in relation to micro-habitat analysis of three different sites of Thiruvananthapuram City and also on the basis of the vector density of related species of Aedes mosquitoes, *A. aegypti* and *A.albopictus*. The changing epidemiology in relation to susceptibility of vector mosquitoes to any particular serotype of DENV has to be taken into consideration of effective management of this disease. This aspect is also discussed in the present scenarios of dengue viremia in Kerala.

MATERIALS AND METHODS

Study Area: The Indian state Kerala has a total area of 38863 km ^{2} and a population of 36.6 million, with 31.16% lives in urban areas. Thiruvananthapuram district of Kerala is fairly humid and warm throughout the year with relative humidity ranging from 70-90% and temperature ranging between 22-35.5^{0}C respectively. The annual precipitation is high, reaching upto 300cm/ year (Meteorological Department, Meteorological Centre, Thiruvananthapuram). The larval surveys were undertaken in all months. March, April and May (summer), June, July and August (south west monsoon), September, Ocober and November (northeast monsoon) and December, January and February(pre-summer). In this four seasons temperature and humidity exhibits sharp difference which determines the mosquito biology and their distribution. The monthly entomological data of different seasons were pooled together for analysis. In Thiruvananthapuram district incidence of dengue was Ã2 / one hudred thousand population during the year 2006 and about 65% of dengue cases in Kerala were reported from Thiruvananthapuram district (Thangaradham *et al.,* 2006). Since Thiruvananthapuram forms the epicentre of this disease, sites such as two lanes of Kunnukuzhy (Urban site), Sreekaryam (Sub-urban) and Kannanthura (Coastal site) were selected for entomological and clinical study.100 houses were selected from each site for the study. Kunnukuzhy is within the heart of the city and poulation density is highest among the three study sites. The study site in Sreekaryam is moderately an elevated and airid zone.

Entomological survey: In each of these representative sites, 100 houses were thoroughly checked for the breeding of Aedes mosquitoes. The survey was carried out on outdoors, indoors and

also at premises of houses. The breeding sites such as cisterns, cement tanks, metal containers, plastic drums, grinding stones, mud pots, plastic bottles, flowerpots, flower vases, polythene sheets and natural breeding sites such as coconut shells, tree holes, fallen spates or bracts were observed from these localities. Among the above breeding sites mud pots were found to be possessing highest number of larval and pupal density.

Small containers (< 20 litter) were drained through strainer in to white larval sampler (25x20x4 cm) to collect the immature stages of mosquitoes. Large breeding places like ground level cement tanks; fountains etc were sampled using a 250ml larval dipper. Five dips were taken from the surface water of each breeding place. The collected larvae were separately brought to the laboratory and identified to species level using standard mosquito and larval identification key (Tyagi *et al* 2015 and DHS Kerala 2011) (CITE). The duration of study was three years from January 2014 to December 2016.

The details of survey were recorded in a format specially designed for this purpose. From the entomological data the following indices were calculated as described in standard methods, House Index (HI), Container Index (CI) and Breteau Index (BI) (WHO, 2009).

Formula for calculating the Mosquito larval indices:

House Index (HI)

= number of houses positive for *Aedes* breeding/ houses checked X 100

Container Index (CI)

= number of positive containers/ total containers checked X 100

Breteau Index (BI)

= number of positive containers/ total number of houses searched X 100

Blood Sample collection: The three sites on which the entomological study was conducted during the last three years were selected for blood sample collection. As the investigators are familiar with the local people of this area they have co-operated for blood sampling after getting a signed affidavit/ declaration from them. Institutional ethical clearance for the above sampling was already obtained (Univ.Coll.IEC/Dept.Zool/001/Vect.Borne Dis.dt.28/05/2014). Blood samples were collected from patients who are suspected for dengue infection. A total of 150 samples were collected during this period. 50 patient samples with high dengue fever was selected from the total samples and were subjeted for the study.

Single step Single tube Multiplex PCR (SSMPCR): The study was done at Laboratory Medicine and Molecular Diagnostics, a division of Rajiv Gandhi Centre for Biotechnology, Thiruvananthapuram. Reverse Transcription Polymerase Chain Reaction (RT PCR) was used as state of the art technique for the detection of serotype. Indigenously developed Single step Single tube Multiplex PCR (SSMPCR) was used as the technique for the detection of specific serotype (Dayakar *et al.,* 2015).

Viral Nucleic Acid (RNA) Isolation: Viral nucleic acid (RNA) was isolated from the patient serum was carried out using QIAGEN's QIAamp Viral RNA Extraction Kit®(QIAGEN, Germany), following the manufacturers protocol.

One-step one-tube Multiplex PCR amplification with serotype specific primers: A direct one-step, single tube multiplex PCR amplification was performed for differentiation of dengue virus serotypes. This method involves the usage of the isolated viral RNA directly with D1 consensus primer and serotype specific primers TS1, TS2.TS3,TS4 in a single tube reaction. The isolated viral RNA was directly used as the template. 0.5 µL each of the serotype specific primers DEN1,TS2, TS3, TS4 as reverse primers. The primers used were taken from previous publication. Primers were added along with 0.5 µL D1 forward primer along with TaKaRa's PrimeScript One Step RT-PCR Master Mix (TaKaRa ® Japan) consisting of 12.5 µL of 2X One Step RT buffer, 0.5 µL of Taq Polymerase (5 units/µL), 0.5 µL of 5X Reverse Transcriptase Enzyme and 3.0 µL of RNase Free

dH_2O. A total reaction volume of 25µL was subjected to PCR for 40 cycles, with an initial cDNA synthesis step at 42^0 C for 5 min, initial denaturation at 94^0 C for 10 sec, denaturation at 94^0 C for 30 secs, annealing at 55^0 C for 60 secs, and extension at 72^0 C for 60 sec, and a final extension at 72^0 C for 60 sec. The amplicons were then detected using 1.5% agarose gel electrophoresis. The PCR product size as estimated using 100bp ladder (Takara™).

Statistical analysis: Descriptive statistics of mean and confidence interval was used to calculate the larval indices. Significance of larval indices in different areas was compared by using ANOVA. Paired sample t test was used to compare significance of indoor and outdoor positive habitats. ANOVA, correlation and t test were carried out using the SPSS version of16.0 software.

RESULTS

Three year study on the distribution of different species of mosquitoes in the selected sites such as urban, semi urban and coastal zones of Thiruvananthapuram City proved that *A.aegypti* and *A.albopictus* are the dominant mosquito species. Sporadic occurrence of *Culex quinquefasciatus*, *Anophelis stephensi* and *Armingerus subalbatus* were also located in the study sites. Occurrence of *Culex quinquefascitus* was observed in foul smelling water collection such as leakages of drainage vessels and septic tanks possessing rich sources of putrefied animal wastes. Larvae of *Ar.subalbatus* were observed in accumulated water associated with cattle sheds. Larvae of *A. aegypti* and *A. albopictus* were observed in comparatively less polluted water with no foul smell. Even indoor collection of water for drinking purposes, stored in closed containers possessing very little space between the lid and rim of containers were the breeding sites of both species of Aedes. The three eco zones of Thiruvananthapuram city showed marked variations on the occurrence of *A. aegypti* and *A. albopictus*.

The semi urban zone of Thiruvananthapuram city (Sreekaryam) is a dry and elevated site from sea level, where almost 90% of the mosquito larvae observed were *A. albopictus* and the remaining was shared by *A.aegypti* and no other species of mosquito was observed (Table 1). In coastal zone, almost 80% of the mosquito larvae were that of *A.aegypti* and remaining 20% of the larvae were *A.albopictus* (Table1). Coastal zone possessed a scanty distribution of *Anopheles stephenci* larvae, which were observed in water collection with less pollution or less stench. In the city core area (Kunnukuzhy ward) both *A.aegypti* and *A.albopictus* were observed almost equal proportion. At some sites of this zone where one or two cattle were reared, the accompanying area showed sporadic occurrence of *Ar. subalbatus*. During the whole study period of three years the proportionate distribution *A.aegypti* and *A.albopictus* in three different study sites did not show any change. The vector density of the three eco zones were different. The larval indices such as HI, CI and BI were high in sub urban and coastal zones but of urban zone, it was very low, compared to other two zones. During the study period of 2014-16 the larval indices of each zone did not exhibit year wise variation (Table 1), which indicated that ecologically each microhabitat possessed a comparatively stable vector density.

Another observation made during the study period was the difference on the egg laying behavior of *A.aegypti* and *A.albopictus* in different seasons. During summer months, the containers of the outdoor(house premises) were dry and no mosquito larvae were located in outdoor area and the indoor containers such as stored water for domestic purposes, drainage tray of refrigerator, water of bath rooms and latrines were with enough larvae. During rainy season there were plenty of water accumulations in every outdoor site and almost all were with larvae but the indoor containers were free of larvae.

Analysis of the epidemiology of dengue viremia in Kerala during the period of six years, from 2012 to 2017, proved that, during the whole six year period dengue viremia was very high in Thiruvananthapuram district (Table 2). In the all six years, dengue viremia in Thiruvananthapuram

Table 1. Larval indices of three eco-zones of Thiruvananthapuram city and the distribution of *A. aegypti* and *A. albopictus*

Study sites	Range	Larval Indices of three years		
Urban zone	Range	2014	2015	2016
HI	(6-18)	10.5	11.5	11.5
CI	(11-86)	43	39.5	23.5
BI	(10-27)	14.5	17.5	15.5
Proportion of *A. aegypti & A. albopictus*		1:1	1:1	1:1
Semi urban zone				
HI	(24-46)	31	32	33
CI	(48-65)	55	59	58
BI	(27-46)	34	37	38
Proportion of *A. aegypti & A. albopictus*		1:9	1:9	1:9
Coastal zone				
Hi	(24-46)	31	32	32
CI	(35-70)	48	56	58
BI	(18-46)	29	37	35
Proportion of *A. aegypti & A. albopictus*		10:3	10:3	10:3

district was 30 to 50% of the total number DF of the state. Simultaneous study on Dengue viremia in humans and on the distribution of vector mosquitoes in three different study sites proved that Dengue fever was negligibly low in semi urban area, where the dominant mosquito was *A.albopictus*. During the three years study (2014-2016) only two DENV cases were detected from this site. Urban and coastal zones showed prevalence of Dengue fever and high prevalence was observed in the coastal zone, in which *A.aegypti* was abundantly present.

Molecular diagnosis and serotyping of clinically proven dengue viremia of 50 cases were performed (Fig.1). The results showed that DENV1 was the most abundant (more than 60%) and the share of all the other three different types of virus were below 40% and it is clear from Fig.2. There were 32 cases of DENV1 alone among the total of 50 patients studied. There were co-infection of three DENV1 with DENV4, two DENV1 with DENV3 and two DENV1 with DENV2. No other types of co-infection were observed, which clearly indicated that DENV1 has adaptive advantage over the other

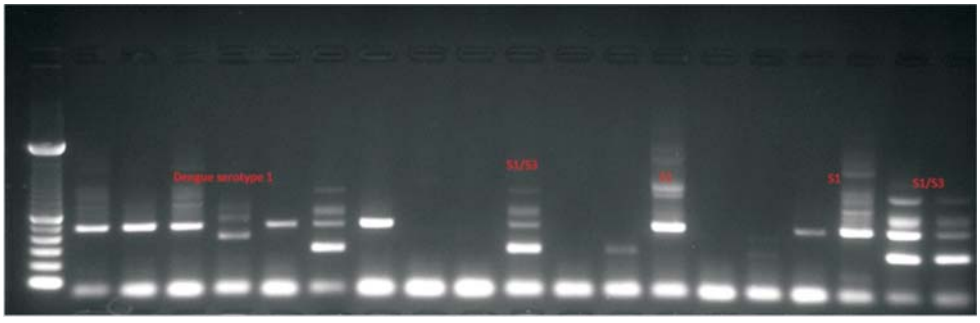

Fig. 1 : Agarose gel electrophoresis of human serum showing different dengue serotypes along with co-infection

Table 2. Incidence of dengue fever in Kerala State and in respect of Thiruvananthapuram district .(Directorate of Health Services, Kerala)

Year	Kerala state		Thiruvananthapuram District	
	DF	Death	DF	Death
2012	4056	16	2447	4
2013	7729	24	4072	5
2014	2548	13	1250	3
2015	4114	29	991	9
2016	7218	21	2158	7
2017	19994	37	8502	13

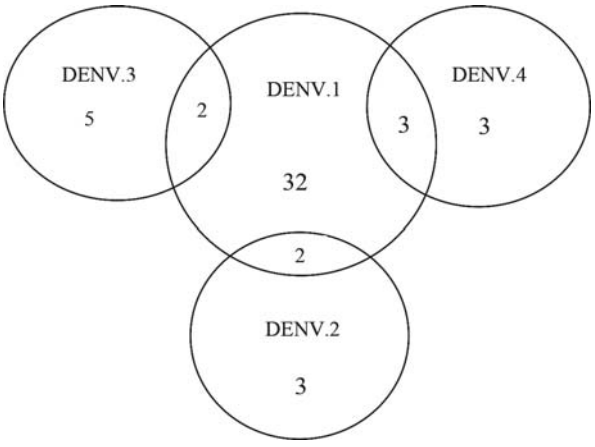

Fig. 2: Distribution of four different types of dengue viruses in Thiruvananthapuram city

serotypes in causing symptomatic disorders in humans (Tyagi *et al.,* 2003).

DISCUSSION

The present study clearly showed that the species diversity of mosquitoes in three eco-zones of Thiruvananthapuram city exhibited contrasting difference especially on the distribution of *A. aegypti* and *A. albopictus*. In the coastal zone *A.aegypti* was the dominant species and in the hilly suburban zone *A. albopictus* was the dominant species. In the city core area (urban) almost equal distribution of both species of Aedes mosquitoes were observed. Similar observations were reported from Rajastan in which different ecozones such as desert area, forest and river area and semi arid area exhibited sharp difference on the distribution of *A.aegypti* and different strains of DENV (Bennet and Joshi, 2009). During the last three years (2014-2016) there was no significant change on the proportionate distribution of *A.aegypti* and *A.albopictus* was observed. This clearly indicated that both species of mosquitoes are highly precise on their preference in niche selection. Previous reports also supports the present investigation that, in Trissur district of Kerala, the rubber plantations possessing coconut shells used for collecting rubber latex showed the larvae of *A. albopictus* only during rainy season and no *A. aegypti* larvae in the whole plantation area (Sumodan, 2003).

A very remarkable observation made in the present study is the relationship between dengue viremia in the study sites and the distribution of mosquito population. In sub urban site, *A. albopictus* was the dominant mosquito, in which Dengue infection was very low (only two cases among 50 cases during three years), but in the other study site, the coastal zone, there was high prevalence of Dengue infection, in which the dominant mosquito vector was *A. aegypti* (WHO, 2003). This clearly indicates that *A. aegypti* is the only true vector of DF and the role of *A. albopictus* is insignificant.

Clinical data from the Department of Health, Govt. of Kerala, clearly showed that, Thiruvanathapuram district of Kerala carry the major share of DF, which is almost 40- 50 % of the total cases reported in Kerala for the last six years. This clearly indicated either ecological factors or genetic factors of vector mosquitoes is favoring Thirvananthapuram district to be the most favorable zone in Kerala for maintaining dengue virus. Similar type of observations are reported from Australia in which socio demographic and ecological features play a

significant role on the distribution of *A.aegypti.* People of high economic group possessing rain water harvest tank above the houses provide ample chances to this mosquito to breed in this tanks, but the people living in small houses, where the disease is uncommon because the abundant vector in such places is *A.albopictus* (Rokeya *et al.*, 2017). Compared to Thiruvananthapuram species level difference on the distribution of DENV, it is not a rare phenomenone. During 2003 dengue viremia in people of Delhi Metropolitan city showed co-circulation of DENV 1, DENV2 and DENV3 with equal efficiency and no DENV4 was located. (Chakravarti *et al.,* 2008; Lalith Dar *et al.,* 2003), but in 2006 there was a shift in favour of DENV3, which became prevalent in Delhi with negligibly low distribution other two serotypes(Gupta *et al.*, 2006). Study of dengue viremia, specifically in Kerala showed that all the four serotypes are distributed in Kerala which increases the chances of DSS in future years (Pradeepkumar *et al.,* 2015). and another study specifically in Ernakulam district of Kerala by Anoop *et al. (*2010) showed that combined infections such as DENV2 & DENV3, DENV1& DENV2 and DENV1 & DENV3 are common. Anoop *et al.* (2013) have also suggested that there is hyper endemicity of dengue viremia in Ernakulam district and suggested the possibility of local gene evolution of dengue virus and the team have also reported that there is a lineage shift of DENV3 in Kerala, probably due to exotic introduction of dengue virus from other Nations (Anoop *et al.,* 2013). In South America similar type of DENV serotypes were demonstrated in human blood and in *A.aegypti* mosquitoes and the investigators experimentaly proved that DENV1 is the most efficient among the four as a causative agent for this disease (Rosen *et al.,* 1983).

The niche selection of *A. aegypti* and *A. albopictus* exhibits microhabitat specificity, which plays an important role in the distribution of mosquitoes at species level in different sites of a broad area. The coastal zone of Thiruvananthapuram city was the prefered site for *A. aegypti* but a hilly site barely 5 km away from the coastal zone was the prefered site for *A. albopictus*, the perticular study site is arid and 40 meters above sea level. The site preference in relation to egg laying behaviour of *A. aegypti* changed in accordance with season. During summer, the prefered egg laying sites for Aedes mosquitoes were indoor collections of water, but after summer rains and and during rainy seasons the prefered sites were outdoor collection of water in discarded containers. Dengue infection in three study sites during 2014-2016 showed a co-relation with species level distribution of *A. aegypti* and *A.albopictus*. Dengue infection in areas with abundance of *A. aegypti* was higher than that of the areas with abundance of *A. albopictus.* The present study proved that *A. aegypti* and *A. albopictus* exhibits microhabitat specificity on their distribution and this has major influence on the transmission of DENV on each microhabitat. In Jodhpur of Rajastan, a desert area, people store water in houses which form effective breeding sites of *A.aegypti* where dengue infection is very common and DENV3 is the most abundant virus (Bennet and Joshi, 2009). Eventhough all the four antigenically distinct dengue virus were located in Thiruvananthapuram city, DENV1 was the most abundant serotype, which was identified through PCR technique on human blood samples. Further epidemiological analysis on the distribution of dengue serotypes and their molecular analysis on evolutionary distance is warrrented for a much complete picture.

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Influence of calcium silicate application on the population of *Aproaerema modicella* Deventer (Lepidoptera: Gelechiidae) on groundnut

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ABSTRACT: Field experiments with foliar application of calcium silicate @ 2.0, 3.5 and 5.0 per cent, soil drenching of calcium silicate @ 10.0, 15.0 and 20.0 per cent and combination of foliar and soil drenching (@ 2.0% + 20.0%, 3.5% + 15.0% and 5.0% + 10.0%) were evaluated on 20 days old groundnut plant and compared with an untreated check. Application of calcium silicate *via* foliage and soil simultaneously @ 5 and 10 per cent on 20 days after dibbling of groundnut was effective to reduce the population of leaf miner and their leaflet damage, recording mean population of 5.25 nos. of larvae/10 plants and 16.46 per cent leaflet damage, respectively, while it was 12.25 nos. of larvae/ 10 plants and 27.95 per cent leaflet damage in untreated control. Reduction in population of leaf miner in groundnut might be due to silica induced plant defensive enzymes, however, the moderate reduction in population of leaf miner pest in groundnut can be well explained due to the high accumulation of silica in groundnut plants.

KEY WORDS: Calcium silicate, groundnut leaf miner, management, silica

INTRODUCTION

Groundnut ranks first among oilseeds with high oil recovery (40%). Around 40 to 50 per cent of the pod output is used for oil production and the rest being used as seed and feed. Groundnut is a good source of niacin. In India, about 115 insect pest species have been recorded to cause damage to groundnut at various growth stages of the crop and also in the storage. Among these only 10 insects *viz*., leaf miner, white grub, leaf hopper, thrips, aphids, tobacco caterpillar, gram caterpillar, red hairy caterpillar, stem borer and termite, found to cause considerable yield loss. Silicon forms 27.8 per cent of the earth's crust next to oxygen (46.1%) (Haynes, 2014; Keeping *et al.*, 2014; Pinto *et al.*, 2014; Vasanthi *et al*., 2014). Silicon is concentrated at level equivalent to those of macro nutrients (Kamenidou *et al*., 2009). Plants absorb silicon in the form of monosilisic acid Si $(OH)_4$ which gets accumulated in cell walls as silica gel (Rodrigues and Datnoff, 2005). Accumulation rates of silicon in different plants may vary between 1 to 10 per cent of plant dry weight (Epstein, 1994) and

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monocots store more silicon than dicots (Rodrigues *et al*., 2001). It is often several times higher than the rate of accumulation of other essential macro nutrients such as nitrogen, phosphorus and potassium (Nakata *et al*., 2008). The minimum amount of silicon needed to withstand the abiotic and biotic stresses in various plants is 3 to 5 per cent (Datnoff *et al*., 1997). Accumulated silicon in rice plants enhances resistance against insects and diseases, increases erectness of leaves resulting in increased photosynthesis, improves water usage, and decreases toxicity due to heavy metals and cuticular transpiration (Nakata *et al*., 2008). Besides, the positive effects which have been mentioned for silicon, its presence in plant tissue at high concentrations does not cause any toxicity or damage to the plant (Ma *et al*., 2006).

MATERIALS AND METHODS

Field experiments were conducted during April 2015 – July 2015 and January 2016 – April 2016 in an area of 25 cents in average weather condition of 30 ± 2^0C and 79 ± 5 % RH at farmers' holdings, Azhagarkovil, Madurai District, Tamil Nadu, India. The experiment was carried out in a randomized block design and each treatment was replicated thrice. Groundnut (cv. VRI 2) seeds were sown in the field at a spacing of 30 x 10 cm. All the standard package of practices recommended for the crops were followed except plant protection measures. Various treatments including foliar application of calcium silicate @ 2.0, 3.5 and 5.0 per cent, soil drenching of calcium silicate @ 10.0, 15.0 and 20.0 per cent and application of calcium silicate *via* foliage and soil were done separately on 20 days old groundnut seedlings. The population of leaf miner, *Aproaerema modicella* Deventer (number of larvae/10 plants) were recorded at ten days interval, starting from 20 days after sowing on ten plants selected at random/replication. The per cent reduction over untreated control for each treatment was calculated for further analysis.

Data on population of leaf miner and leaflet damage were subject to square root and arcsine transformation before subjecting to two way ANOVA using IRRISTAT software version 6.5. The difference between the means of various treatments was compared with LSD test at 5% significance level (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Population of leaf miner: With reference to the incidence of *A. modicella*, T_9 recorded significantly the lowest mean population of 5.25 larvae/10 plants with per cent reduction of 57.14 per cent, compared to untreated control (5.25 larvae/10 plants) (Table 1) which was significantly superior to the remaining treatments, followed by T_8, which registered the mean population (5.63 larvae/10 plants; 54.04%) and T_3 (5.83 larvae/10 plants; 52.41%) which were on par statistically with reference to *A. modicella*, followed by T_7 (6.17 larvae/10 plants; 49.63%), T_2 (6.17 larvae/10 plants; 49.63%), T_1 (6.96 larvae/10 plants; 43.18%), T_6 (7.00 larvae/10 plants; 42.86%), T_5 (7.46 larvae/10 plants; 39.10%) and T_4 (7.75 larvae/10 plants; 36.73%), and control was recorded the 12.25 larvae/10 plants. On 20 DAS, no significant difference was noticed between treatments on the incidence of leaf miner, while on 30 DAS, the lowest mean population was recorded in T_9 (3.67 larvae/10 plants), followed by T_3 (4.00 larvae/10 plants), T_8 (4.33 larvae/10 plants), T_2 (4.33 larvae/10 plants), T_7 (4.67 larvae/10 plants), T_1 (4.67 larvae/10 plants), T_6 (5.00 larvae/10 plants), T_5 (5.00 larvae/10 plants) and T_4 (5.33 larvae/10 plants) which were significantly different from each other with reference to *A. modicella*. Similar trend was noticed on 40, 50, 60, 70 and 80 DAS in various treatments.

Leaflet damage: Among different treatments tried for the management of *A. modicella* in groundnut, T_9 recorded the lowest mean leaflet damage of 16.46 per cent, followed by T_8 (17.03%) and T_3 (17.50%) which were on par statistically (Table 2), followed by T_2 (18.13%), T_7 (18.15%), T_1 (19.31%), T_6 (19.34%), T_5 (20.01%) and T_4 (20.83%), while control plot recorded 27.95 per cent leaflet damage by *A. modicella*. There was no significant difference between treatments on 20 DAS. Same trend was noticed on 30, 40, 50, 60, 70, 80 and 90 DAS also in various treatments.

Numerous studies have proven that silicon application could increase the pest resistance of

Table 1. Population of *Aproaerema modicella* Deventer in groundnut ecosystem as influenced by silica nutrition (Pooled analysis)

Treatments		Population of *A. modicella* (No. of larvae / 10 plants)**									% reduction over untreated control
		20 DAS***	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS	Mean	
T_1	Foliar spray of calcium silicate @ 2.0 %	2.33 (1.53)	4.67 (2.16)^{bcd}	7.67 (2.77)^{cd}	11.00 (3.32)^{de}	9.00 (3.00)^{cd}	8.00 (2.83)^{cd}	7.67 (2.77)^{cd}	5.33 (2.31)^{c}	6.96 (2.64)^{cd}	43.18
T_2	Foliar spray of calcium silicate @ 3.5 %	2.00 (1.41)	4.33 (2.08)^{abc}	7.00 (2.65)^{bc}	10.33 (3.21)^{cd}	8.33 (2.89)^{abc}	7.33 (2.71)^{bc}	5.67 (2.38)^{b}	4.33 (2.08)^{b}	6.17 (2.48)^{bc}	49.63
T_3	Foliar spray of calcium silicate @ 5.0 %	2.33 (1.53)	4.00 (2.00)^{ab}	6.33 (2.52)^{ab}	9.00 (3.00)^{ab}	8.33 (2.89)^{abc}	7.00 (2.65)^{b}	5.67 (2.38)^{b}	4.00 (2.00)^{ab}	5.83 (2.41)^{ab}	52.41
T_4	Drenching of calcium silicate @ 10.0 %	1.67 (1.29)	5.33 (2.31)^{de}	8.67 (2.94)^{e}	12.00 (3.46)^{f}	10.33 (3.21)^{e}	9.00 (3.00)^{e}	8.00 (2.83)^{d}	7.00 (2.65)^{d}	7.75 (2.78)^{d}	36.73
T_5	Drenching of calcium silicate @ 15.0 %	2.00 (1.41)	5.00 (2.24)^{cde}	8.33 (2.89)^{de}	11.67 (3.42)^{ef}	10.00 (3.16)^{e}	9.00 (3.00)^{e}	7.33 (2.71)^{cd}	6.33 (2.52)^{d}	7.46 (2.73)^{d}	39.10
T_6	Drenching of calcium silicate @ 20.0 %	2.33 (1.53)	5.00 (2.24)^{cde}	8.00 (2.83)^{de}	10.67 (3.27)^{d}	9.33 (3.05)^{d}	8.33 (2.89)^{de}	7.00 (2.65)^{c}	5.33 (2.31)^{c}	7.00 (2.65)^{cd}	42.86
T_7	T_1 + Drenching of calcium silicate @ 20.0 %	2.00 (1.41)	4.67 (2.16)^{bcd}	6.67 (2.58)^{ab}	9.67 (3.11)^{bc}	8.67 (2.94)^{bcd}	7.33 (2.71)^{bc}	6.00 (2.45)^{b}	4.33 (2.08)^{b}	6.17 (2.48)^{bc}	49.63
T_8	T_2 + Drenching of calcium silicate @ 15.0 %	1.67 (1.29)	4.33 (2.08)^{abc}	6.33 (2.52)^{ab}	9.00 (3.00)^{ab}	8.00 (2.83)^{ab}	6.67 (2.58)^{ab}	5.33 (2.31)^{ab}	3.67 (1.92)^{ab}	5.63 (2.37)^{ab}	54.04
T_9	T_3 + Drenching of calcium silicate @ 10.0 %	2.33 (1.53)	3.67 (1.92)^{a}	6.00 (2.45)^{a}	8.33 (2.89)^{a}	7.67 (2.77)^{a}	6.00 (2.45)^{a}	4.67 (2.16)^{a}	3.33 (1.82)^{a}	5.25 (2.29)^{a}	57.14
T_{10}	Untreated control	1.67 (1.29)	5.67 (2.38)^{e}	9.67 (3.11)^{f}	13.00 (3.61)^{g}	15.33 (3.92)^{g}	18.33 (4.28)^{f}	18.00 (4.24)^{e}	16.33 (4.04)^{e}	12.25 (3.50)^{e}	—
	SEd	NS*	0.0964	0.0765	0.0643	0.0686	0.0740	0.0819	0.0952	0.0805	—
	CD (P=0.05)	NS	0.2026	0.1608	0.1351	0.1440	0.1555	0.1720	0.2000	0.1691	—

*NS: Non significant; ** Mean of three replications ***DAS: Days after sowing Figures in parentheses are square root transformed values
In a column, means followed by common letter(s) are not significantly different by LSD (P= 0.05)

Table 2. Per cent leaflet damage by *A. modicella* in groundnut ecosystem as influenced by silica nutrition (Pooled analysis)

Treatments		% leaflet damage**									% reduction over untreated control
		20 DAS***	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS	Mean	
T_1	Foliar spray of calcium silicate @ 2.0 %	15.43 (23.13)	15.79 (23.41)^{bcd}	19.04 (25.87)^{c}	25.04 (30.03)^{de}	24.61 (29.74)^{d}	20.21 (26.71)^{e}	18.72 (25.64)^{e}	15.62 (23.28)^{d}	19.31 (26.09)^{d}	30.91
T_2	Foliar spray of calcium silicate @ 3.5 %	15.11 (22.87)	15.24 (22.98)^{abc}	18.13 (25.20)^{ab}	23.12 (28.74)^{c}	23.05 (28.69)^{c}	19.16 (25.96)^{d}	16.01 (23.59)^{c}	15.24 (22.98)^{d}	18.13 (25.20)^{c}	35.13
T_3	Foliar spray of calcium silicate @ 5.0 %	15.69 (23.33)	15.16 (22.91)^{ab}	17.96 (25.07)^{a}	22.14 (28.07)^{b}	21.19 (27.41)^{b}	17.84 (24.98)^{bc}	15.73 (23.37)^{bc}	14.31 (22.23)^{bc}	17.50 (24.73)^{bc}	37.13
T_4	Drenching of calcium silicate @ 10.0 %	14.86 (22.67)	16.67 (24.10)^{ef}	20.02 (26.58)^{d}	27.14 (31.40)^{f}	26.23 (30.81)^{e}	23.12 (28.74)^{g}	20.34 (26.81)^{f}	18.26 (25.30)^{f}	20.83 (27.15)^{e}	25.47
T_5	Drenching of calcium silicate @ 15.0 %	15.19 (22.94)	16.26 (23.78)^{def}	19.59 (26.27)^{cd}	25.87 (30.37)^{e}	25.12 (30.08)^{d}	21.46 (27.60)^{f}	19.46 (26.18)^{ef}	17.14 (24.46)^{e}	20.01 (26.57)^{de}	28.41
T_6	Drenching of calcium silicate @ 20.0 %	15.54 (23.22)	16.04 (23.61)^{cde}	18.95 (25.80)^{bc}	24.95 (29.97)^{d}	24.65 (29.77)^{d}	20.34 (26.81)^{e}	18.65 (25.58)^{e}	15.56 (23.23)^{d}	19.34 (26.09)^{d}	30.81
T_7	T_1 + Drenching of calcium silicate @ 20.0 %	15.09 (22.86)	15.65 (23.30)^{abcd}	18.02 (25.12)^{a}	22.47 (28.30)^{bc}	23.16 (28.77)^{c}	18.65 (25.58)^{cd}	17.21 (24.51)^{d}	14.96 (22.75)^{cd}	18.15 (25.21)^{c}	35.06
T_8	T_2 + Drenching of calcium silicate @ 15.0 %	14.96 (22.75)	15.22 (22.96)^{abc}	17.62 (24.82)^{a}	22.11 (28.05)^{b}	20.32 (26.79)^{a}	17.06 (24.39)^{b}	15.12 (22.88)^{ab}	13.85 (21.85)^{ab}	17.03 (24.37)^{ab}	39.07
T_9	T_3 + Drenching of calcium silicate @ 10.0 %	15.66 (23.31)	14.84 (22.66)^{a}	17.46 (24.70)^{a}	20.06 (26.61)^{a}	19.64 (26.31)^{a}	16.23 (23.76)^{a}	14.64 (22.49)^{a}	13.12 (21.23)^{a}	16.46 (23.93)^{a}	41.11
T_{10}	Untreated control	14.92 (22.72)	17.13 (22.45)^{f}	21.36 (27.53)^{e}	29.63 (32.98)^{g}	34.05 (35.70)^{f}	37.19 (37.58)^{h}	36.21 (37.00)^{g}	33.14 (35.15)^{g}	27.95 (31.92)^{f}	—
SEd		NS*	0.3217	0.3007	0.2761	0.2777	0.2962	0.3093	0.3235	0.3005	—
CD (P=0.05)		NS	0.6760	0.6318	0.5801	0.5834	0.6222	0.6498	0.6796	0.6313	

*NS: Non significant; **Mean of three replications ***DAS: Days after sowing Figures in parentheses are arcsine transformed values
In a column, means followed by common letter(s) are not significantly different by LSD (P= 0.05)

many plant species (Datnoff *et al*., 1997). Silica fertilizer could be an environmental friendly alternative to control crop pests. The mechanisms of Si-induced resistance of plants to pests result from its association with cell wall components. The induced resistance of plants to insects is a potential strategy in the integrated pest management aiming the reduction of deleterious effects of chemical compounds. Among the various treatments, foliar spray of calcium silicate @ 5.0% + drenching of calcium silicate @ 10.0% treatment (T_9) was the best in reducing the population of leaf miner and their leaflet damage, recording mean population of 5.25 nos. of larvae/10 plants and 16.46 per cent leaflet damage, respectively, while it was 12.25 nos. of larvae/10 plants and 27.95 per cent leaflet damage in untreated control.

The outcome of the present study modify the usage with the findings of Tayabi and Azizi (1984) concluded that the application of silica @ 1 tonne / ha reduced the incidence of stem borer, *Scirpophaga incertulas* in rice. Mandras (1991) pointed out that the harder epidermal cells on stems and leaf sheaths in response to silica addition delayed larval penetration. The present study modify with the report of Ranganathan *et al*. (2006) who showed that addition of silicon led to reduction of damage due to yellow stem borer (*Scirpophaga incertulas*) which could be attributed to the reduced preference as well as digestibility of the host leaves and straw by the insect owing to the presence of higher silica content. Voleti *et al*. (2008) who also suggested that the application of silica to rice, stem borer damage was significantly reduced and enhanced the solubilization of silica by 3 to 5 fold as indicated by the augmented silica acid present in stem of the rice plant and that of silica in rice leaves.

Anderson and Sosa (2001) who also stated that the application of various sources of Si including bagasse furnace ash, silica slag, potash and calcium silicate have also reduced infestation and crop damage by sugarcane stem borers *viz*., *Scirpophaga excerptalis* and *Diatraea saccharalis*. This is again in line with the findings of Camargo *et al*. (2010) who reported that silicate-induced Si accumulation in sugarcane resulted in partial control of the sugarcane borer *D. saccharalis*.

Coors (1987) demonstrated that high levels of silica in leaves of beetroot decreased the digestibility of *Spodoptera eridania* apart from increased consumption rate. Goussain *et al*. (2002) proved that *Spodoptera frugiperda* (Smith) larvae displayed increased mortality, cannibalism and mandibular wear after feeding on corn plants applied with Si. Massey *et al.* (2006) also too proved that provision of Si increased abrasiveness of the leaves of four or five grass species studied, while changing the relative palatability of the grasses, deterring feeding, reducing the growth rates and feeding efficiency of two generalist insect, *Spodoptera exempta* and *Schistocerca gregaria.* Parrella *et al.* (2007) proved a signiûcant reduction in leaf miner emergence in chrysanthemum plants treated (root dipping) with potassium silicate @ 200 ppm. Almeida *et al*. (2009) stated that application of calcium silicate reduces the *Frankliniella schultzei* Trybon incidence on tomato. Similarly, Hou and Han (2010) reported silica amendment that reduces the *Chilo suppressalis* incidence (Walker) in rice. Shalaby (2011) reported magnesium and sodium silicate also suppressed cotton leaf worm, *Spodoptera littoralis* Boisd damage on sugar beet. Han *et al*. (2015) who confirmed that the silicon amendment, @ 0.16 and 0.32 g Si/kg soil, enhanced the resistance level of a susceptible rice variety against rice leaf folder. It is concluded that application of calcium silicate *via* foliage and soil @ 5 and 10%, respectively on 20 days after dibbling of groundnut, though reduced the population of *A. modicella* in groundnut.

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Taxonomic review of the tribe Nymphalini (Lepidoptera: Nymphalidae: Nymphalinae) from western Himalaya, India with special emphasis on external genitalic attributes.

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ABSTRACT: Taxonomic review for 11 species referable to six genera under the tribe Nymphalini has been presented. Taxonomic characterization, and elucidation of external genitalic attributes, has been done for five species namely, *Nymphalis xanthomelas* (Esper), *Polygonia c-album* (Linnaeus), *Kaniska canace* (Linnaeus), *Symbrenthia lilaea* (Hewitson) and *Symbrenthia hypselis* (Godart) from western Himalaya, India. Along with that, distribution and taxonomic remarks on species *Symbrenthia niphanda* Moore and *Symbrenthia brabira* Moore, and species under genera *Aglais* Dalman and *Vanessa* Fabricius from the western Himalaya has been discussed from the older literature. Major gaps in the taxonomic history of the tribe Nymphalini has been mentioned in the concluding remarks. © 2018 Association for Advancement of Entomology

KEYWORDS: Nymphalini, five species, external genitalia, western Himalaya Running title: Taxonomic review of the tribe Nymphalini

INTRODUCTION

The type-subfamily Nymphalinae of family Nymphalidae consists of six tribes namely, Nymphalini, Melitaeini, Kallimini, Victorinini, Junoniini, and probably the Coeini (Wahlberg *et al*., 2005; Chengyong *et al*., 2017). The tribe Nymphalini consists of 13 genera distributed worldwide (Harvey, 1991). A total number of 15 species referable to seven genera are reported from India, out of which, 13 species referable to six genera are found in western Himalaya (Evans, 1932; Wynter-Blyth, 1957). The tribe Nymphalini is closely associated mainly with plants of the family Urticaceae, and it is likely that the ancestors of this tribe were specialist on this family (Janz *et al*., 2001).

The butterflies in this tribe are of moderate size. These butterflies also form important model system for investigating host-plant interactions, seasonal polymorphism, and adult diapause (such as *Polygonia* Hübner) (Nylin, 1988). Within the Nymphalini, systematics has been in a great deal of flux, although species circumscriptions have remained fairly stable (Nylin *et al*., 2001).

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The Himalaya, along the northern border of the Indian Subcontinent, extends 2500 km from Pamir Knot in the west to Arunachal Pradesh. In India, the Himalayan Ranges extending from Jammu & Kashmir, Himachal Pradesh and up to Uttarakhand is known as Western Himalaya, and has an arid, more temperate climate with greater Palearctic affinities (Mehra *et al*., 2017). Till date, no comprehensive taxonomic review/genitalic survey is available for western Himalayan Nymphalini. In many insects, genitalia often provide the only way to reliably distinguish the species using morphology (Özgül-Siemund and Ahrens, 2015). In insect systematics, the male genitalia have the species-diagnostic characters and its importance cannot be overlooked. Hence in the present study, morphology and external genitalia of five species under tribe Nymphalini (*Nymphalis xanthomelas* (Esper), *Polygonia c-album* (Linnaeus), *Kaniska canace* (Linnaeus), *Symbrenthia lilaea* (Hewitson), *Symbrenthia hypselis* (Godart)) from western Himalaya, India have been described and illustrated. Along with that, distribution and taxonomic remarks for species namely *Aglais ladakensis* Moore, A. *caschmirensis* Kollar, *Vanessa cardui* (Linnaeus), V. *indica* (Herbst), *Symbrenthia brabira* Moore, S. *niphanda* Moore from western Himalaya has been presented.

MATERIAL AND METHODS

Specimens were procured from the insect collection preserved in the museum of Department of Zoology and Environmental Studies, Punjabi University, Patiala and Zoological Survey of India (HARC), Solan (HP). The specimens were photographed from dorsal and ventral side, using a digital camera Nikon DSLR 3300 fitted with an 80 mm lens. In order to study the wing venation, permanent slides of fore and hind wings were made by following the methodology proposed by Common (1970). For dissection and preparation of the external genitalia, the method proposed by Robinson (1976) was adopted. The terminology for the male genitalia has been adopted from Sibatani et al. (1954), Shirozu and Yamamoto (1956), Klots (1970), and Sibatani (1972).

RESULTS AND DISCUSSION

Family Nymphalidae Rafinesque, 1815

Subfamily Nymphalinae Swainson, 1827

Tribe Nymphalini Rafinesque, 1815

Common name: The Angle-wings

Rafinesque, 1815. *Jean Barravecceia: Palermo*. 224 pages

The fore and hind wings strongly angular or notched, generally of dark brown or black colour above with fulvous to reddish or orange maculation; antennal club moderate, stout; body moderately stout, covered in black to brown coloured scales; last tarsal sub-segment of hind legs furnished with a pair of spines, except in genus Vanessa, which bears two paired rows of spines.

Genus *Nymphalis* Kluk, 1780

Common name: The Anglewings

Kluk, 1780; *Hist. nat. pocz. gospod*. 4: 86.

Aglais Dalman, 1816; K. VetenskAcad. Handl. 1816 (1): 56.

Eugonia Hübner, [1819]; Verz. bek. Schmett. (3): 36.

Inachis Hübner, [1819]; Verz. bek. Schmett. (3): 37.

Comma Rennie, 1832; Conspectus Butts. Moths: 8.

Grapta Kirby, 1837; in Richardson, Fauna Boreal Amer.: 292.

Scudderia Grote, 1873; Can. Ent. 5 (8): 144.

Euvanessa Scudder, 1889; Butts eastern U.S. Canada 1: 387.

Kaniska Moore, [1899]; Lepidoptera Indica 4: 91.

Ichnusa Reuss, 1939; Ent. Z. 53: 3.

Roddia Korshunov, 1995; Dnevnye babochki Aziatskoi chasti Rossii. Spravochnik.: 81.

Type-species: *Papilio polychloros* Linnaeus

polychloros Linnaeus, 1758; Syst. Nat. (Edn 10) 1: 477.

Type locality: Sweden

Eyes hirsute; labial palpi porrect, projecting beyond head, ascending; antennae almost as long as half costa, club prominent and gradual, tip round and deep orange in colour; fore wing inner margin straight; termen slightly concave and slightly scalloped; produced at vein M_1; hind wing tornus slightly produced; apex round; toothed at vein M_3; middle and hind legs with long and curved claws.

Remarks: The genus *Nymphalis* Kluk was erected on the type species *Papilio polychloros* Linnaeus. This taxon has Holarctic affinities. Shapiro (1981 and 1986) reported the phenotypic plasticity, and seasonal phenology and migration in the species *N.antiopa* Linnaeus in California. Miller and Miller (1990) discussed the taxonomic affinities of *Aglais* and *Nymphalis* Kluk. Nylin *et al*. (2001) studied the phylogenetic analysis of *Nymphalis* Kluk and other related genera.

Three species are found in India i.e. *N. antiopa* (Linnaeus) in Chumbi Valley, Sikkim; *N. l-album* (Esper) in Kashmir and N. *xanthomelas* (Esper) found in western Himalaya. There are no recent recordings in literature for species *N. l-album* (Esper) from Kashmir (northwest Himalaya). Its distribution in India hence is sceptical and needs attention.

Nymphalis xanthomelas (Esper)

Common name: The Large Tortoiseshell

(Figure 1)

xanthomelas Esper, 1781; Die Schmett. Th. I, Bd. 2 (3): 77 (*Papilio*).

Type locality: Mardan, Khyber Pakhtunkhwa Province, Pakistan

Adult (Male): Fore wing trigonate, costa arched at base, apex truncate, termen sinuate and produced at vein M_3 and Cu_2, upper side ground colour tawny orange, two black spots in discal cell, a very broad black band over end cell, an irregular, highly sinuate and broken black band across discal area, sub-marginal area black, margin broad and dull brown in colour, underside dried leaf like, smudged with dull violet pattern, a very broad light brown discal band traversed from costa to inner margin; hind wing round, costa straight, apex round, termen sinuate, inner angle straight, upper side ground colour same as forewing, a large black spot in discal area near costal margin, sub-marginal area black, followed by shiny blue spots, margin broad and dull brown, underside similar as fore wing, broad discal band in continuation from forewing and extends up to inner margin.

Venation: Fore wing with discal cell shorter than half length of wing, vein Sc long and terminates well before half costa, R_1 and R_2 parallel to vein Sc and well before upper apex of end cell, stalk of veins R_3+R_4+R_5 originates just before upper apex of end cell, vein R_2 and R_3 arises well before middle of R_5 and terminates just at apex, M1 arises from slightly below upper apex of end cell, vein M_2 closer to M_1 at origin than to M_3, latter arises just from lower apex of end cell, Cu_1 opposite to origin of vein M_2, discal cell closed; hind wing with forwardly curved precostal vein, vein Sc+R_1 parallel to costa and terminates just below apex, stalk Rs+M_1+M_2 and M_3+Cu_1+Cu_2 present, discal cell open, ldc absent.

Adult (Female): not examined

Male genitalia: Tegumen dorso-ventrally flattened, extended backwards, wide and somewhat rectangular dorsally; uncus straight, longer than tegumen, broad at base and gradually narrows down into a blunt tip assuming a y-shape from dorsal view, tubular in lateral view gnathos narrow, heavily sclerotized, concave; saccus short, thin, tubular, slender, well sclerotized, upturned obliquely towards dorsal side, tip blunt; vinculum quite broad along entire length, u-shaped from ventral view, much longer than latero-ventral projection of tegumen; juxta sclerotized, u-shaped; valvae large, quite broad, protrudes beyond tip of uncus, well sclerotized and hirsute with long and fine setae; costa and sacculus simple; ampulla sickle like but not deeply curved, tip blunt directed downwards; harpe well sclerotized, tapering into a pointed tip; aedeagus long, stout at base and sharply narrow beyond two-third of its length and descends into a sharp pointed tip directed towards dorsal side, robust, heavily sclerotized, acutely curved into a sickle shape;

vesica absent; ductus ejacultorius enters dorsad.

Female genitalia: Not examined.

Distribution: India (Jammu and Kashmir to Uttrakhand), Pakistan, Nepal.

Material examined: 1♂, 25.vii.2009, Sural, Pangi Valley, Chamba (H.P.).

Host plants: *Salix elegans*,Ulmaceae, Anacardiaceae (Wynter-Blyth (1957) and Smetacek (2012)).

Remarks: The nominate species *N. xanthomelas* (Esper) have Palearctic affinities, and is indeed very rare in Western Himalaya, and yet is not protected under the Wildlife (Protection) Act (1972). It has two broods per year (one pre-monsoon and another post monsoon) (Wynter-Blyth, 1957) and pupal diapause is reported and adults exhibit hibernation. It occupies subtropical evergreen forests above 1200m (Smetacek, 2012). It is a polyphagous species. It appears on wings in different months at different localities likewise, in early summer in Shimla and Kullu; in May at Khajjiar, Chamba; in July and August in Gulmarg, Jammu and Kashmir; from February to April in Mussorrie, Dehradun. Singh (2009) reported it from Kedarnath Musk Deer Reserve, Chamoli and Rudraprayag, Uttrakhand in months of April to May at an altitude of 3600m. Bhardwaj *et al*. (2012) reported the nominate species from Isratgad watershed, Tons Valley, Uttrakhand. Singh and Sondhi (2016) also reported it from February to May (Kedarnath Musk Deer Reserve; Kunwari Pass; Benog-Mussoorie; Gangotri National park). Ample records of the nominate species occur from Utttrakhand, but no recent recordings from Jammu and Kashmir and Himachal Pradesh were found in literature.

Adult morphology of *N. xanthomelas* Esper has been described and external genitalia has been illustrated in detail for the first time in the present research work.

Genus *Polygonia* Hübner

Common name: The Comma

Hübner, [1819]; Verz. bek. Schmett. (3): 36.

Type species: *Papilio c-aureum* Linnaeus

Linnaeus, 1758; Syst. Nat. (Edn 10) 1: 477.

Type locality: China, Penang.

Head moderate in size, fronto-clypeal region clothed with long hair; eyes hairy, labial palpi ascending, extending well beyond forehead, porrect and scaly, first joint curved and very short, second joint swollen in middle and tapering beyond, third joint very short with pointed apex; antennae shorter than half costa, club short and gradual; thorax moderately stout, ovate, dressed with greenish long hair; forewing triangular, costa straight, apex round, termen falcate, inner margin sinuate; forelegs with femur and tibia of equal length, middle and hid leg stout, femur and tibia equivalent in length, tibia bears spines and spurs, latter robust and long, tarsi as long as tibia, spines present except fifth joint, claws long and slightly curved and grooved below.

Remarks: The nominate genus was erected on the basis of the type species *Papilio c-aureum* Linnaeus. Genus *Polygonia* includes five Palaearctic species (*P. c-album*, *P. c-aureum*, *P. egea*, *P. gigantea* and *P. interposita*), and nine Nearctic species (*P. comma*, *P. faunus*, *P. gracilis*, *P. interrogationis*, *P. oreas*, *P. progne*, *P. satyrus*, *P. g-argenteum* and *P. haroldii*). Moore (1899) described the distribution of *P. interposita* (Staudinger) as Persia, Blauchistan, Chitral and Turkestan. However, Evans (1932) clearly mentioned that two species under the nominate genus are found in India i.e. *P. c-album* (Linnaeus) (from Kashmir to Bhutan) and *P. interposita* (Staudinger) (Kashmir, Ladakh). The latter was earlier considered as a subspecies of *P. c-album* due to morphological and genetic similarities in mtDNA (Wahlberg *et al*., 2009). But after analysis of nuclear DNA (nDNA), it became clear that *P. interposita* and *P. c-album* are a separate species (Wahlberg *et al*., 2009). There are recent or near past literature records of *P. interposita* (Staudinger) from Kashmir. However, Smith *et al*. (2007) reported the latter species from Hunza region in northern Pakistan and Afganistan and described its habitat as 'Juniper forests of Blauchistan, from drier

regions of Chitral and rarely in the Murree hills ranging downwards to 8000ft'. Its present status in India needs to be updated. In the present work, only *P. c-album* (Linnaeus) is taxonomically dealt.

Polygonia c-album (Linnaeus)

Common name: The Comma

Linnaeus, 1758; Syst. Nat. (Edn 10) 1: 477 (*Papilio*).

Type locality: Europe

f-album Esper, 1783; Die Schmett. Th. I, Bd. 2 (8): 168, pl. 87 (*Papilio*).

marsyas Edwards, 1870; Trans. amer. ent. Soc. 3 (1): 16 (*Polygonia*).

Polygonia c-album agnicula (Moore)

Common name: The Eastern Comma

(Figure 2)

Moore, 1872; Proc. zool. Soc. Lond. 1872 (2): 559 (*Grapta*)

Type locality: Gulmarg (Kashmir), Nepal.

Adult (Male): Fore wing upper side ground colour deep orange, wing base dressed with golden scales, one broad black bar in middle of discal cell, one at end cell and another near apex, three descending black spots in discal area, margin broad and dull brown, underside of fore wing with smudged pattern, blackish brown in colour; hind wing costa sinuate, apex round, termen sinuate, tail at vein M3, inner margin almost straight, upper side colouration same as forewing, basal half suffused with golden brown scales, an irregular series of black discal spots present, margins very wide, dull brown, underside colouration same as forewing, a shiny C-shaped shiny white lunular spot in discal area present.

Venation: Fore wing with discal cell shorter than half length of wing, vein Sc long and terminates at half costa, vein R_1 and R_2 parallel to Sc, vein R_1 well before upper apex of end cell and terminates at costa, vein R_2 and stalk R_3+R_4+R_5 just from upper apex of end cell, vein R_2 and R_3 arise well before middle of R_5 and terminates just at apex, M_1 arises from slightly below upper apex of end cell, vein M_2 closer to M_1 at origin than to M_3, latter arises just from lower apex of end cell, Cu_1 opposite to origin of M_2, discal cell closed; hind wing with Sc+R_1 parallel to costa and terminates just below apex, stalk Rs+M_1+M_2 and M_3+Cu_1+Cu_2 present, discal cell open, ldc absent.

Abdomen short and not stout, shorter than half length of inner margin.

Adult (Female): Similar as male except five jointed tarsi in forelegs; latter unfit for walking.

Male genitalia: Tegumen heavily sclerotized, convex, extended backwards, wide and rectangular dorsally; uncus straight, as long as length of tegumen, broad at base and gradually narrows down into a blunt tip assuming a V-shape from dorsal view, tubular in lateral view gnathos heavily sclerotized, horn like from dorsal view; saccus short, thin, tubular, slender, well sclerotized, upturned obliquely towards dorsal side, tip blunt and slightly swollen; vinculum moderately broad along entire length, u-shaped from ventral view, much longer than latero-ventral projection of tegumen; juxta sclerotized, U-shaped; valvae large, quite broad, not protruding beyond tip of uncus, well sclerotized and hirsute with long and fine setae; costa and sacculus simple; ampulla simple with blunt tip; harpe well sclerotized, tapering into a pointed tip sickle shaped; aedeagus long, stout at base and sharply narrow beyond two-third of its length and descends into a sharp pointed tip directed towards dorsal side, robust, heavily sclerotized, deeply curved.

Female genitalia: Not examined.

Distribution: India (Western Himalaya, Sikkim to Arunachal Pradesh), Nepal, Bhutan.

Material examined: 1♂, 2.iv.2012, Kalatop Wildlife Sanctuary, Dalhousie, Chamba (H.P.).

Host plants: Salicaceae, *Urtica dioica*, *Ulmus glabra*, *Salix caprea*, *R. uva-crispa*, *Betula pubescens*, *Ribes alpinum*, *R. nigrum*, *R. rubrum*, *Rubus idaeus*, *Betula spp*., *Corylus avellana*, *S.*

aurita, *S. cinerea*, *S. phylicifolia*, *Ulmus laevis*, *Humulus lupulus*, *Urtica dioeca* (Janz *et al*.,1994; Chou,1994; Seppänen,1970)

Remarks: Two distinct seasonal morphs of this species are known to occur (spring morph which enters into a reproductive diapause and hibernate as adult before ovipositing; summer morph which rapidly mature sexually and oviposit in summer giving rise new generation of the dark hibernation morph) (Nylin, 1988).

This species has a wide distributional range in Himalayan region from Kashmir to Sikkim, but is rare everywhere. Three subspecies are found in Himalaya namely, *P. c-album cognate* (Moore) (north western Himalaya); *kashmira* Evans (Kashmir, Ladakh); and *agnicula* (Moore). Moore (1872) originally described the latter subspecies as a distinct species: *Grapta agnicula* Moore distributed from 'Gulmarg (Kashmir) to Nepal'. However, later on, the same author (Moore, 1899-1900) lowered its status to a sub-specific level under *P. c-album* (Linnaeus) and described its distribution as from 'Nepal; Chumbi Valley, Sikkim; N.W. Bhutan'. Various authors like Evans (1932) and Kehimkar (2016) also followed the same and completely omitted its distribution in Western Himalaya. But in the present research work, the wet season form of this sub-species was collected from Kalatop Wildlife sanctuary, Chamba, Himachal Pradesh (Western Himalaya).

Singh (2009) also reported the nominate subspecies from Kedarnath Musk Deer Reserve, Garhwal

Himalaya during August-October at an altitudinal range 2700-3500m. Recently, Gogoi *et al*. (2015) also reported the range extension of *Polygonia c-album agnicula* into Tawang District, Arunachal Pradesh (north-eastern India). Hence, according to the present record and recent literature survey the older expanded distributional range of this subspecies should be considered i.e. Western Himalaya to Nepal to Sikkim, Arunachal Pradesh, Bhutan.

In the present work, the nominate sub-species from Kalatop Wildlife sanctuary, Chamba, Himachal Pradesh (Western Himalaya) has been studied for its morphological characters including external male genitalia.

Genus *Kaniska* Moore

Common name: The Admirals

Moore, [1899]; Lepidoptera Indica 4: 91.

Type-species: *Papilio canace* Linnaeus

Linnaeus, 1763, Amoenitates Acad. 6: 406.

Type locality: E. China

Eyes oval and densely hairy; labial palpi ascending, porrect, extends well beyond head; antennae longer than half costa, club prominent but gradual and long; thorax stout and oval.

Kaniska canace (Linnaeus)

Common name: The Blue Admiral

(Figure 3)

canace Linnaeus, 1763; Amoenitates Acad. 6: 406 (*Papilio*).

glauconia Motschulsky, 1860 (*Vanessa*).

canace siphnos Fruhstorfer, 1912; in Seitz, Gross-Schmett. Erde 9: 527. (*Vanessa*).

canace f. *mandarina* Matsumura, 1939; Bull. biogeogr. Soc. Japan 9 (20): 356 (*Vanessa*).

Adult (Male): Fore wing trigonate, costa arched, apex truncate, termen sinuate, angulate, tornus round, inner margin sinuate, upper side of fore wing greyish black in colour, a broad blue sinous band traversed from costa to inner margin in post discal area, under side dull brown, tinted violet, matte brown beyond half of wing; hind wing round, costa straight, apex round, termen sinous, inner margin straight, upper side ground colour similar as male, broad blue sinous band in continuation from fore wing, underside similar as forewing.

Venation: Fore wing with discal cell shorter than half costa, vein Sc long and terminates at half costa, vein R_1 and R_2 parallel to Sc and well before upper apex of end cell and terminates at costa, stalk R_3+R_4+R_5 just before upper apex of end cell, vein R_2 and R_3 arises well before middle of R_5 and terminates just at apex of wing, vein M1 arises

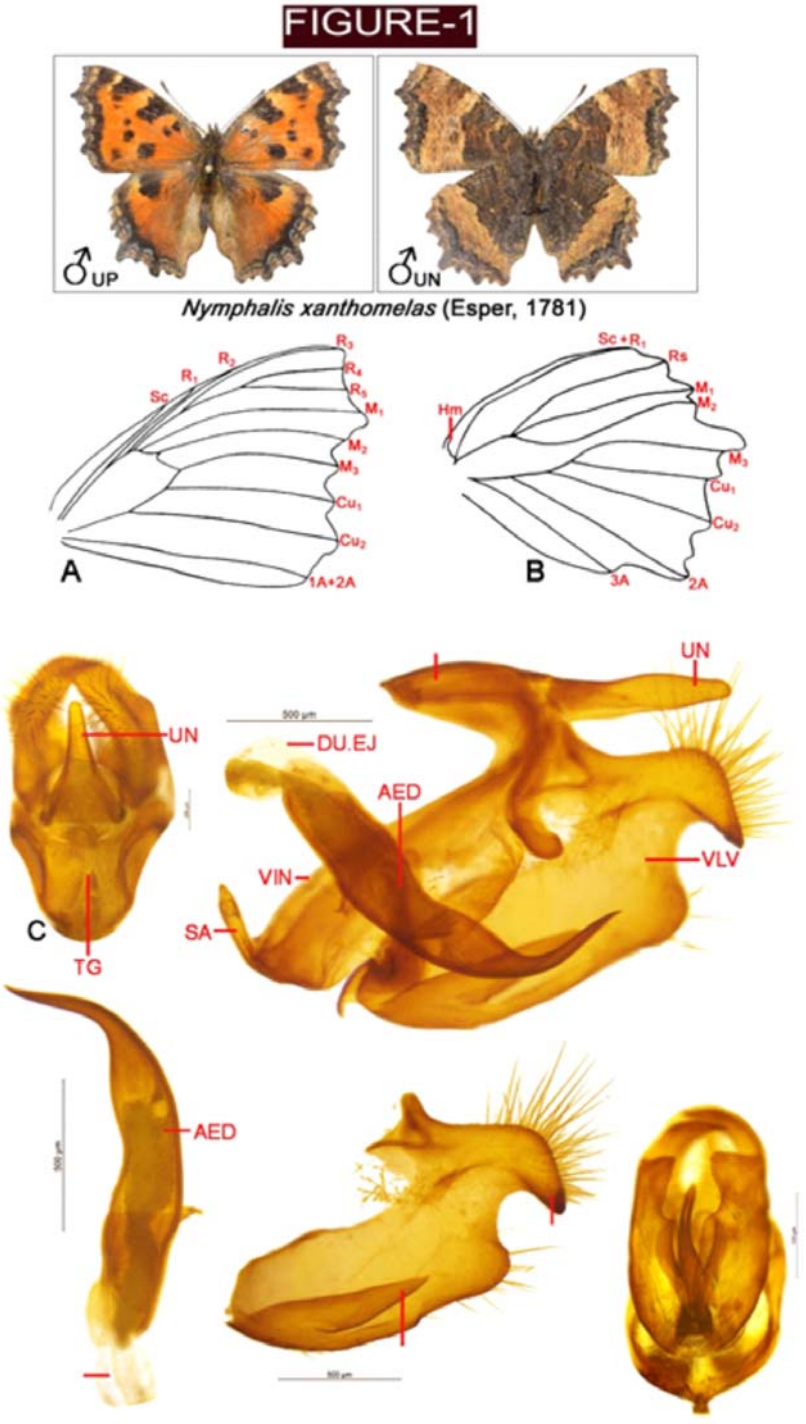

Fig 1. *Nymphalis xanthomelas* (Esper); A. Forewing, B. Hindwing, C. Uncus (Dorsal View), D. Male genitalia, E. Aedeagus, F. Right Valva (Inner View), G. Male genitalia (Ventral View).

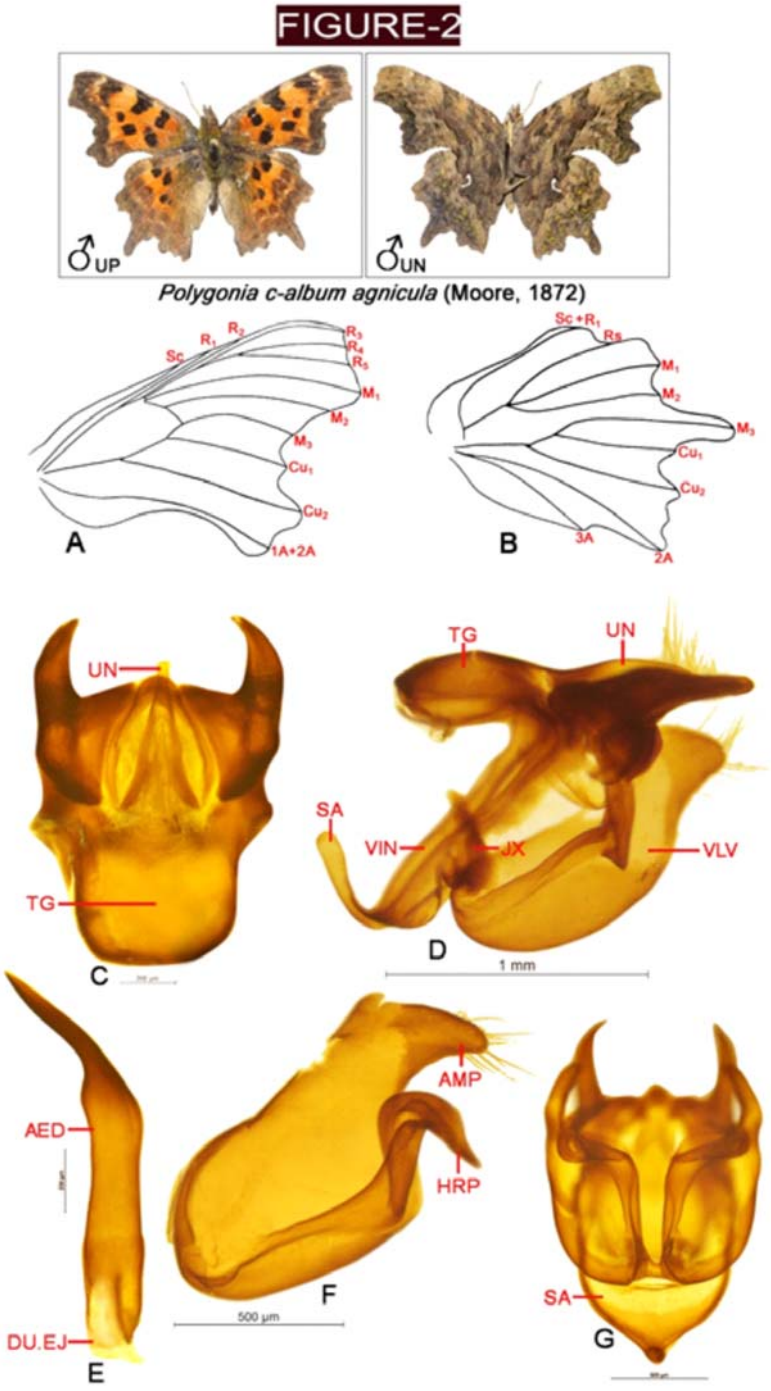

Fig 2. *Polygonia c-album agnicula* (Moore); A. Forewing, B. Hindwing, C. Uncus (Dorsal View), D. Male genitalia, E. Aedeagus, F. Right Valva (Inner View), G. Male genitalia (Ventral View).

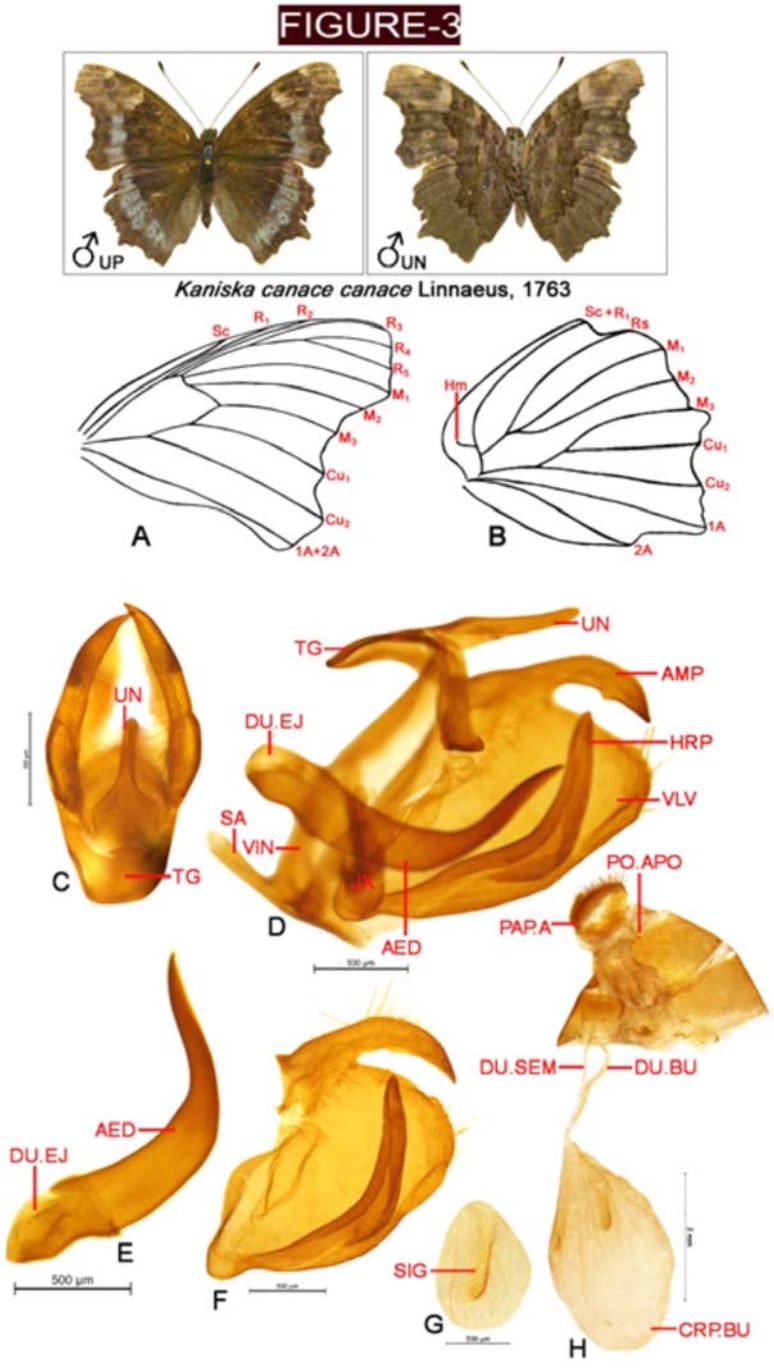

Fig 3. *Kaniska canace* (Linnaeus); A. Forewing, B. Hindwing, C. Uncus (Dorsal View), D. Male genitalia, E. Aedeagus, F. Valva, G. Signum, H. Female genitalia.

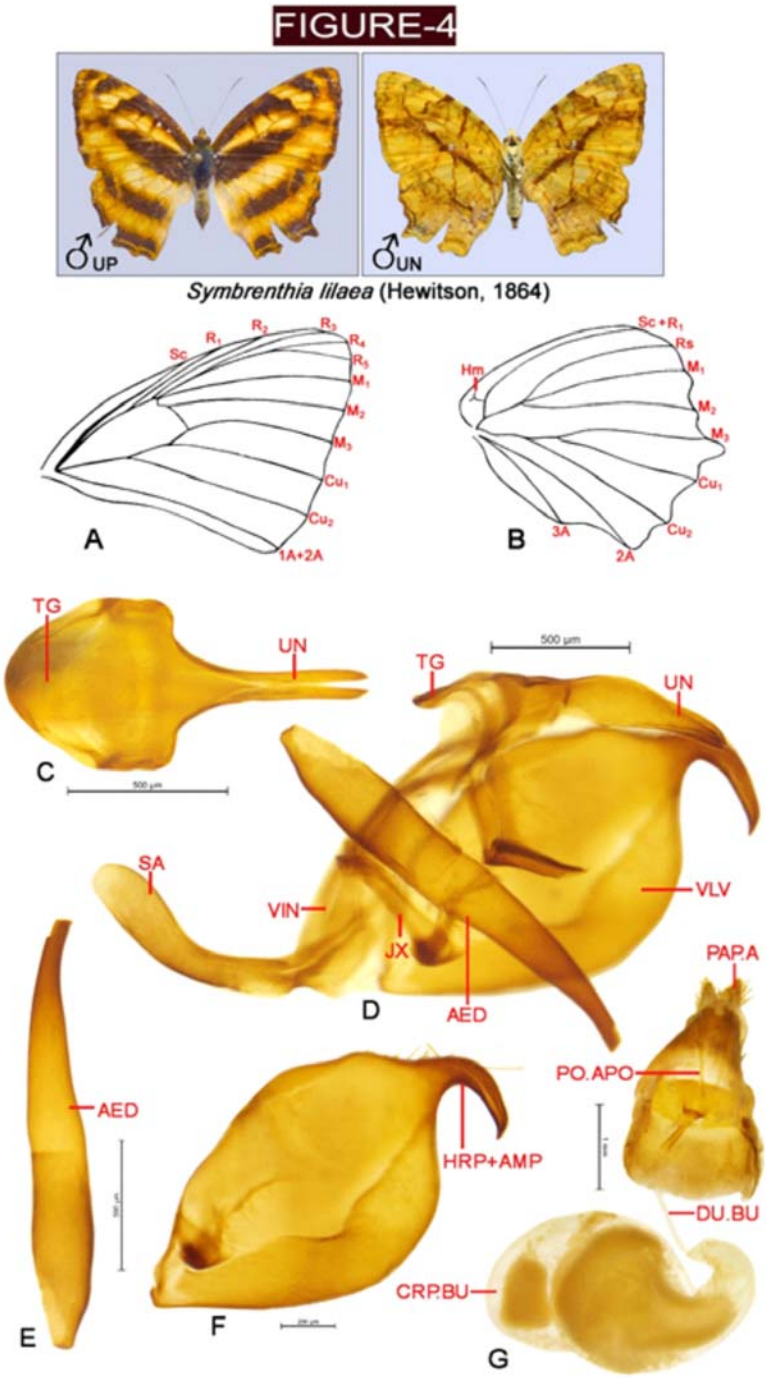

Fig 4. *Symbrenthia lilaea* (Hewitson); A. Forewing, B. Hindwing, C. Uncus (Dorsal View), D. Male genitalia, E. Aedeagus, F. Valva, G. Female genitalia.

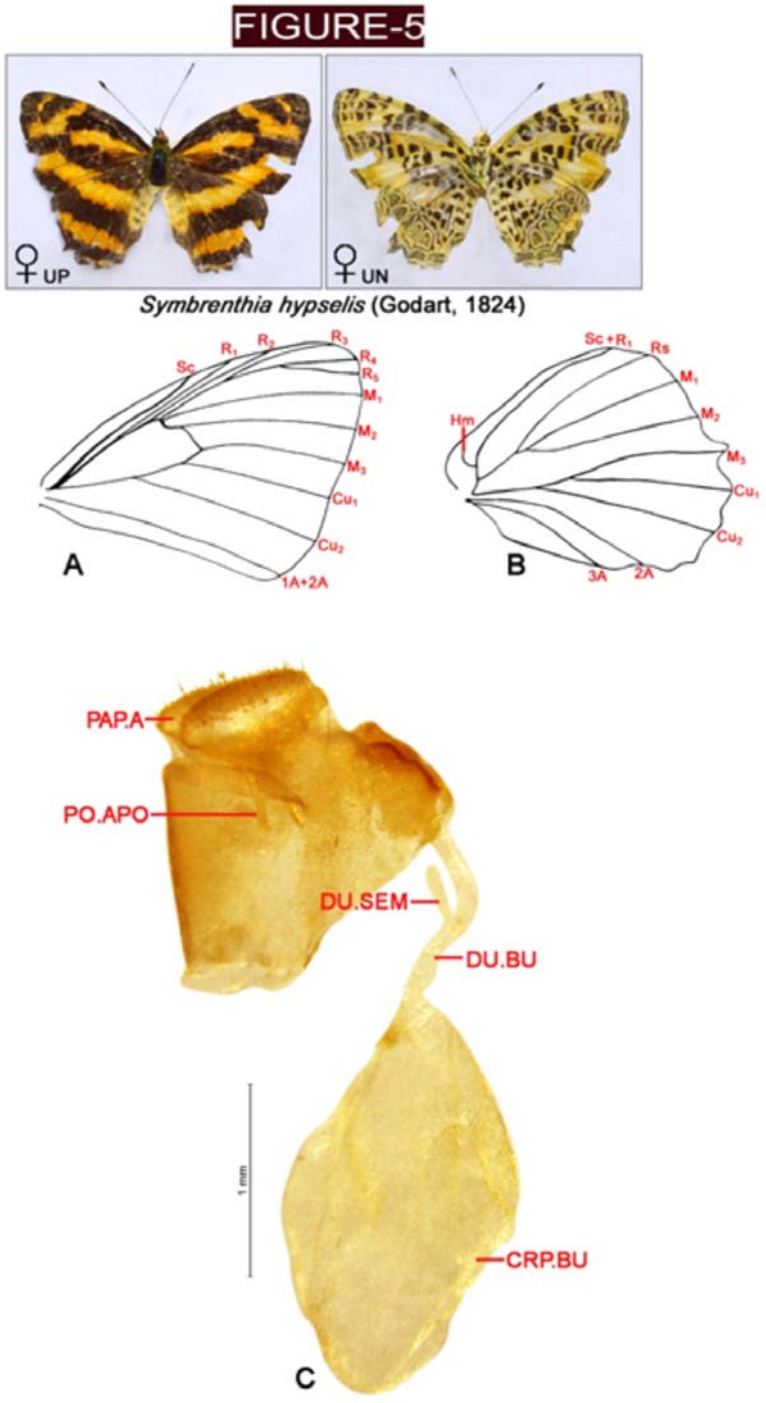

Fig 5. *Symbrenthia hypselis* (Godart); A. Forewing, B. Hindwing, C. Female genitalia

from slightly below upper apex of end cell, vein M_2 slightly closer to M_1 at origin than to M_3, latter just from lower apex of end cell, vein Cu_1 opposite to origin of M_2, discal cell closed, hind wing with forwardly curved humeral vein, Sc+R1 parallel to costa and terminates just below apex, stalk $Rs+M_1+M_2$ and $M_3+Cu_1+Cu_2$ present, discal cell open, ldc absent.

Adult (Female): Similar to male.

Male genitalia: Tegumen dorsoventrally flattened, extended backwards, wide and somewhat rectangular dorsally; uncus dorsoventrally falttened, slightly longer than tegument, broad at base and narrows down into a tubular shape, y-shaped from dorsal view, tip blunt; gnathos narrow, heavily sclerotized; saccus short, thin, tubular, slender, well sclerotized, directed obliquely towards dorsal side, tip blunt, saccus also extended caudally; vinculum narrow, u-shaped from ventral view, much laonger than latero-ventral projection of tegumen; juxta sclerotized, u-shaped; valvae large, broad, protrudes beyond tip of uncus, well sclerotized and hirsute with long and fine setae; costa round and broad; ampulla sickle like but not deeply curved, tip pointed directed downwards; sacculus broad, produced into a crest at base; harpe well sclerotized, sickle shaped with blunt tip directed towards dorsal side; aedeagus long, stout at base and narrow sharply beyond mid-length and descends into a pointed tip, directed towards dorsal side, robust, heavily sclerotized, deeply curved into a sickle shape.

Female genitalia: Sterigma well developed and weakly sclerotized, with both lamella antevaginalis and lamella postvaginalis fused to form a small cone or funnel like sclerotized plate; ductus seminalis tubular, opening dorsally into basal portion of ductus bursae; latter almost as long as corpus bursae, membranous, reception at corpus bursae well-marked; corpus bursae elongated, egg-shaped, membranous, a pair of streak-like signa present; apophyses anteriores absent; apophyses posteriores short, sclerotized and straight; papilla analis moderate in size, squarsh, outer margin more sclerotized, pilose.

Distribution: India (Jammu and Kashmir, Northeast, hills of Southern India), Pakistan, Nepal, Bhutan, Myanmar, Sri Lanka.

Material examined: 1♂, 28.iii.2015, Totu village, Shimla (H.P.); 1♀, 30.iii.2015, Totu village, Shimla (H.P.).

Larval host plants: Liliaceae, Smilacaceae, Dioscoreaceae (Smetacek, 2012).

Remarks: The nominate genus was established on the basis of the type species *Papilio canace* Linnaeus. This is a monotypic genus with type species *Kaniska canace* Linnaeus belonging to the Oriental region (D'Abrera, 1985). Three subspecies *viz*., *K. c. himalaya* Evans (North-West Himalaya (Pakistan to Kumaon); *canace* Linnaeus from North-East Himalaya (from Sikkim to North Burma)); and *viridis* Evans (Southern India) (Evans, 1932) are known under the nominate species in India. In Himalaya, this species occupies the elevation range from 609 to 2743 m (Wynter-Blyth, 1957). It is typically a forest species and prefers to fly swiftly through Oak and Rhododendron forest. Occasionally it settles on the tree trunks or rotting fruits to sip exude, and males can often be spotted while roosting. During a survey by Singh *et al*. (2016), this species was reported from Talwara village, Hoshiarpur for the first time. Additionally this species was also spotted in Ludhiana, Punjab. This species was previously known to be restricted to only hilly areas; however, reporting of this species from plains of Punjab is a new observation and extended range of this species (Singh *et al*., 2016).

Genus *Symbrenthia* Hübner

Common name: The Jesters

Hübner, [1819]; Verz. bek. Schmett. (3): 43.

Laogona Boisduval, [1836]; Hist. nat. Ins., Spec. gén. Lépid. 1: pl. 10.

Type-species: *Symbrenthia hippocla* Hübner

Hübner, [1819]; Verz. bek. Schmett. (3): 43.

Type locality: Amboina

Head moderate with fronto clypeal region hairy; eyes hairy; labial palpi projecting beyond head, ascending, dressed with long rather closely oppressed scales; antennae approximately as long as half costa, club inconspicuous, long and gradual; thorax oval, weak and hairy; abdomen weak; middle and hind legs with short and curved claws; hind wing toothed at vein M_3.

Remarks: The genus *Symbrenthia* Hübner was established on the basis of the type species *Symbrenthia hippocla* Hubner. The arrangement of species and races of this genus is in a state of profound confusion which makes the diagnosis of the taxa very difficult (D'Abrera, 1985). The genus includes 10-15 species distributed from the Western Himalaya in India to southern China, and southward to Sundaland, the Philippines and New Guinea (Smith, 1989; Corbet *et al*., 1992; Huang, 1998; Huang and Xue, 2004). Seven currently recognized subspecies, classified among five species, occur in the Himalaya and in the Patkai mountain ranges in northeastern India, some of which are very rare and endemic to these mountain ranges (Kunte, 2010). Kunte (loc.cit.) rediscovered the butterfly *Symbrenthia silana* de Nicéville from the Eastern Himalaya and Garo Hills after 90 years.

Symbrenthia lilaea (Hewitson)

Common name: The Common Jester

(Figure 4)

Hewitson, 1864; Trans. ent. Soc. Lond. (3) 2 (3): 246 (*Laogona*).

Adult (Male): Forewing upper side dark brown, deep yellow streak extends from base to discal region, post discal area deep yellow, margins dark brown, underside bright yellow with rufous brown streaks; hind wing basal colour deep brown, deep yellow coloured discal and post discal bands present, underside similar as fore wing.

Venation: Forewing with discal cell slightly shorter than half length of wing, vein Sc moderately long and terminates at half costa, vein R_1 parallel to Sc and originate well before upper apex of end cell, R_2 from well before end cell, stalk R_3+R_4+R_5 just from upper apex of end cell, vein R_3 originate well before mid of R_5, vein R_3 terminates slightly before apex of wing, M_1 arises from just below upper apex of end cell, vein M_2 closer to M_1 than to M_3 at origin, vein M_3 curved and arises just from lower apex of end cell, Cu_1 arises opposite to M_2, discal cell closed; hind wing with forwardly curved humeral vein, Sc+R_1 parallel to costa and terminates just at apex of wing, stalk Rs+M_1+M_2 and M_3+Cu_1+Cu_2 present, discal cell open, ldc absent.

Adult (Female): Similar to male, but the orange markings are broader and paler on upper side of wings.

Male genitalia: Tegumen narrow and extended backward, oval from dorsal view; uncus well sclerotized, bifid, Y-shaped from dorsal view, dilated from middle portion in later view; gnathos narrow and lightly sclerotized; saccus moderately long, slightly curved upwards, tubular, tip blunt and swollen; vinculum narrow along entire length, quite long than latero-ventral projections of tegumen, convex; juxta prominent, long, U-shaped and slit like; valvae broad, oriented obliquely touching tip of uncus, tip of valvae produced into heavily sclerotized sickle like pointed hook; aedeagus long, slightly stout, tubular, tip blunt; vesica absent; ductus ejaculatorius enters dorsad.

Female genitalia: Sterigma well sclerotized and developed into a small funnel like structure composed with fusion of lamella antevaginalis and lamella postvaginalis; ostium bursae cresent shaped; ductus seminalis tubular, attached on dorsal side at middle of ductus bursae; latter with short proximal portion sclerotized, otherwise membranous, tubular, well demarcation at inception of corpus bursae; corpus bursae much longer than ductus bursae, membranous, egg shaped with apex rounded but curved into an irregular S-shaped; apophyses anteriores absent; apophyses posteriores moderately long, slender, well sclerotized and straight; papilla analis oval, distal portion heavily sclerotized, pilose.

Distribution: India (Eastern Ghats, Himalaya, North-eastern India, W. Bengal, Odisha), Indo-China, SE

Asia (Kunte, 2010).

Material examined: 1♂♀, 29.v.1991, Kasauli, Solan (H.P.); 1♂, 15.vi.1992, Chail wildlife sanctuary, Shimla (H.P.); 2♂, 26.ix.2015, Andretta, Palampur, Kangra (H.P.).

Host plant: Urticaceae (Smetacek, 2012).

Remarks: The present species is distributed from northern India to Indo-China. It is an occasional species in the western Himalaya and inhabits the subtropical evergreen forest between 300 m to 1,700 m (Smetacek, 2012). This species frequently visits stream beds for mud-puddling. In the present study, an interesting specimen in the museum of Department of Zoology and environmental Sciences was observed with very broad fulvous and obsolete black maculation on the upper side of fore and hind wing. The morphology of external male and female genitalia has been described and illustrated in the present work.

Symbrenthia hypselis cotanda Moore

Common name: The Himalayan Spotted Jester

(Figure 5)

Godart, [1824]; Encyclopédie Méthodique 9 (2): 818, no. 5-6 (*Vanessa*).

Type locality: Darjeeling

Adult (Female): Upper side of both wings blackish brown with dark fulvous maculation; underside clouded with creamy yellow colour, a series of sub-marginal metallic green conical spots present and caudal lunular spots quite prominent.

Venation: Forewing with discal cell slightly shorter than half length of wing, vein Sc moderately long and terminates at half costa, vein R_1 originate well before upper apex of end cell, R_2 from well before end cell, stalk R_3+R_4+R_5 just from upper apex of end cell, vein R_3 originate well before mid of R_5, vein R_3 terminates slightly before apex of wing, M_1 arises from just below upper apex of end cell, vein M_2 closer to M_1 than to M_3 at origin, M_3 curved and arises just from lower apex of end cell, Cu_1 arises opposite to M_2, discal cell closed; hind wing with forwardly curved humeral vein, Sc+R_1 parallel to costa and terminates just at apex of wing, stalk Rs+M_1+M_2 and M_3+Cu_1+Cu_2 present, discal cell open, ldc absent.

Male genitalia: Not examined.

Female genitalia: Sterigma reduced, lamella antevaginalis merely as emarginated sclerotization around ostium bursae; ductus seminalis tubular, attached on dorsal side at middle of ductus bursae; latter membranous, tubular, no demarcation at inception of corpus bursae; corpus bursae much longer than ductus bursae, membranous, egg shaped with apex rounded; apophyses anteriores absent; apophyses posteriores not long, slender, well sclerotized and slightly curved; papilla analis oval, with shallow emarginations along proximal and distal margins, distal portion heavily sclerotized, pilose.

Distribution: India (Himalaya, NE India), S. China, Indo-China, SE Asia (Kunte, 2010).

Material examined: 1♀, 30.x.1995, Pitthoragarh (Uttrakhand).

Host Plant: Urticaceae

Remarks: The species under reference mainly inhabits the forested areas between the altitudinal ranges from 300m to 2,400m above mean sea level. D'Abrera (1985) has not mentioned the distribution of this species in North-west Himalaya. However, Bhardwaj *et al*. (2012) recorded the nominate species from Gangotri National Park and referred it as a very rare species. Kehimkar (2016) has also reported the nominate species from North-west Himalaya. Only female genitalia of the nominate species has been described and illustrated for the first time in the present work. The specimens dealt in the present study were procured from the older insect collection lying in the museum of Department of Zoology and Environmental Science, Punjabi University, Patiala.

Symbrenthia niphanda Moore

Common name: Kumaon Blue-Tail Jester

Moore, 1872; Proc. zool. Soc. Lond. 1872 (2): 559.

Type locality: Sikkim, Himalaya

Distribution: W. Himalaya (Kashmir to Kumaon), India, Naga Hills, Bhutan.

Remarks: The subspecies *S.n.hysudra* Moore is found in the western Himalaya. It is indeed a very rare species in western Himalaya. It has been reported from Western Himalaya by Moore (1872), Evans (1932); Arora *et al*. (2005); Kunte (2010); Smetacek (2012); Singh and Sondhi (2016). However, there is a lack of recent records of this sub-species from Himachal Pradesh and Jammu and Kashmir.

No specimen of the nominate species could be collected under the present survey. Genitalia of the species *Symbrenthia niphanda* Moore has been studied by (Huang and Xue, 2004).

Symbrenthia brabira Moore

Common name: The Yellow Jester

Moore, 1872;. zool. Soc. Lond. 1872 (2): 558.

Type locality: N. India.

Distribution: Himalaya, SE Tibet, S. China.

Remarks: *S.b. brabira* Moore is the subspecies distributed in western Himalaya, India. It is also a very rare species. A few records of this subspecies are by: Moore (1872), Hannyngton (1910); Evans (1932); Kunte (2010); Singh (2009); Smetacek (2012); Singh and Sondhi (2016). However, no specimen could be collected under the present study. Its genitalia have also been earlier elucidated by Huang (1998)

Vanessa cardui (Linnaeus)

Common name: The Painted Lady

cardui Linnaeus, *Syst. Nat.*, 10th ed.: 475.1758 (*Papilio*).

Type locality: Sweden.

Distribution: Nearctic, African, Oriental, Australian, Palaearctic Regions.

Host Plants: Urticaceae, Asteraceae (Smetacek, 2012).

Remarks: It is an extremely common species throughout its distributional range. It is one of the most common butterflies in western Himalaya. The male and female external genitalia of the nominate species has been described by Field (1971) and Mattu *et al*. (2017).

Vanessa indica (Herbst)

Common name: The Indian red admiral

indica Herbst, Nat. Schmett., 7: 171; 1794 (*Papilio*).

Type locality: India

Distribution: India to S.E. Asia.

Host Plants: Urticaceae; Tiliaceae; Ulmaceae (Smetacek, 2012).

Remarks: It is also an extremely common species throughout its distributional range. It is a multivoltine species having several overlapping generations. The external genitalia of male and female of the nominate species has been described by Field (1971) and Mattu *et al*. (2017).

Aglais cashmirensis (Kollar)

Common name: The Indian Tortoiseshell

Kollar, [1844]; in Hügel, Kaschmir und das Reich der Siek 4: 442 (*Vanessa*).

Type locality: Kashmir, India.

Distribution: India to S.E. Asia.

Host Plants: Urticacae

Remarks: In India, the species *A. caschmirensis* (Kollar) is represented by two subspecies; *A.c. caschmirensis* (Kollar) which is a western subspecies known from the Kashmir Valley (Jammu and Kashmir) to Kulu (Himachal Pradesh) (Varshney and Smetacek, 2015), and *A.c. aesis* (Fruhstorfer) distributed through Uttarakhand to Arunachal Pradesh and Nagaland (Greeshma, 2010; Naro, 2012; Varshney and Smetacek, 2015; Irungbam, 2017). Irungbam (2017) recorded the range extension of *A.c. aesis* (Fruhstorfer, 1912) into different parts of the Manipur State. More recent records of this species from the western Himalaya are as follows: Uniyal (2007); Singh (2009); Smetacek (2012); Bhardwaj et al. (2012);

Sidhu *et al*. (2012); Qureshi *et al*. (2014); Singh and Sondhi (2016); Sondhi *et al*. (2017).

The male and female genitalia along with the life history stages was described and illustrated by Rose (2005).

Aglais ladakensis (Moore)

Common name: The Ladakh Tortoiseshell

Moore, 1878; Ann. Mag. nat. Hist. (5) 1 (3): 227 (*Vanessa*).

Type locality: Gogra, Changchenmo (15000ft), Ladak; Karatagh lake, on snow (16890ft), Yarkund

Distribution: Jammu and Kashmir to Sikkim

Host Plants: Urticacae

Remarks: It is indeed a very rare species. Smith *et al*. (2007) reported this species from Muchuwar valley, Pakistan. It has been reported by Doherty (1886); Moore (1899-1900); Hannyngton (1910); Evans (1932); Vis and Coene (1987); Varshney and Smetacek (2015); Sondhi *et al*. (2017).

Discussion:

A review of the western Himalayan butterflies under the tribe Nymphalini has been presented. Based on the external genitalic survey the following conclusions can be drawn:

Tegumen is very robust (except in genus *Symbrenthia* Hübner, in which it is relatively small) and projecting backwardly (in lateral view) in all the species under consideration. Uncus is also well developed and sclerotized (dorso-ventrally flattened in *K. canace* (Linnaeus); straight and tapering into blunt tip in *N. xanthomelas* (Esper) and *P.c-album* (Linnaeus); somewhat swollen near base, long and divided in *S. lilaea* (Hewitson); simple and long in *S. hypselis* (Godart); simple with broad base and tapering in *S. niphanda* Moore; simple, long with Y-shaped apex in *S. brabira* Moore; beak like, stout with a bifid apex in *V. indica* (Herbst); stout, beak like with a blunt tip in *V. cardui* (Linnaeus); undivided, straight, dorsoventrally compressed in *A. cashmirensis* (Kollar) and *ladakensis* (Moore)). Vinculum is well developed. Saccus is generally small and upturned obliquely (*N. xanthomelas* (Esper), *P.c-album* (Linnaeus), *K. canace* (Linnaeus), *V. indica* (Herbst), *V. cardui (Linnaeus))*. The genus *Symbrenthia* Hübner is an exception, as in *S. lilaea* (Hewitson) the saccus is long, tubular and slightly curved upwards towards the tip, where as in *S. hypselis* (Godart), *S. niphanda* Moore and *S. brabira* Moore (as well in *A. cashmirensis* (Kollar) and *ladakensis* (Moore)) it is long and straight. Gnathos is prominently developed (especially in *P. c-album* (Linnaeus)). Juxta is sclerotized, and valva is very broad and heavily sclerotized in in all the species under consideration. However, latter's shape vary in every species. Aedeagus is long, heavily sclerotized, robust, abruptly and obliquely bent beyond the half-length, and tapers into a sharp tip (*N. xanthomelas* (Esper), *P. c-album* (Linnaeus), *K. canace* (Linnaeus), *V. indica* (Herbst)), whereas it is broad and almost straight in *S. lilaea* (Hewitson); long, narrow and slightly curved in *S. hypselis* (Godart), *S. niphanda* Moore and *S. brabira* Moore*;* long, narrow and wavy in *A. cashmirensis* (Kollar) and *ladakensis* (Moore).

The data for female genitalia is however incomplete. In general, the genital plate is weakly developed with pod-like ostium bursae. Ductus bursae is long, narrow and partly sclerotized at the proximal end and otherwise membranous (*S.lilea* (Hewitson), *S. hypselis* (Godart), *V.indica* (Herbst), *A.cashmerensis* (Kollar), K. canace (Linnaeus)). Corpus bursae is oval, elongated or balloon like, membranous with a pair of diffused signum. Ductus seminalis enters at the junction of sclerotized and membranous portion of ductus bursae. Anterior apophysis are absent and posterior apophysis are short and weakly sclerotized. Papila analis moderately sclerotized.

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Efficacy of some insecticide modules against major insect pests and spider population of rice, *Oryza sativa* L.

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ABSTRACT: Experiments were carried out to assess some insecticide modules against major insect pests of rice. Each module consists of a basal application of carbofuran 3G @ 1 kg a.i ha^{-1} at 20 DAT and Rynaxypyr 20 SC @ 30 g a.i ha^{-1} at 45 DAT except untreated control. All modules differ with each other only in third treatment which was applied in 65 DAT. The third treatment includes: Imidacloprid 17.8 SL @ 27 g a.i ha^{-1}, Pymetrozine 50 WG @ 150 g a.i ha^{-1}, Triflumezopyrim 106 SC @ 27 g a.i ha^{-1}, Buprofezin 25 SC @ 250 g a.i ha^{-1}; Glamore (Imidacloprid 40+Ethiprole 40% w/w) 80 WG @ 100 g a.i. ha^{-1}, Thiacloprid 24 SC @ 60 g a.i ha^{-1}, Azadirachtin 0.03 EC @ 8 g a.i ha^{-1}, Dinotefuran 20 SG@ 40 g a.i ha^{-1} and untreated control. All the treated plots recorded significantly lower percent of dead heart, white ear- head caused by stem borer and silver shoot caused by gall midge. Module with Pymetrozine 50 WG @ 150 g a.i ha^{-1} treated plot recorded significantly higher per cent reduction of plant hoppers (>80% over untreated control) and produced higher grain yield (50.75 qha^{-1}) than the other modules. Among the different treated modules the maximum number of spiders was found in Azadirachtin 0.03 EC @ 8 g a.i ha^{-1} treated module plot followed by other treatments.

KEYWORDS: Stem borer, plant hoppers, gall midge, spiders, insecticide modules, rice

INTRODUCTION

Rice (*Oryza sativa L.)* is one of the most important cereal crops providing a staple food for nearly half of the global population (FAO, 2004). In India, it is cultivated almost in one-fourth of the total cropped area providing food to about half of the Indian population. It thrives well under varying ecosystems starting from rain fed upland to rain fed lowland and the deep water condition. But, introduction and wide adoption of high yielding varieties has led to severe incidence of different insect pests. Nearly 300 species of insect pests attack the rice crop at different stages and among them only 23 species cause notable damage (Pasalu and Katti, 2006). Among them, yellow stem borer (YSB) - *Scirpophaga incerulas* (Walk.), brown plant hopper (BPH) - *Nilaparvata lugens* (Stål), white backed plant hopper (WBPH) - *Sogatella furcifera* (Horvath) and Asian rice gall midge (GM) - *Orseolia oryzae* (Wood-Mason) are the major cause for the economic crop loss in rice. Chemical insecticides are still effective method to control insect pests particularly in the rice crop. Many conventional insecticides though have been evaluated against these insects, yet, most of the chemicals have failed to provide adequate control. Hence, new molecules are being added for their

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evaluation with an aim of least disruption to environmental quality. For this, the present study was carried out to find the efficacy of certain insecticide modules with new and conventional molecules against major insect pests and spider population in rice.

MATERIALS AND METHODS

The experiment was conducted in the experimental farm of Regional Research and Technology Transfer Station (OUAT), Chiplima, Sambalpur, Odisha, during *kharif* 2016 and 2017. The Station is situated at $20^0$21' N latitude and $80^0$55'E longitude in Dhankauda block of Sambalpur district at an altitude of 178.8 m above MSL. The climate of the area is warm sub humid. The experiment was conducted in Randomized Block Design (RBD), having 9 modules which were replicated thrice in a net experimental area of 5 m x 4 m each. Nursery of rice variety Swarna was raised in the first week of July and transplanting was done after 25 days of sowing at 20 cm x 15 cm hill spacing. All the agronomic practices were followed during crop growth period.

There were eight insecticide modules and each module consists of application of carbofuran 3G @ 1 kg a.i ha^{-1} at 20 DAT and Rynaxypyr 20 SC @ 30 g a.i ha^{-1}at 45 DAT. All insecticide modules differ with each other only in the third application at 65 DAT. The third application include: Imidacloprid 17.8 SL @ 27 g a.i ha^{-1}, Pymetrozine 50 WG @ 150 g a.i ha^{-1}, Triflumezopyrim 106 SC @ 27 g a.i ha^{-1}, Buprofezin 25 SC @ 250 g a.i ha^{-1}; Glamore (Imidacloprid 40+Ethiprole 40% w/w) 80 WG @ 100 g a.i ha^{-1}, Thiacloprid 24 SC @ 60 g a.i ha^{-1}, Azadirachtin 0.03 EC @ 8 g a.i $ha^{-1}$and Dinotefuran 20 SG @ 40 g a.i ha^{-1}respectively in 1^{st} to 8th module. Module nine was untreated control. The insecticides were applied as high volume sprays using 500 litres of spray waterha^{-1}. Observations on the incidence of dead heart and silver shoot were taken on 10 randomly selected hills per plot from each replication at 30 and 55 days after transplanting. The white ear head was counted on 10 randomly selected hills from each plot just before harvest. Then percentage of dead hearts, white ear heads and silver shoot was worked out. The hopper population per 10 hills was recorded 7 days after third spray. The spider (natural enemies) population per 10 hills was recorded 55 and 75 days after transplanting. Mean value of data obtained from field experiments were transformed into square root values and analyzed statistically by ANOVA. Finally the grain yield was recorded per plot basis and expressed in quintal ha^{-1}.

RESULTS AND DISCUSSION

Stem borer management: The result showed that all the insecticide modules were effective in reducing the infestation of rice yellow stem borer (YSB) and thus, reducing the formation of dead hearts and white ear heads significantly as compared to the untreated control (Table 1). In treated plots, in 2016, the yellow stem borer infestation recorded as dead hearts ranged from 3.21 to 3.87% and white ears ranged from 4.26 to 7.13% as against 8.82 and 12.01% in control respectively. Whereas, in 2017, the dead hearts ranged from 3.41 to 4.26% and white ears ranged from 4.58 to 7.03% as against 9.36 and 10.68% in control respectively.

Gall midge management: Gall midge is one of the major insect pests of rice in Hirakud command area, Chiplima, Sambalpur. From the experimental result, it is observed that all the insecticide modules were effective in reducing the infestation of gall midge (GM) and thus, suppressing the formation of silver shoot significantly as compared to the untreated control (Table 2). In insecticide treated plots, in 2016 the gall midge infestation recorded as silver shoot ranged from 5.76 to 6.44% as against 14.27% in control. Whereas, in 2017 the silver shoot ranged from 5.78 to 6.97% as against 12.03% in untreated control.

Plant Hoppers management: Module with Pymetrozine 50 WG @ 150 g a.i ha^{-1} recorded significantly superior (>80 % reduction over control) in efficacy against plant hoppers during both the years followed by treatment with Triflumezopyrim 106 SC @ 27 g a.i ha^{-1}, Thiacloprid 24 SC @ 60 g a.i ha^{-1}, Glamore (Imidacloprid 40+Ethiprole 40%

Table 1. Efficacy of different insecticide modules against stem borer of rice

Modules*	Dead Hearts(%)		Pooled	White Ear Head (%)		Pooled
	2016	2017		2016	2017	
1	3.42 (1.98)	3.91 (2.10)	3.67 (2.04)	5.42 (2.43)	5.63 (2.48)	5.53 (2.45)
2	3.41 (1.98)	3.89 (2.09)	3.65 (2.04)	4.26 (2.18)	4.58 (2.25)	4.42 (2.22)
3	3.63 (2.03)	4.26 (2.18)	3.94 (2.11)	4.60 (2.26)	4.89 (2.32)	4.75 (2.29)
4	3.21 (1.92)	3.41 (1.97)	3.31 (1.94)	6.29 (2.61)	6.56 (2.66)	6.43 (2.63)
5	3.87 (2.09)	4.10 (2.14)	3.98 (2.11)	4.97 (2.34)	5.88 (2.52)	5.43 (2.43)
6	3.40 (1.97)	3.79 (2.07)	3.70 (2.05)	5.20 (2.39)	5.53 (2.46)	5.37 (2.42)
7	3.61 (2.02)	3.83 (2.07)	3.72 (2.04)	7.13 (2.76)	7.03 (2.74)	7.08 (2.75)
8	3.42 (1.98)	3.64 (2.03)	3.53 (2.01)	6.31 (2.61)	5.96 (2.54)	6.13 (2.57)
9	8.82 (3.05)	9.36 (3.14)	9.09 (3.10)	12.01(3.53)	10.68 (3.34)	11.34 (3.44)
S.Em	0.08	0.10	0.08	0.05	0.05	0.04
CD (5%)	0.24	0.31	0.23	0.16	0.16	0.12

Figures in parentheses are square root transformed values
*Module 1**: A+B+ Imidacloprid 17.8 SL @ 27 g a.iha^{-1}, Module 2: A+B+Pymetrozine 50 WG @ 150 g a.i ha^{-1} Module 3: A+B+ Triflumezopyrim 106 SC @ 27 g a.iha^{-1} Module 4: A+B+ Buprofezin 25 SC @ 250 g a.iha^{-1} Module 5: A+B+ Glamore (Imidacloprid 40+Ethiprole 40% w/w) 80 WG @ 100 g a.i ha^{-1} Module 6: A+B+ Thiacloprid 24 SC @ 60 g a.iha^{-1} Module 7: A+B+ Azadirachtin 0.03 EC @ 8 g a.iha^{-1} Module 8: A+B+ Dinotefuran 20 SG@ 40 g a.iha^{-1} and Module 9: untreated control.
**A+ B = Carbofuran 3G @ 1 kg a.i ha^{-1} at 20 DAT and Rynaxypyr 20 SC @ 30 g a.i ha^{-1} at 45 DAT

Table 2. Efficacy of different insecticide modules against gall midge and plant hoppers in rice

Modules*	Silver shoot (%)		Pooled	Plant Hoppers 10 hills^{-1}		Pooled
	2016	2017		2016	2017	
1	6.42 (2.63)	6.97 (2.73)	6.69 (2.68)	68.00	94.67	81.33
2	5.76 (2.50)	6.05 (2.55)	5.91 (2.53)	28.33	39.67	34.00
3	5.98 (2.54)	6.17 (2.58)	6.07 (2.56)	32.33	45.67	39.00
4	6.43 (2.63)	6.16 (2.58)	6.29 (2.60)	70.33	97.67	84.00
5	6.44 (2.63)	6.25 (2.59)	6.34 (2.62)	56.33	82.00	69.17
6	5.94 (2.54)	6.10 (2.57)	6.02 (2.55)	52.33	72.33	62.33
7	6.19 (2.58)	6.21 (2.59)	6.20 (2.59)	78.00	107.00	92.50
8	6.42 (2.63)	5.78 (2.50)	6.10 (2.57)	62.00	83.67	72.83
9	14.27 (3.84)	12.03 (3.54)	13.15 (3.69)	150.67	190.67	170.67
S.Em	0.07	0.09	0.07	1.78	2.31	1.42
CD (5%)	0.21	0.28	0.20	5.34	6.93	4.25

Figures in parentheses are square root transformed values
*Module details are given in table 1

w/w) 80 WG @ 100 g a.i ha^{-1}, Dinotefuran 20 SG@ 40 g a.i ha^{-1},Imidacloprid 17.8 SL @ 27 g a.iha^{-1}, Buprofezin 25 SC @ 250 g a.i ha^{-1} and Azadirachtin 0.03 EC @ 8 g a.i ha^{-1}. Module with Imidacloprid 17.8 SL @ 27 g a.i ha^{-1} and Buprofezin 25 SC @ 250 g a.i ha^{-1}were at par in efficacy against hoppers. All the modules were superior in plant hopper management and differed significantly from untreated control plot (Table 2).

Effect on spiders: Spiders are most important predators of rice hoppers and other insect pests. But, indiscriminate and nonselective use of insecticides causes disruption in their life cycle. Most of the spiders in rice fields seem to leave the field after application of chemical insecticides, thus their predatory capacity was suppressed and caused a positive impact on the population densities of major insect pests of rice. For this, selection of insecticides is very important for insect management point of view. The results on the presence of spiders in different treatments (Table 3) showed that highest numbers of spiders were found in the un-treated control (8 per 10 hills) than in other treated plots. The abundant spider families are Araneidae *(Argiope catenulate),* Lycosidae (*Lycosa pseudoannulata),* Tetragnathidae *(Tetragnatha sp.),*Theridiidae *(Argyrodes sp.)* and Salticidae (*Plexippus sp).*It is also observed that hunter spiders were more abundant in treated plots than weaving spiders which were more common in untreated control plots. It means the treatment had a strong effect on weaving spiders. Among different insecticide treatments, it was found that maximum spider population was present in module with Azadirachtin 0.03 EC @ 8 g a.i ha^{-1}treated plot (6 per 10 hills) followed by buprofezin 25 SC @ 250 g a.i ha^{-1}, Pymetrozine 50 WG @ 150 g a.i ha^{-1}, Triflumezopyrim 106 SC @ 27 g a.i ha^{-1}, Thiacloprid 24 SC @ 60 g a.i ha^{-1}, Dinotefuran 20 SG @ 40 g a.i ha^{-1},Imidacloprid 17.8 SL @ 27 g a.i ha^{-1} and Glamore (Imidacloprid 40+Ethiprole 40% w/w) 80 WG @ 100 g a.i ha^{-1} treated modules.

Table 3. Effect of different insecticide modules against spiders

Modules*	Spider 10 hills^{-1}		Pooled
	2016	2017	
1	2.0 (1.58)	1.7 (1.46)	1.83 (1.53)
2	4.7 (2.27)	5.0 (2.34)	4.83 (2.31)
3	2.7 (1.77)	2.3 (1.68)	2.50 (1.73)
4	5.0 (2.35)	5.3 (2.41)	5.17 (2.38)
5	1.3 (1.34)	2.0 (1.58)	1.67 (1.47)
6	2.3 (1.68)	2.0 (1.58)	2.17 (1.63)
7	5.7 (2.48)	6.3 (2.61)	6.00 (2.55)
8	2.0 (1.56)	2.3 (1.68)	2.17 (1.63)
9	8.3 (2.97)	7.7 (2.85)	8.00 (2.91)
S.Em	0.10	0.12	0.06
CD (5%)	0.29	0.35	0.19

Figures in parentheses are square root transformed values; *Module details are given in table 1

Grain Yield: Pymetrozine 50 WG @ 150 g a.i ha^{-1} (module 2) treated plot recorded highest grain yield of 50.75 qha^{-1} followed by Triflumezopyrim 106 SC @ 27 g a.i ha^{-1} (49.33 qha^{-1}), Glamore (Imidacloprid 40+Ethiprole 40% w/w) 80 WG @ 100 g a.i ha^{-1} (47.54 qha^{-1}), Thiacloprid 24 SC @ 60 g a.i ha^{-1} (47.5 qha^{-1}), Imidacloprid 17.8 SL @ 27 g a.i ha^{-1} (46.18 qha^{-1}), Dinotefuran 20 SG @ 40 g a.i ha^{-1} (46.17 qha^{-1}), Buprofezin 25 SC @ 250g a.i ha^{-1} (45.17 qha^{-1}) and Azadirachtin 0.03 EC @ 8 g a.i ha^{-1} (44.25 qha^{-1}) treated modules. All the treatments imparted plots gave superior yield than untreated control plot (32.08 qha^{-1}) (Table 4).

Present study revealed that all the tested modules were effective for major rice insect pests management. But, among the different modules, application of carbofuran 3G @ 1 kg a.i ha^{-1} at 20 days after transplanting followed by spraying of Rynaxypyr 20 SC @ 30 g a.i ha^{-1}at 45 days after transplanting and Pymetrozine 50 WG @ 300 g ha^{-1} at 65 days after transplanting were very effective for the management of rice stem borer, gall midge and plant hoppers. Karthikeyan and Christy (2014) observed significantly least stem borer damage in chlorantraniliprole18.5 EC @150 ml ha^{-1} treated plot over untreated check. Seni and Naik (2017) observed that Rynaxypyr 20 SC @ 30 g a.i ha^{-1} treated plot recorded significantly lower per-cent

Table 4. Effect of different insecticide modules on grain yield of rice

Modules*	Grain yield (qha^{-1})		Pooled
	Kharif, 2016	Kharif, 2017	
1	46.50	45.87	46.18
2	51.50	50.00	50.75
3	50.00	48.67	49.33
4	45.83	44.50	45.17
5	47.58	47.50	47.54
6	48.33	46.67	47.50
7	45.00	43.50	44.25
8	46.33	46.00	46.17
9	33.50	30.67	32.08
S.Em	0.43	0.67	0.40
CD (5%)	1.28	2.00	1.19

*Module details are given in table 1

of dead heart (0.42%) and white ear head (1.24%) and produced highest grain yield in comparison to other treatments. Application of granular insecticide, carbofuran 3G @ 20 kg ha^{-1} was found very effective in maintaining the yellow stem borer population below the economic threshold level and gave the highest grain yield (Singh *et al*.,1995; Kaul and Bhagat, 1997; Rath, 2013). Similarly, application of carbofuran @ 1.0 kg a.i ha^{-1} on 25 days after transplanting was quite effective against gall midge (Samalo *et al*., 1983). Harinkhere *et al*. (1993) showed that application of carbofuran granules at planting and at 30 days after transplanting @ 1.0 kg a.i ha^{-1} was the most effective treatment for controlling gall midge. Mardi *et al.* (2009) also studied the efficacy of some insecticide against the gall midge incidence and found lowest incidence of rice gall midge in the plots treated with Carbofuran 3G followed by Chloropyriphos 40EC and Phorate 10G.

It is observed that among different insecticide modules, module with Pymetrozine 50 WG @ 150 g a.i ha^{-1} was superior in efficacy against plant hoppers during both the years. Kirankumar (2016) and Seni and Naik (2017) also reported the effectiveness of Pymetrozine 50 WG @ 300 g ha^{-1} against brown plant hoppers. Among different insecticide treatments, maximum spider population was present in module with Azadirachtin 0.03 EC @ 8 g a.i ha^{-1} treated plot followed by other treatments. The present findings are in conformity with Kadam *et al*. (2005) who reported that the maximum number of spider populations was present in the plot treated with neem oil spray and NSKE. Seni and Naik (2017) found that Pymetrozine 50 WG @ 150 g a.i ha^{-1} and Buprofezin 25 SC @ 250 g a.i ha^{-1} treated plots had more number of spiders than other chemical treated plots and were safe for spiders. Tanaka *et al. (*2000) observed that imidacloprid was toxic to predatory spiders and mirid bugs in rice ecosystem. Our studies also revealed that neonicotinoid group of insecticides applied plots had less spiders in comparison to other plots. Although carbofuran has some toxic effect on spiders (Park and Lee, 2009) its application in the early date did not affect the spider population built up, as spider colonize actively in late vegetative stage of rice plant. Jafar *et al*. (2013) also reported that insecticides *viz*., chlorantraniliprole 18.5 SC at 30 g a.i ha^{-1}, cartap hydrochloride 50 SP at 500 g a.i ha^{-1} and fipronil 5 SC @ 625 ml ha^{-1} were found to be safe to natural enemies in the rice ecosystem. So, the adoption of the module (application of carbofuran 3G @ 1 kg a.i ha^{-1} at 20 days after transplanting followed by spraying of Rynaxypyr 20 SC @ 30 g a.i ha^{-1} at 45 days after transplanting and Pymetrozine 50 WG @ 300 g ha^{-1} at 65 days after transplanting) helps the farmers from indiscriminate spraying of insecticides and also remains safe to predators. So, the selection of insecticides which are target specific and harmless to natural enemies are very important as it will increase the effectiveness of natural control and maintains environmental health.

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Treatment of coconut palm wood using inorganic preservatives

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ABSTRACT: Freshly felled coconut wood is very much susceptible to wood boring insects, moulds and stain fungi as it has high levels of sugar, starch and moisture content throughout the trunk. The objective of this study was to develop appropriate preservative methods to protect sawn coconut palm wood from insects and other pathogens under the prevailing eco-climatic conditions in Kerala and to evaluate the effect of different preservative factors on the treatability of coconut wood. Wood samples were treated with inorganic chemicals like Copper Chrome Boron - CCB and Borax Boric Acid – BBA by diffusion and pressure treatment, of which pressure treatment performed better. Diffusion treatment of inorganic preservatives in high and medium density wood showed no significant difference in retention whereas significant difference was observed for penetration percentage. For pressure treatment, retention and penetration were significant in high density wood whereas medium density wood showed only significant retention. Solution concentrations and overall retention and penetration percentage were found to be significantly related. The study found that sawn coconut wood samples could be effectively treated with preservatives complying with the prescribed retention and penetration percentages as per the different standards and therefore, could be used as a potential substitute for conventional timbers and the insect damage was negligible. No incidence of insects, particularly termites and pin hole borers was observed during the graveyard studies.

KEY WORDS: Sawn coconut wood, diffusion, pressure treatment, preservatives, insects

INTRODUCTION

The coconut palm (*Cocos nucifera* L.) is found along the coastal and inlands regions of almost all tropical countries. The uses of coconut palms are almost limitless as it provides food, drink and shelter and raw material to a number of industries (Menon and Pandalai, 1958; Oduor and Githiomi, 2006; Djokoto, 2013). It is one of the world's most versatile and economically important palms (Moore, 1948; Subramanian, 2003). All the plant parts are used, on account of which, the palm has been regarded as *Kalapavriksham* or Tree of Life or Tree of heaven, a gift from nature to man (ENVIS, 2014). India is one of the largest producers of coconut which comprises 31 per cent of production and 17.6 per cent of the planted area (APCC, 2014). The bulk of country's plantation is concentrated in

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southern states. Kerala has 20.8 per cent of the total geographical area under coconut and accounts for 33 per cent of total coconut plantation in India (GOK, 2015).

Coconut exhibits no secondary growth but, the lateral increase of trunk is due to the multiplication of cells and enlargement of parenchymatic cells and vascular bundles (Killmann, 1993). The unique anatomical features of the coconut wood results in high variation in physical and mechanical properties. Based on density, coconut stem has three distinct zones such as the dermal zone, sub-dermal zone and core region and there is a decrease in the density of wood from the outer to inner as well as base to top portions of coconut (Killmann and Fink, 1996; Fathi, 2014). Density plays a significant role in determining the end use of coconut palm wood (Mead, 2001). Coconut wood has little resistance to wood degrading organisms including insects when it is exposed to the weather, particularly on ground contact. Freshly sawn coconut wood is extremely susceptible to the attack of termites and pin hole borers apart from sap stain fungi.

Seasoning is the first step in the efficient utilization of the timbers, especially in tropical countries. Protection against the ambrosia beetles could be secured after kiln seasoning of coconut wood (George, 1985). The efficacy of preservative treatment depends on the proper choice of preservative chemicals and the treatment process, which ensures the required absorption and penetration of the preservative. Seasoning prior to preservation makes preservative treatment easy and effective. Seasoning and preservation should be regarded as an integral part of timber utilization (ISI, 2001). The coconut trunk remained under-utilized due to its highly perishable nature.

The present study is an attempt to standardize the preservation technologies of coconut wood to increase the durability of coconut wood products with protection from insects and other organisms. The knowledge developed can be used for the industrial production of preserved timbers or manufacturing of products from treated wood. Increased utilization of coconut wood can reduce the dependency on forests or conventional plantation grown timber and can pave the way for an additional source of income to coconut farmers. Effect of various factors on the treatability of coconut wood as well as variation in retention and penetration in different parts of coconut wood were the objectives of this study.

MATERIALS AND METHODS

Coconut palms (*Cocos nucifera* L.) of age group (30-40 years) of "West Coast Tall" (WCT) variety grown in Thrissur district of Central Kerala (between N 10° 11' 8.16" and N 10° 41' 2.76" latitude; E 75° 58' 2.64" and E 76° 53' 29.04" longitude), was used for the study. Experiments were conducted in the Department of Wood Science, College of Forestry, Kerala Agricultural University, Vellanikkara, Thrissur district, India during 2015 – 2017. Wood was taken from 30 cm above the ground till 4 meters from the top of the palm. Palm trunk was converted into 2 meter logs after cross cutting with the help of a power saw and transported to a saw mill for sawing (Killmann and Fink, 1996). Coconut logs were converted to scantlings of 5 cm x 5 cm cross section and 50 cm length for further analysis Prophylactic surface treatment was carried out with Borax - Boric Acid (BBA) solution in the ratio of 1: 1.5 (parts per weight) in water at 3 per cent concentration level by dipping and samples were then air dried under shade.

For estimating moisture content, three sticks were taken from each stack randomly and small clear specimens of 2 cm× 2cm× 2.5 cm dimensions were made according to IS: 1708- - 1986. The samples were weighed with an accuracy of 0.001 in a weighing balance and dried in a hot air oven at a temperature of 103°± 2°c till constant weight. From the initial and final weight (oven dry weight), moisture content of each specimen was calculated.

Coconut wood samples were sorted into different grades such as low, medium and high density. A pilodyn was used to classify the samples into high and medium density wood materials (Schulte, 1991). Pilodyn is a handy tool weighing about 1 kg which

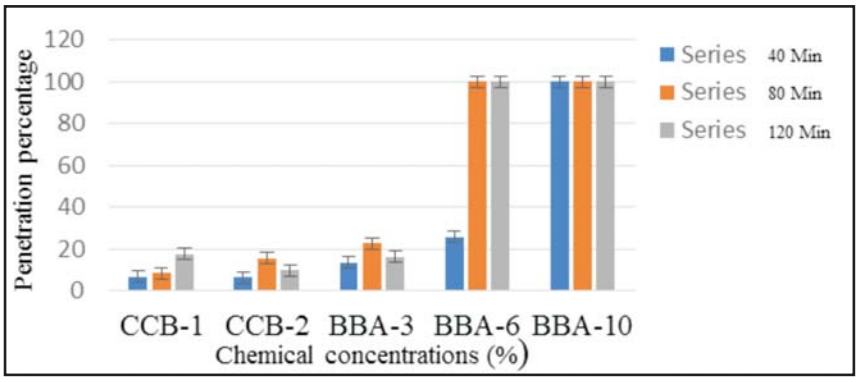

Fig. 1. Variation in DSR with respect to the duration of diffusion treatment in HDW

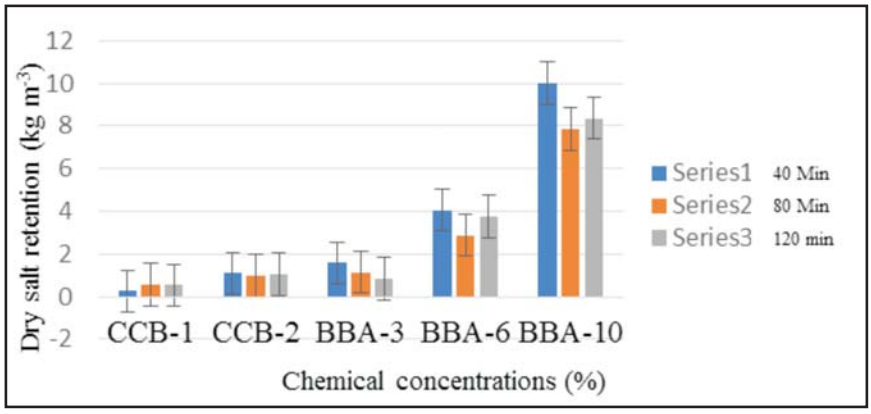

Fig. 2. Variation in penetration percentage with respect to the duration of diffusion treatment in HDW

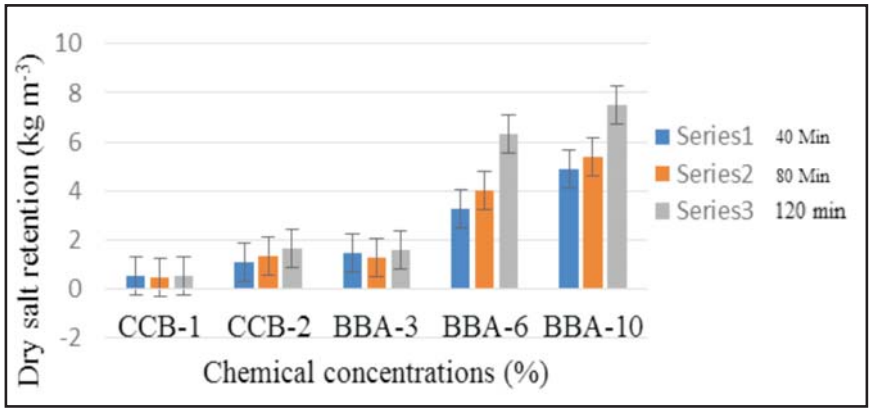

Fig. 3. Variation in DSR (kg m^{-3}) with respect to the duration of diffusion treatment in MDW

can be used for indirect non- destructive assessment of basic density of logs as well as standing trees. The pilodyn drives a steel pin which is driven into the wood by releasing a spring with a predetermined energy and the penetration (referred as pin penetration depth - PPD) is indicated on the instrument. The scale of PPD ranges from 0-40. The depth of penetration is inversely related to the density of the timber and in turn with its modulus of elasticity (MoE) and modulus of rupture (MoR). In

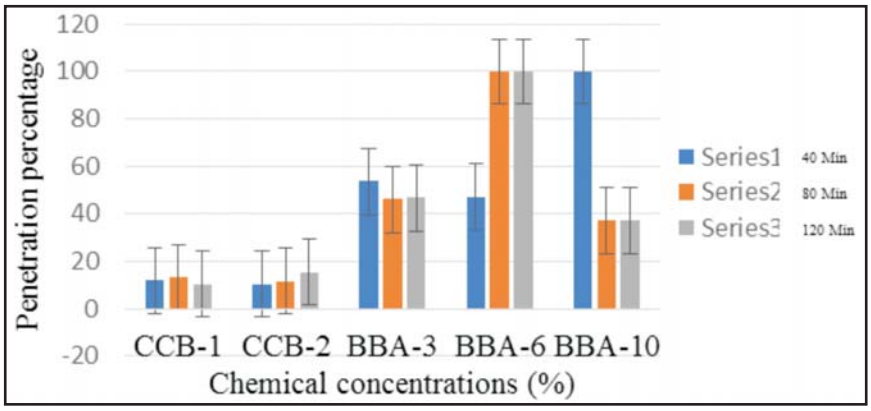

Fig. 4. Variation in penetration percentage with respect to the duration of diffusion treatment in MDW

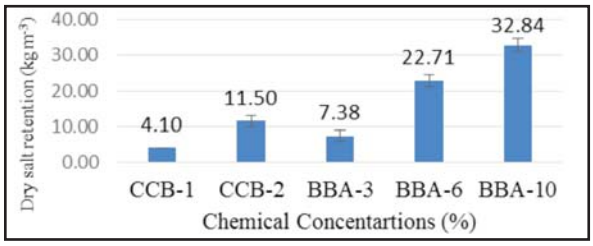

Fig. 5. Variation in DSR with concentration at constant pressure in HDW

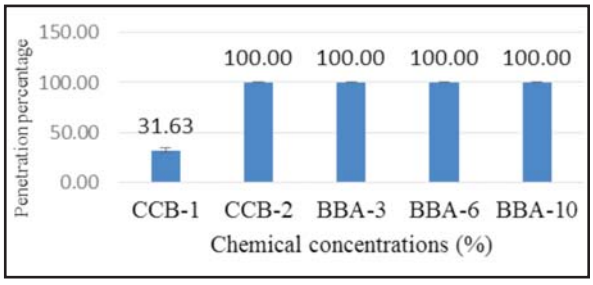

Fig. 6. Variation in penetration percentage with concentration at constant pressure in HDW

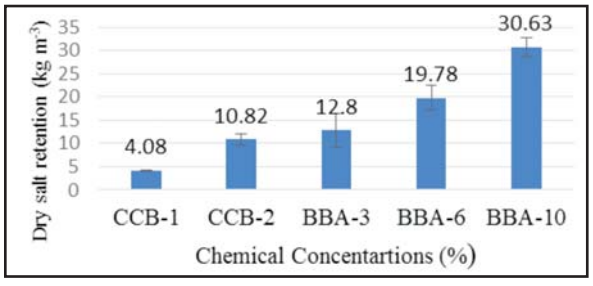

Fig. 7. Variation in DSR with concentration at constant pressure in MDW

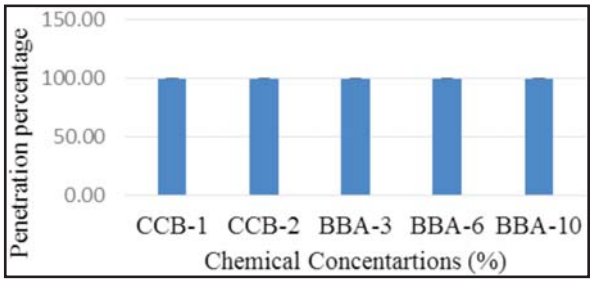

Fig. 8. Variation in penetration percentage with concentration at constant pressure in MDW

the present study, pilodyn (FUJI TECK, Tokyo, Japan) with 6 Joules and 2.5 mm pin diameter was used for taking measurements. The readings were taken at the middle point of each samples and grouped into high and medium density wood on the basis of PPD. All the samples that showed 20 PPD were sorted as high density wood and the readings between 20 to 28 PPD were graded as medium density wood. The samples having reading above 28 PPD were regarded as low density material which as such could not be used for structural purpose and were hence discarded.

Partially dried wood samples of two density (high and medium) classes were treated with inorganic preservatives - copper chrome boron (CCB) and borax – boric acid (BBA) at various concentrations. CCB was prepared by mixing Copper sulphate, Sodium dichromate and Boric acid in the ratio of 3:4:1.5 (parts per weight) respectively (ISI, 1986).

Two levels of concentration (1 and 2 per cent) were used in the investigation. BBA was prepared by mixing boric acid and borax in the ratio of 1: 1.5 (parts per weight) in water. Three levels of concentration (3, 6 and 10 per cent) were used in the investigation (Gnanaharan and Dhamodaran, 1989).

The treatment methods adopted for the impregnation of chemical into the wood were diffusion and pressure treatment. Duration of diffusion treatment was taken as 40, 80 and 120 minutes respectively. Pressure treatment plant located at the KFRI Substation, Palappally, Thrissur was used and Bethel's full cell process was employed. (Vacuum at 15 inch Hg for 10 minutes and pressure was maintained at 10 kg/cm2 for 30 minutes).

After treatment, the evaluation of treatment methods and chemicals were studied by different parameters like, dry salt retention (DSR), penetration depth, diffusion storage period and leaching factor. Treated samples were removed from the tank and excess liquid was drained off for 30 minutes and wrapped in polyethylene sheets for more penetration of chemicals into the wood. 374 samples were analysed and the effect of various diffusion periods on retention and penetration were analysed using two-way ANOVA. Effect of solution concentration at constant pressure was evaluated through one way ANOVA and LSD was used to compare the significance of means.

RESULTS

The effect of factors like chemical concentration, diffusion period and pressure on the treatability of coconut wood was evaluated in this study. Variation in dry salt retention and penetration percentage were compared with the recommended standards to assess potential utilities of the treatments for coconut wood. The major objective of the present investigation was to develop appropriate preservative treatment methods with inorganic chemicals (CCB and BBA) which might help to enhance the service life of coconut wood and protection from wood damaging insects and other organisms. Penetration depth of chemicals in wood is affected by many factors. Apart from solution concentration and diffusion period, moisture content in the wood, density of the material, temperature etc. also affect the penetration depth (Archer, 1991; Williams, 1991).

Diffusion Treatment

In High Density Wood (HDW), variation penetration percentage of individual samples did not follow any uniform pattern (Fig. 1). Dry salt retention with respect to the duration of diffusion treatment also did not follow any particular pattern (Fig. 2). The chemical concentration was directly proportional to the DSR. The value of DSR ranged from 0.82 kg $m^{-3}$to 10.76 kg m^{-3} for BBA and from 0.25 kg $m^{-3}$to 1.09 kg m^{-3} for CCB. For BBA, complete penetration was achieved at 10 per cent and lowest value for penetration was observed as 13.67 per cent at 3 per cent concentration ·The penetration percentage of CCB ranged from 6.53 per cent to 17.37 per cent. The achieved DSR was above 10 kgm^{-3} and the retention was achieved at 6 per cent concentration of BBA.

For Medium Density Wood (MDW), analysis of means depicted that with an increase in diffusion period, the chemical retention increased in the wood samples. DSR increased with increasing chemical concentrations for the same duration (Fig. 3). But the individual factors such as chemical concentrations and duration were significant. Chemical strength and interaction between chemical strength and duration were found to be significant for penetration percentage. No significant differences were observed between durations. The values for DSR ranged from 0.44 to 7.49 kgm^{-3} (Fig. 4).

Pressure Treatment

In the case of HDW, increase in chemical concentration of BBA and CCB was directly proportional to DSR (Fig. 5). All the chemical concentrations obtained complete penetration except at one per cent of CCB (Fig. 6). The value of DSR ranged from 5.27 to 35.18 kgm^{-3} for BBA and from 4.03 to 13.23 kg m^{-3} for CCB. Pressure

treatment showed complete penetration of chemicals except CCB at 1 per cent concentration. Chemical concentration was the factor considered in the analysis of DSR and penetration percentage in MDW (Fig. 7 and 8).

DISCUSSION

Diffusion of high and medium density wood showed significant difference for penetration percentage but no differences in retention. In pressure treatment, retention and penetration was significant in HDW, but MDW showed significant difference only in retention. Pressure treatment achieved complete penetration for all solution concentration of the chemicals used. Diffusion treatment of CCB obtained low retention compared to BBA. Only through the application of pressure, CCB attained the recommended retention suggested in the standards. Relation of diffusion period and retention in HDW showed no uniform pattern and followed increasing trend in MDW. Penetration depth followed an increasing pattern with respect to the increasing treatment duration in the two density classes. Low retention and penetration for CCB was achieved for both density classes through diffusion treatment. At 3 per cent BBA, retention achieved was 7.38 kgm^{-3} through pressure treatment which could be achieved through diffusion treatment using BBA at 10 per cent. As far as small scale preservation or furniture unit is concerned, desired retention could be achieved through diffusion treatment and the costs for the expensive pressure plant can be offset by an increase in solution concentration in both HDW and MDW. From the industrial point of view, pressure treatment is superior to diffusion treatment for both density classes. In the case of CCB, the desired retention was achieved at 2 per cent concentration and higher retention was needed for the use of coconut wood in external condition in contact with ground. Increasing concentration of solution or pressure applied can help to achieve higher retention of CCB. In general, the natural durability of coconut ranges from 6 months to 2 years and it needs significant up gradation to meet the requirements. No incidence of insects, particularly termites and pin hole borers was observed during the graveyard studies being undertaken in continuation of the present study to evaluate the effectiveness of the preservatives. Adequate intervention through preservation which was standardised through this study can expand the service life of coconut wood and thereby augment the supply of durable timbers with lesser durable timbers.

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Evaluation of the acaropathogen, *Acremonium zeylanicum* (Petch) Gams and Evans against *Tetranychus truncatus* Ehara (Prostigata:Tetranychidae) on cucumber under protected cultivation

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ABSTRACT: The efficacy of two concentrations of *Acremonium zeylanicum* (Petch), two acaricide molecules *viz*., spiromesifen and diafenthiuron and two botanicals *viz*., neem oil and azadirachtin against *Tetranychus truncatus* (Ehara) on cucumber in polyhouse was evaluated. The results revealed that fourteen days after treatment, *A. zeylanicum* significantly reduced mite population to the tune of 55.03 to 58.98 per cent at 1×10^8 spores ml^{-1} and 72.71 to 74.51 per cent at 1×10^9 spores ml^{-1}. However its efficacy was not comparable with that of the acaricides and botanicals which recorded significantly higher percent reduction in mite population.

KEY WORDS: *Mite*, acaropathogen, acaricide, cucumber

INTRODUCTION

Cucumber (*Cucumis sativus* L.) is a popular vegetable crop grown in polyhouses in Kerala. Under polyhouse, cucumber is prone to attack by a number of insect and non-insect pests. Among the non-insect pests, spider mites of the family Tetranychidae, are considered as serious pests. A study on the diversity of mite pests associated with vegetable crops grown in polyhouses of Thrissur district, Kerala, identified *Tetranychus truncatus* Ehara (Prostigata:Tetranychidae) as the predominant species of spider mite (Lenin *et al*., 2015). Farmers depend solely on acaricide molecules for mite management in polyhouses, which can lead to development of resistance in mites to acaricides, in addition to probable health hazards. Hence, there is an increasing interest in natural pesticides which are derived from plants and microorganisms, since they are perceived to be safer than the synthetic chemicals. Recently, an acaropathogen, *Acremonium zeylanicum* was isolated from *Tetranychus urticae* Koch infesting brinjal grown under protected cultivation in Thrissur district by All India Network Project on Agricultural Acarology (AINPAA), where it was observed to cause significant mortality to the spider mite (Krishna *et al*., 2014). Bioefficacy studies conducted earlier in the laboratory against *T. truncatus* had shown that *A. zeylanicum* significantly reduced the mite count at concentrations of 1×10^8 and 1×10^9 spores ml^{-1},

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indicating that the local isolate of *A. zeylanicum* can be a potential candidate in biological control of spider mites on vegetable crops (Sherief *et al*., 2017). With this background, the present study was conducted to evaluate the efficacy of *A. zeylanicum* against *T. truncatus* on cucumber in polyhouse.

MATERIAL AND METHODS

An experiment was conducted in the polyhouse of All India Network Project on Agricultural Acarology (AINPAA), College of Horticulture, Kerala Agricultural University from March to May, 2017 to evaluate the efficacy of *A. zeylanicum* against *T. truncatus* on cucumber (variety Sania). The experiment was laid out in Completely Randomized Design with seven treatments and three replications. The treatments evaluated included *A. zeylanicum* at two different concentrations *viz*., 1 × 10^7 spores ml^{-1} and 1 × 10^8 spores ml^{-1}; two novel acaricides *viz*., spiromesifen (100g ai ha^{-1}) and diafenthiuron (400g ai ha^{-1}); two botanicals, neem oil (2%) and azadirachtin (0.005%) along with an untreated control.The crop was raised in the polyhouse as per the Package of Practices Recommendations of Kerala Agricultural University, 2016 at a spacing of 60×30 cm in plots of 1.6 m × 1.3 m size. Mites from the laboratory culture of AINPAA, maintained on mulberry leaves were released on three leaves of twenty five days old cucumber plants at the rate of 20 active mites/leaf by stapling mite infested mulberry leaf bits of 5 cm^2size on top, middle and bottom leaves of cucumber plant.

Treatments were imposed three weeks after the release of mites. Spray solution was prepared by thorough mixing of measured quantity of different treatments and required amount of water to form a uniform suspension. The treatments were applied using a hand sprayer. A control treatment was maintained with water spray. Observations were recorded on the count of eggs and active stages of *T. truncatus in situ* from three windows of 1 cm^2 each from three leaves per plant representing the top, middle and bottom canopy using a hand lens of 10 X magnification.The population counts were recorded one day before spraying and 1, 3, 7, 10 and 14 days after spraying. To confirm the results, the experiment was repeated on the same crop. However, the population of *T. truncatus* was found to be negligible in all treatments except control, hence a second release of the mite was made two weeks after the release, and the same treatments were imposed. Observations were recorded in a similar manner. The data were statistically analysed using analysis of variance technique (ANOVA) considering population counts prior to the first application.

RESULTS

Efficacy of treatments - First experiment:

The mean mite counts before the application of treatments ranged from 18.05 to 20.80 per cm^2 leaf area (Table 1). The data indicated that *A. zeylanicum* significantly reduced the mite count over untreated control at both the concentrations evaluated. At 1×10^7 spores ml^{-1} in the acaropathogen treated leaves the mite count was 15.30, 10.67, 8.85, 11.25 and 9.09 per cm^2 leaf area after 1, 3, 7, 10 and 14 days of treatment, respectively as compared to the pre-treatment mite count of 19.68 per cm^2 leaf area. *A. zeylanicum* at the concentration of 1×10^8 spores ml^{-1} was more effective on *T. truncatus* than the concentration 1×10^7 spores ml^{-1} in which, the population was 10.81, 8.70, 5.08, 7.35 and 7.14 per cm^2 leaf area after 1, 3, 7, 10 and 14 days of spray, respectively as compared to pre-treatment mite population of 18.62 per cm^2 leaf area. However, the acaricides and botanicals caused significantly higher reduction in mite count compared to *A. zeylanicum*. On Spiromesifen treated plants the mite count was 4.97, 1.38, 0.92, 0.68 and 0.46per cm^2 leaf area after 1, 3, 7, 10 and 14 days of spray, respectively. On Diafenthiuron treated plants 5.08, 1.97, 1.07, 0.85 and 0.57 mites per cm^2 leaf area were recorded after 1, 3, 7, 10 and 14 days of spray, respectively as compared to the pre-treatment mite count of 18.29 per cm^2 leaf area, and was on par with spiromesifen. Plants treated with neem oil had mite population of 8.29, 3.46, 2.05, 2.38 and 3.33 per cm^2 leaf area while those treated with azadirachtin had 8.78, 4.15, 2.95, 3.62 and 4.03 per

Table 1. Effect of *Acremonium zeylanicum* in comparison to acaricides and botanicals on *Tetranychus truncatus* infesting cucumber in polyhouse- experiment 1

Sl. No.	Treatments	Pre-treatment count	Mean no. of mite/cm² leaf area			Per cent reduction after 7 days	Mean no. of mite/cm² leaf area		Per cent reduction i after 14 days
			1 DAS	3 DAS	7 DAS		10 DAS	14 DAS	
1	*Acremonium zeylanicum* 1×10^7 spores ml^{-1}	19.68	15.30 [b] (15.31)	10.67[b] (10.69)	8.85 [b] (8.80)	55.03	11.25[b] (11.26)	9.09 [b] (9.13)	53.81
2	*Acremonium zeylanicum* 1×10^8 spores ml^{-1}	18.62	10.81[c] (10.80)	8.70 [c] (8.69)	5.08 [c] (5.10)	72.71	7.35 [c] (7.34)	7.14 [c] (7.12)	61.65
3	Spiromesifen 100g ai ha^{-1}	18.50	4.97 [e] (4.95)	1.38 [f] (1.36)	0.92 [e] (0.94)	95.02	0.68 [f] (0.66)	0.46 [e] (0.43)	97.51
4	Diafenthiuron 400g ai ha^{-1}	18.29	5.08 [e] (5.06)	1.97 [f] (1.94)	1.07 [e] (1.10)	94.14	0.85 [ef] (0.84)	0.57 [e] (0.52)	96.88
5	Neem oil 2 %	18.05	8.29 [d] (8.27)	3.46 [e] (3.42)	2.05 [de] (2.09)	88.64	2.38 [de] (2.36)	3.33 [d] (3.27)	81.55
6	Azadirachtin 0.005 %	18.68	8.78 [d] (8.77)	4.15 [d] (4.14)	2.95 [d] (2.96)	84.20	3.62 [d] (3.61)	4.03 [d] (4.01)	78.42
7	Control	20.80	22.39 [a] (22.42)	29.33[a] (29.39)	34.77[a] (34.67)	-	30.03 [a] (30.06)	30.03[a] (30.14)	-

DAS = Days after spraying. Means followed by same letters do not differ significantly by DMRT (p = 0.05), Values in the parentheses are adjusted treatment means.

cm^2 leaf area, respectively after 1, 3, 7, 10 and 14 days and were on par with each other. Plants in control plots had mite population of 20.80, 22.39, 34.77, 30.03 and 30.03per cm^2 leaf area after 1, 3, 7, 10 and 14 days of spray, respectively.

Seven days after treatment, *A. zeylanicum* reduced mite population by 72.71 and 55.03 per cent at concentrations of 1×10^8 spores $ml^{-1}$and 1×10^7 spores ml^{-1} respectively. However, spiromesifen caused the highest per cent reduction in the mite population (95.02%) closely followed by diafenthiuron (94.14%), neem oil (88.64 %) and azadirachtin (84.20%). Fourteen days after treatment, spiromesifen, difenthiuron, neem oil and azadirachtin reduced the mite numbers by 97.51,96.88, 81.55 and 78.42 per cent respectively, while on the acaropathogen, *A. zeylanicum* treated plants 61.65 and 53.81 per cent reduction in mite numbers at concentration of 1×10^8 spores ml^{-1} and 1×10^7 spores ml^{-1} respectively was observed.

Efficacy of treatments - Second experiment:

The mean mite count, before imposing second spray in different plots ranged from 17.16 to 19.29 per cm^2 leaf area (Table 2). The results showed a similar trend in the second experiment also, *A. zeylanicum* significantly reduced mite count on cucumber over control. On 1×10^7 spores ml^{-1} treated plants 13.41, 10.46, 7.71, 9.63 and 8.37 mites per cm^2 leaf area were recorded after 1, 3, 7, 10 and 14 days of treatment, respectively as against the pre-treatment mite population of 18.80 per cm^2 leaf area. On 1×10^8spores ml^{-1} treated plants the mite population was 10.10, 7.82, 4.73, 5.42 and 6.34 mites per cm^2 leaf area, after 1, 3, 7, 10 and 14 days of treatment, respectively as compared to pre-treatment mite population of 18.56 per cm^2 leaf area. The acaricides spiromesifen and diafenthiuron caused significantly higher reduction in mite population followed by the botanicals neem oil and azadirachtin. On Spiromesifen treated plants 3.73,

Table 2. Effect of *Acremonium zeylanicum* in comparison to acaricides and botanicals on *Tetranychus truncatus* infesting cucumber in polyhouse- experiment 2

Sl. No.	Treatments	Pre-treatment count	Mean no. of mite/cm² leaf area			Per cent reduction after 7 days	Mean no. of mites/cm² leaf area		Per cent reduction after 14 days
			1 DAS	3 DAS	7 DAS		10 DAS	14 DAS	
1	*Acremonium zeylanicum* 1×10^7 spores ml^{-1}	18.80	13.41[b] (13.69)	10.46[b] (10.72)	7.71 [b] (7.79)	58.98	9.63 [b] (9.53)	8.37 [b] (8.41)	55.47
2	*Acremonium zeylanicum* 1×10^8 spores ml^{-1}	18.56	10.10 [c] (10.26)	7.82 [c] (7.98)	4.73 [c] (4.77)	74.51	5.42 [c] (5.37)	6.34 [c] (6.36)	65.84
3	Spiromesifen 100g ai ha^{-1}	17.45	3.73 [e] (3.34)	1.94 [e] (1.57)	1.36 [e] (1.25)	92.20	0.85 [f] (0.97)	0.54 [f] (0.47)	96.90
4	Diafenthiuron 400g ai ha^{-1}	17.16	4.65 [e] (4.11)	2.12 [e] (1.61)	1.5 [e] (1.35)	91.25	0.93 [f] (1.104)	0.60 [f] (0.50)	96.50
5	Neem oil 2 %	18.28	7.87 [d] (7.89)	3.17 [de] (3.19)	2.21 [de] (2.21)	87.91	2.70 [e] (2.692)	3.24 [e] (3.24)	82.27
6	Azadirachtin 0.005 %	18.05	8.62 [d] (8.53)	4.27 [d] (4.18)	3.27 [d] (3.24)	81.88	3.73 [d] (3.76)	4.33 [d] (4.31)	76.01
7	Control	19.29	20.66 [a] (21.19)	27.6 [a] (28.10)	30.84 [a] (30.98)		27.33 [a] (27.16)	31.19[a] (31.28)	

DAS = Days after spraying. Means followed by same letters do not differ significantly (p = 0.05) Values in the parentheses are adjusted treatment means.

1.94, 1.36, 0.85 and 0.54 mites per cm^2 leaf area were recorded after 1, 3, 7, 10 and 14 days of spray, respectively as compared to pre-treatment mite population of 17.45 per cm^2 leaf area. The population of mites on cucumber plants, sprayed with diafenthiuron, was 4.65, 2.12, 1.50, 0.93 and 0.60 per cm^2 leaf area after 1, 3, 7, 10 and 14 days of spray respectively as compared to pre-treatment population of 17.16 per cm^2 leaf area. Mite population on the botanicals, neem oil and azadirachtin treated plants after 1, 3, 7, 10 and 14 days of spray was 7.87, 3.17, 2.21, 2.70 and 3.24 per cm^2 leaf area and 8.62, 4.27, 3.27, 3.73 and 4.33 per cm^2 leaf area, respectively. In control plots, the mite population increased of 19.29 per cm^2 leaf area to 31.19 during this period.

Seven days after treatment, spiromesifen significantly caused reduction in mite population (92.20%), closely followed by diafenthiuron (91.25%). The next best treatment was neem oil with a mean reduction in mite count of 87.91 per cent followed by azadirachtin (81.88%). The acaropathogen *A. zeylanicum* at 1×10^8 spores ml^{-1} reduced mite population by 74.51 per cent and at 1×10^7spores ml^{-1} by 58.98 per cent. Fourteen days after treatment, application of spiromesifen, diafenthiuron, neem oil and azadirachtin resulted in 96.90, 96.50, 82.27 and 76.01 per cent reduction in the mite population, respectively. The acaropathogen, *A. zeylanicum* at 1×10^8 spores ml^{-1} reduced the mite population by 65.84 per cent followed by 55.47 per cent at 1×10^7 spores ml^{-1}.

DISCUSSION

In the polyhouse, *A. zeylanicum* significantly reduced mite population on cucumber seven days after treatment at both the concentrations of 1×10^8 spores ml^{-1} and 1×10^7 spores ml^{-1}. The study clearly indicated the potential of *A. zeylanicum* in bringing down the population of the spider mite, *T. truncatus*. In the polyhouse, at the higher concentration of 1×10^8 spores ml^{-1} the acaropathogen could reduce the mite population by 72.71 and 74.51 per cent on seventh day in first and second experiments

respectively. At a lower dosage of 1×10^7spores ml^{-1} it brought about a reduction of 55.03 and 58.98 per cent in the mite population by seven days in the first and second experiment, respectively. Pathogenicity studies conducted earlier with several acaropathogens have indicated the potential to reduce mite numbers of the local isolates of pathogenic fungi. For instance, an entomopathogen, *Cladosporium cladosporioides* isolated from *T. urticae* on okra at Coimbatore caused 96.5 per cent mortality of mites when tested in the laboratory (Jeyarani *et al*., 2011). Similarly, local strain of *Hirsutella thompsoni,* when evaluated against *Oligonychus coffeae* in tea caused mortality of 65 per cent in laboratory (Amarasena *et al*., 2011).

A. zeylanicum isolated from sugarcane woolly aphid from northern Karnataka was evaluated for pathogenicity against important sucking pests of different crops in the laboratory at Dharwad. The fungus proved to be highly pathogenic to cabbage aphid (*Brevicoryne brassicae* Linn.), sorghum aphid (*Melanaphis sacchari* Zehnt.) and sugarcane wooly aphid (*Ceratovacuna lanigera* Zehnt.). However, it was relatively less pathogenic to chilli mite (*Polyphagotarsonemus latus* Banks) and brinjal spider mite (*Tetranychus neocaledonicus* Andre) (Divan and Mallapur, 2011). But in the present study, the fungus *A. zeylanicum* was found to be highly pathogenic to the spider mite *T. truncatus.*This might be because the fungal isolate evaluated in the present study was isolated from a mycosed spider mite and hence is highly adapted to the host and locality. Pena *et al*. (1996) found that fungal isolates originating from *Polyphagotarsonemus latus* Banks (Tarsonemidae) were more pathogenic to *P. latus* species than those isolated from other hosts.

In the present study, though the mite population significantly declined by seventh day, after application of *A. zeylanicum* in the polyhouse, there was an increase in population from seventh day to fourteenth day. In an earlier study with the acaropathogen, laboratory bioassay has indicated comparatively poor ovicidal action of *A. zeylanicum* against *T. truncatus* (Sherief *et al*., 2017). As a result, it could be that a considerable proportion of eggs in the population would have hatched during this period, leading to increase in population by fourteenth day in the polyhouse. The study showed that the efficacy of *A. zeylanicum* was not comparable with that of novel acaricides and botanicals. The new acaricide molecules, spiromesifen and diafenthiuron were effective and superior to the fungus in reducing the population of *T. truncatus*. Efficacy of these acaricides in reducing mite population was observed from the first day after spray application itself. In the present study spiromesifen caused 97.51 and 96.70 per cent reduction in mite population after 14 days, in first and second experiment, respectively. Baloch *et al*. (2016) also reported that spiromesifen resulted in significant reduction of 96.27 per cent in the population of *T. urticae* 15 days after treatment, on okra. Study on the efficacy of spiromesifen against *T. urticae* on ridge gourd showed that the molecule caused more than 90 per cent mortality (Reddy and Latha, 2013). Under field conditions, spiromesifen could result in complete suppression of population of *T. urticae* in ten days (Sato *et al*., 2011).

Diafenthiuron also caused significant reduction of 96.88 and 96.50 per cent in mite population, respectively, at fourteen days after treatment, in first and second experiments which was on par with spiromesifen. High efficacy of diafenthiuron in suppressing population of spider mite in different crops was earlier reported by several workers (Patil, 2005; Bhaskaran *et al*., 2007, Aswin *et al*., 2015). Among the botanicals evaluated, neem oil (81.55% and 82.27%) and azadirachtin (78.42% and 76.01%) recorded considerable reduction in mite population in the first and second experiment. This was in accordance with the observation of Krishna and Bhaskar (2016) who reported that two per neem oil cent caused 81.15 per cent reduction in population of *T. urticae* on okra. Kumar (2007) observed that neem oil two per cent was effective in managing mite population on rose cultivated under polyhouse condition. Acaricidal property of azadirachtin was reported by Bernandi *et al*. (2012) who recorded 94 to 100 per cent reduction in the population of *T. urticae* on strawberry. The results clearly indicate that *A. zeylanicum* has potential in suppressing mite

population and it can be suggested as an ideal candidate for incorporation in integrated mite management programme in crops, however its safety to humans and beneficial organisms need to be established.

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Management of rice weevil, *Sitophilus oryzae* using essential volatile oils

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ABSTRACT: Effect of four essential volatile oils *viz*., clove (*Syzygium aromaticum* L.), cinnamon (*Cinnamomum zeylanicum* Blume), lemon grass (*Cymbopogon flexuosus* (Nees *ex* steud)) and pepper (*Piper nigrum* L.) on mortality of rice weevil, *Sitophilus oryzae* L. in stored rice was studied under laboratory conditions. Preliminary toxicity bioassays (without food and with food) were carried for fixing the concentrations of these oils. Percentage mortality of weevils by volatile essential oils increased with increase in concentration and period of exposure. Pepper oil @ 200 µl/500 cm^{-3} volume caused cent per cent mortality without any progeny emergence whereas cinnamon oil @ 30 µl 500 cm^{-3} caused 95.55 per cent mortality of weevils with 98.81 inhibitions on progeny emergence. The highest concentration (30 µl 500 cm^{-3}) of clove oil caused 76.67 percentage mortality of weevils while lemon grass oil (200 µl 500 cm^{-3}) caused 68.89 percentage mortality.

KEY WORDS: Essential volatile oils, rice weevil, *Sitophilus oryzae*

Stored product insects cause 3 to 18 per cent postharvest loss in rice during storage which is relation to the area and period of storage (Tagola *et al.,* 2013). There were 1,663 insect species are reported as pest of stored food commodities, among which few insects were known for its greater damage ability and well distribution all over the world. Their presence was reported from grain elevators, mills and retailers (Hagstrum and Phillips, 2017). Pest infestation contributes to contamination in food products through the presence of dead and live insects, excretions and body fragments. Both whole and milled rice are severely attacked by insect pests belongs to Coleoptera and Lepidoptera. Beetles are highly diversified and cause huge destruction of stored grain when compared with that of moth (Upadhyay and Ahmad, 2011). The increased awareness on the deleterious effect of chemical insecticides and the demand for insecticide free food has prompted the development of safer alternative management option. The use of botanicals offers an alternative management strategy against stored grain insect pests. Essential oils from plant parts exhibit contact, fumigant, repellent and antifeedant actions to several coleopteran insect pests infesting stored products. Fumigant action of volatile oils are due to the presence of monoterpenes (Koul *et al.,* 2008). In

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this context, four volatile essential oils such as clove oil (*Syzygium aromaticum* L.), lemon grass oil (*Cymbopogon flexuosus* (Nees *ex* steud)), cinnamon oil (*Cinnamomum zeylanicum* Blume) and pepper oil (*Piper nigrum* L.) were selected to assess their toxicity against rice weevil, *S. oryzae* in stored rice.

Initial culture of rice weevil was obtained from survey conducted in public provision stores, Thiruvananthapuram Kerala. Twenty pairs of rice weevil adults were released into plastic jars of one litre capacity containing 250 g grains. The jars were covered with plastic lids provided with 10 to 15 pin holes to avoid moisture build up and fungal growth. The mated females were allowed to oviposit on the grains for a period of two weeks and thereafter the adults were removed from the grains. Such jars were maintained to get sufficient number of beetles for the conduct of the experiments. Damaged grains were replaced at regular intervals. The culture was maintained in the laboratory conditions of temperature 24 to 32^{0}C and relative humidity 73 to 92 per cent.

Toxicity of volatile essential oils on *S. oryzea* was studied by dosage mortality bioassays. A plastic jar of 500 ml capacity (11 cm height and 7.5 cm diameter) was used for the experiment. Initially two bioassays (without food and with food) were conducted with different concentrations to fix the final concentrations of essential volatile oils. Clove oil at 20, 25 and 30 µl, cinnamon oil at 20, 25 and 30 µl, lemon grass oil at 125, 150 and 200 µl and pepper oil at 125, 150 and 200 µl with three replications were tested against rice weevil. Observations on mortality were recorded at 2nd, 4th, 6th, 8th and 10th day after treatment. Percentage mortality in all treatments was corrected for control mortality by Abbott's formula (Abbott, 1925).

$$\text{Corrected per cent mortality} = \frac{(Tm - Cm)x100}{(100 - Cm)}$$

Tm – Per cent mortality in treatment and Cm – Per cent mortality in control

Emerged adults were counted after 55th day of treatment and recorded. Progeny emergence inhibition was calculated using the formula,

$$\text{Progeny emergence inhibition (\%)} = \frac{(Cp - Tp)x100}{Cp}$$

Cp – Number of progenies emerged in control and Tp – Number of progenies emerged in treatment

Efficacy of volatile essential oils on *S. oryzae:* On comparing the different concentrations of essential oils at four days after treatment, weevil mortality correspondingly increased with increasing concentration. All the treatments were significantly superior to control. Complete mortality of weevils was recorded in pepper oil @ 200 µl 500 cm^{-3}. Treatment with cinnamon oil @ 30 µl 500 cm^{-3} (91.11) was statistically on par with pepper oil @ 150 µl 500 cm^{-3} (83.33). Significant difference was observed in percentage mortality of weevils at six days after treatment which ranged from 38.89 to 100.00. On sixth day, pepper oil @ 200 µl 500 cm^{-3} showed cent per cent mortality and it was followed by pepper oil @ 150 µl 500 cm^{-3} with percentage mortality 93.33. A similar trend was observed on tenth day after treatment (Table 1).

Percentage mortality of weevils by volatile essential oils increased with increase in concentration and period of exposure. On comparing percentage mortality of weevils, the highest concentration (30 µl 500 cm^{-3}) of cinnamon oil caused more than 90.00 percentage mortality than clove oil at same concentration. Higher concentration of pepper oil (200 µl 500 cm^{-3}) caused cent per cent mortality which was superior over same concentration of lemon grass oil. Pepper oil @ 200 µl 500 cm^{-3} caused complete inhibition of progeny emergence over control whereas clove oil @ 20 µl 500 cm^{-3} inhibited only 73.37 per cent progeny emergence which was noted as least effective in the control of rice weevil. Pepper oil regarded as highly toxic followed by cinnamon oil; while clove and lemon grass oils were reported to be moderately toxic. This finding was supported by the mortality data obtained in both bioassays, without food and with food. Khani *et al.* (2012) reported that essential oil from black pepper (*P. nigrum*) caused mortality in rice weevil. The highest mortality of weevils in without food condition

Table1. Effect of volatile essential oils on mortality and progeny emergence of rice weevil

Treatments (µl 500 cm^{-3})	Mortality (%) DAT				# Progeny inhibition
	4	6	8	10	55
Cinnamon oil 20	56.67 (48.84)^{de}	64.45 (53.41)^{ef}	70.00 (56.93)^{cd}	70.00 (56.93)^{bcd}	96.86
Cinnamon oil 25	63.33 (52.78)^{d}	69.99 (56.84)^{de}	72.22 (58.25)^{cd}	73.33 (59.02)^{bcd}	97.64
Cinnamon oil 30	91.11 (73.48)^{b}	92.22 (74.36)^{bc}	95.55 (79.85)^{ab}	95.55 (79.85)^{a}	98.81
Clove oil 20	32.22 (34.42)^{g}	38.89 (38.52)^{h}	43.33 (41.14)^{e}	44.44 (41.79)^{e}	73.37
Clove oil 25	40.00 (39.16)^{fg}	50.00 (44.98)^{fgh}	56.67 (48.93)^{de}	57.78 (49.58)^{de}	80.47
Clove oil 30	54.44 (47.65)^{def}	65.56 (54.79)^{e}	72.22 (59.03)^{cd}	76.67 (62.18)^{bc}	89.35
Lemon grass oil 125	35.55 (36.55)^{g}	45.55 (42.45)^{gh}	61.11 (51.45)^{de}	61.11 (51.45)^{de}	85.80
Lemon grass oil 150	38.89 (38.43)^{fg}	50.00 (45.00)^{fgh}	61.11 (51.49)^{de}	63.33 (52.78)^{cd}	91.12
Lemon grass oil 200	44.44 (41.72)^{efg}	57.78 (49.53)^{efg}	68.89 (56.29)^{cd}	68.89 (56.29)^{cd}	94.67
Pepper oil 125	78.89 (62.22)^{c}	82.22 (65.08)^{cd}	82.22 (65.08)^{c}	84.44 (66.79)^{b}	97.64
Pepper oil 150	83.33 (66.19)^{bc}	93.33 (77.54)^{b}	94.44 (78.69)^{b}	96.67 (81.34)^{a}	98.83
Pepper oil 200	100.00 (89.48)^{a}	100.00 (89.48)^{a}	100.00 (89.48)^{a}	100.00 (89.48)^{a}	100.00
Control	0.00 (0.52)^{h}	0.00 (0.52)^{i}	0.00 (0.52)^{f}	0.00 (0.52)^{f}	-
CD (0.05)	9.690	9.724	10.437	9.991	

DAT-Days after treatment Mean of 3 replications
Figures in parenthesis are angular transformed values; #Inhibition of progeny emergence (%)

may be due to the direct exposure of insect with oil which may interfere with respiratory system (Table 1).

In the present study, complete mortality of weevils with no progeny emergence were recorded in treatment with pepper oil at 200 µl 500 cm^{-3} within four days of exposure which were on par with pepper oil at 150 µl 500 cm^{-3} and cinnamon oil at 30 µl 500

cm^{-3} at 10 days after treatment. Results revealed that earlier death of beetles in pepper oil treatment may be due to the pungency. Khani *et al*, (2012) revealed that major component of pepper were piperine followed by oleic acid, linoleic acid, caryophyllene and limonene which may be the reason for mortality of test insects. Devi and Devi (2013) also reported potential lethal effect of pepper oil on rice weevil.

Treatment with cinnamon oil at concentration of 30 µl 500 cm^{-3} recorded a percentage mortality of 95.55 and less progeny emergence. This could be attributed to the possible insecticidal and ovicidal effect of cinnamon oil. These findings are in line with Lee *et al*. (2008), Ishii *et al.* (2010) and Kanda *et al*. (2017) who reported insecticidal and repellent activity of cinnamon oils due to the presence of benzaldehyde, cinnamonitrile, hydrocinnamyl acetate and á-terpineol. Properties like repellency, post ingestive toxicity, alteration in nutritional index and reduced relative growth rate were observed in cinnamon oil towards rice weevil (Stefanazzi *et al.*, 2011). Moderate mortality of lemon grass oil and clove oil were observed in this experiment. Insecticidal activity of clove oil was reported in a study conducted by Devi and Devi (2013). This concurs with Kerdchoechuen *et al*. (2010) and Saad *et al*. (2017) where they reported that clove bud oil containing eugenol (71.56 %) and eugenol

acetate (8.99 %) gave higher toxicity after 72 h of exposure. Among the four tested volatile oils, lemon grass showed lower initial mortality which were increased on increasing exposure period. It may be due to its slow toxicity release and activation of insecticidal property. These results agree well with findings of Jayaratne *et al.* (2001) and Saljoqi *et al*. (2006) who reported repellent and insecticidal activity in lemon grass oil.

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Effect of chemical seed protectants on quality parameters of red gram seed against. pulse beetle *Callosobruchus chinensis* L under ambient storage

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ABSTRACT: Among the insecticides tested as seed protectants against *Callosobruchus chinensis* under ambient condition for a period of nine months revealed that all seed protectants were significantly effective. Maximum germination was observed (86.67%) when seed treated with novaluron 10 EC @0.05ml/kg followed by emamectin benzoate 5 SG@40mg/kg (85.67 per cent). The vigour index was maximum in emamectin benzoate (1913.87) followed by novaluron.

KEYWORDS: seed, insecticides, pulse beetle, germination, vigour index

About 90% of the world production of pigeon pea is contributed by India occupying more than 10% of the total area under pulses. Total area under pigeon pea in India is about 3.6 million ha with annual production of 2.8 million tons and productivity of pigeon pea is about 753 kg/ ha respectively. (Anonymous, 2012-13). Among the various pulses, red gram or pigeon pea is an important crop both in respect of area as well as production. It is one of the important kharif crop. Pulses play an important role in Indian agriculture. Besides, they sustain the productivity of cropping system by fixing atmospheric nitrogen through biological process and improving soil fertility. In order to meet requirement of protein for increasing production, it is necessary to increase the production of pulses in India. In the post-harvest management of production, we have not been able to lower down its losses due to insect-pests infestation during storage (Jilani, 1984; Swaminathan, 1937). The insects causing damage to stored pulses are pulse beetle, *Callosobruchus chinensis*, khapra beetle, *Trogoderma gramarium* and lesser grain borer *Rhizopertha dominica*. Among these, the pulse beetle is most important infesting both in field as well as in storage, causing loss of nearly 10-90% (Rathore and Sharma, 2002; Mishra *et al*., 2007).

The bruchids (*Callosobruchus chinensis* L.) breed exclusively on pulses, having a very short life span with high degree of reproductive potential. The pest developed during storage and detached only when adult beetles comes out the year but its infestation is maximum from July is up to 50% losses. The

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maintenance of seed quality which is deteriorated by infestation of insect during ambient storage is managed by using various insecticide rapidly and effective method for destroying the life of bruchid in ambient stored of pigeon pea seed. The seeds can be protected from insect pests during storage by applying suitable insecticidal treatments (Patil *et al*., 2006; Booker, 1967). In view of above backgrounds, an attempt has been made to find out the most suitable and cheapest insecticide for seed treatment for maintaining seed quality during ambient storage condition.

In order to assess the effects of insecticides as seed protectants against quality parameters of seed, the test seed of the cultivar NDA-1 was obtained from the seed processing unit of Narendra Deva University of Agriculture and Technology, Kumarganj and Krishi Vigyan Kendra Masaudha, Faizabad. The total amount of obtained seed was first fumigated with aluminium phosphide (3g) and treated as @3 tab / t in airtight containers and disinfested before starting the experiment. There were total nine treatments with three replications for each. The amount of seed was 1 kg, taken under each replication. The treatments used were as follows:

Sl. No.	Seed protectants		Rate (Per kg of seed)
	Trade name	Common name	
1.	Proclaim (5 SG)	Emamectin benzoate	2 ppm (40.0 mg)
2.	Tracer (45 SC)	Spinosad	2 ppm (4.4 mg)
3.	Avaunt (14.5 SC)	Indoxacarb	2 ppm (13.8 mg)
4.	Coragen (20 SC)	Rynaxypyr	2 ppm (0.01 ml)
5.	Intrepid (10 EC)	Chlorfenapyr	2 ppm (0.02 ml)
6.	Curacron (50 EC)	Profenofos	2 ppm (0.004 ml)
7.	Rimon (10 EC)	Novaluron	5 ppm (0.05 ml)
8.	Decis (2.8 EC)	Deltamethrin	1 ppm (0.04 ml)
9.	Control	Untreated	

Required quantity of pesticides was diluted in 5 ml of water for proper coating on seed. The treated seeds were packed in 2 kg gunny bag (1 kg seed in each bag) and placed in racks of the laboratory under ambient condition for further investigations with three replications. The data of residual toxicity as mortality of pulse beetle in treatments was recorded at an interval of 3 months, up to a period of nine months of ambient storage. For observations according to the experiment the required number of seed was randomly obtained from each bags of every treatment in each replication.

To know the germination of pigeonpea seed the germination paper (towel paper) method was adopted. One hundred randomly selected seed of each replication from each treatment placed on already water-soaked towel paper, which were rolled after covering them with another water-soaked towel paper. The rolled towel papers were covered with butter paper and kept in seed germinator at 25^0C and 75% RH at 7^{th} day the germination per cent were recorded on the basis of normal seed ling. The germination was recorded at 0, 3, 6 & 9 months. Seedling vigour index was computed by adopting the following formula as suggested by Abdul-Baki and Anderson (1973) and was expressed in whole number for seed vigour index, germination percentage of was multiplied by total seedling length.

Vigour index = germination (%) X Seedling length (cm)

Effect of seed Protectants on Percent seed damage by *C. chinensis* from each sample of each replication hundred seed will be randomly selected carefully to short out healthy and unhealthy seed with the help of magnifying lens (10x). The observation will be recorded at 90,180 and 270 days after treatment. The data thus obtained will be used for computing per cent damage seed by using above formula.

Per cent seed damage =

$$\frac{\text{Number of Seed in Sample}}{\text{Total number of seed in Sample}} \times 100$$

Effect of seed protectants (treatments) on per cent seed damage:

The results showed variations in percent seed damage in pigeon pea at different storage periods.

All the Seed protectants at 6 and 9 months were found significant over control however damage by seeds was non-significant at 3 months of storage. At 3 month of storage, the damage of pulse beetle ranged 0 - 1 per cent within the seed protectants and the maximum damage was recorded in profenofos with 1per cent followed by spinosad, rynaxypyr, profenofos and deltamethrin with 0.67 per cent seed damage and were statistically at par. The minimum damage was recorded in novaluron followed by emamectin benzoate, indoxacarb and chlorfenpyer with 0.33 per cent damage and were statistically at par. At 6 month of storage, the per cent seed damage ranged 0.67- 2.67 where the maximum damage was observed in rynaxypyr (2.67 per cent) followed by deltamethrin (2.33), chlorfenpyer and indoxacarb (2.00). The minimum damage was observed in (0.67 per cent) damage followed by emamectin benzoate (1.33) and profenofos (1.67 per cent). At 9 month of storage, the percent seed damage ranged 1.33 - 3.00 per cent. The maximum damage was observed in rynaxypyr followed by deltamethrin (2.67) and Indoxacarb (2.33). The minimum damage was observed in novaluron (1.33) followed by emamectin benzoate, spinosad, chlorfenpyer and indoxacarb. All treatments were significantly superior than the untreated control (5.33%). Seed damage increased significantly as storage period increased (Table 1).

Effect of seed protectants on germination:

At 3 month of storage, the germination among different treatments ranged between 88.33 -89.33 per cent. The maximum germination was recorded in novaluron followed by emamectin, spinosad and chlorfenpyer with 89.00 per cent germination which was statistically at par for each other. The minimum germination was observed in indoxacarb with 87.67 per cent followed by rynaxypyr (88.00) and

Table 1. Effect of seed protectant (insecticide) on pulse beetle damage (%), seed germination (%) and seed vigour index [germination (%) x seedling length (cm)] in pigeon pea at different storage periods (months)

Treatment/ Dose (per kg Seed)	Damage (%) at - months			Germination (%) at - months			Seed vigour index at – months		
	3	6	9	3	6	9	3	6	9
T_1 Emamectin benzoate @ 40 mg	0.33	1.33	1.67	89.00	86.00	85.67	2177.79	2089.87	1913.87
T_2 Spinosad @ 4.4 mg	0.67	1.67	2.00	89.00	81.67	79.67	1897.54	1765.34	1783.24
T_3 Indoxacarb @ 13.8 mg	0.33	2.00	2.33	87.67	79.67	77.67	1909.67	1697.07	1449.14
T_4 Rynaxypyr @ 0.01ml	0.67	2.67	3.00	88.00	84.00	78.67	1693	1809.54	1825.3
T_5 Chlorfenapyr @0.02ml	0.33	2.00	2.00	89.00	85.00	84.67	1934.07	1800.34	1758.12
T_6 Profenofos @ 0.004ml	1.00	1.67	2.00	88.33	86.00	83.33	1699	2094.87	1779.74
T_7 Novaluron @ 0.05ml	0.00	0.67	1.33	89.33	87.67	86.67	1893.2	2083.24	1893.46
T_8 Delltamethrin @ 0.04 ml	0.67	2.33	2.67	88.33	84.67	83.33	1942.4	1746.80	1772.14
T_9 Control	1.33	3.33	5.33	81.33	77.33	70.67	1902.07	1661.7	1518.4
CD	NS	0.93	0.57	0.87	0.66	0.93	57.61	51.01	48.78
SEm±	0.38	0.44	0.27	0.41	0.31	0.44	27.42	24.27	23.22

deltamethrin (88.33). All the treatments showed higher germination than control 81.33 per cent germination. At 6 month of storage, the germination within seed protectants were ranged 79.67 - 87.67 per cent in which maximum germination was observed in novaluron. Emamectin benzoate and profenofos showed 86.00 per cent and statistically at par. The minimum germination was in indoxacarb followed by spinosad, Rynaxypyr and significantly higher compared to control (77.33 per cent). At 9 month of storage, the highest germination within seed protectants was ranged 86.67 - 77.67. The highest germination was recorded in novaluron followed by emamectin benzoate and chlorfenpyer. The minimum germination was recorded in indoxacarb followed by rynaxypyr and spinosad. All the treatments are superior to control (Table 1).

Effect of seed protectants on seed vigour index:

At 3 month of storage, the vigour ranged 2177.79 - 1693. The highest vigour was recorded in emamectin benzoate followed by deltamethrin and chlorfenapyr. The minimum vigour was recorded in rynaxypyr followed by profenofos and novaluron. At 6 month of storage, the vigour ranged 2094 - 1697.07 and the higher vigour was recorded in emamectin benzoate followed by novaluron and profenofos. Minimum vigour was recorded in indoxacarb followed by deltamethrin and spinosad. The vigour index in control was 1661.7 and was very low compared to all other treatments. At 9 months of storage emamectin benzoate showed highest seed vigour index followed by novaluron and rynaxypyr. The minimum vigour was recorded in chlorfenpyer, followed by profenofos and deltamethrin. The vigour index was higher at nine months of storage (Table 1). The results clearly indicated that all the seed protectants showed better performance at significant level over control. The insect infestation was found non-significant at 3 months of storage but in case of 6 and 9 month of storage the damage was increased up to significant level. In present study, it was clear that the considerable grain damage increased progressively with increased in storage period. Longnathan *et al*. (2011) and Adhikary and Barik (2012) reports support the results.

The germination level decreased simultaneously as storage period increased in all treatments but maintained above IMSCS except control up to 9 months of storage. These results are also supported by Raghvani and Kapadia (2003), Lal and Raj (2012) and Singh *et al.* (2014) in Pigeonpea, Babu *et al.* (2008) in Soyabean and Raheem *et al*. (2011) and Khashaveh *et al*. (2009) in red gram. The vigour index was found significant over control up to 9 months of storage in all the seed protectants. Mandeep and Thakur (2011) and Raheem *et al*. (2011) reported similar findings. There was significant difference among all the treatments over control in case of all the experimental parameters. Among all tested insecticides as seed protectants, the novaluron 10 EC@0.05ml/kg emamectin benzoate 5 SG@40mg/kg and profenofos 50 EC@0.004ml/kg seed were found more effective due to minimum insect infestation. In case of seed germination, all tested seed protectants were able to maintain the seed germination above IMSCS level up to 9months of storage. The maximum seed germination was maintained by novaluron 10 EC@0.05ml/kg followed by emamectin benzoate 5 SG@40mg/kg and Chlorfenapyr at 3, 6 & 9 months of ambient storage. The maximum vigour was obtained in emamectin benzoate 5 SG@40mg/kg treated seed followed by novaluron 10 EC@90.05ml/kg up to 9 months of ambient storage. On the basis of above we can say that novaluron 10 EC@0.05ml/kg seed was best among all the tested seed protectants to protect the seed effectively and can be used to protect the pigeonpea seed above IMSCS Level up to 9 months of ambient storage.

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A low cost bisexual food baited trap for *Bactrocera cucurbitae* (Coquillet) (Tephritidae: Diptera) in gourds

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ABSTRACT: A low cost fruit fly trap was designed to attract the fruit flies with food baits. The preliminary field experiments were conducted for selecting the food bait and its concentration. A combination of 30 g of banana pulp + 3 ml of food grade alcohol selected and tested in gourds namely snake gourd (*Trichosanthes anguina* L.), ridge gourd (*Luffa acutangula* L.) and bitter gourd (*Momordica charantia* L.) in Coimbatore and Dharmapuri. The food bait attracted both sexes of *B. cucurbitae* with female: male ratio 0.78:1 and the cost of trap and food bait costs only 43 rupees per acre.

KEY WORDS: Low cost trap, food bait, para- pheromones, *Bactocera cucurbitae*

Fruit flies (Diptera: Tephritidae) are important pests that may cause even up to 100 per cent yield loss in cucurbits. Among the fruit fly species, the melon fly, *Bactrocera cucurbitae* (Coquillet) infests over 70 hosts and it is the key insect species infesting snake gourd (*Trichosanthes anguina* L.), ridge gourd (*Luffa acutangula* L.) and bitter gourd (*Momordica charantia* L.), muskmelon (*Cucumis melo* L.) and snap melon (*C. melo var. momordica* L.). The control of fruit flies is difficult in small orchard and vegetable plots because of the constant immigration of flies from nearby areas (Mumford and Kalloo, 2005). The parapheromones *viz.*, methyl eugenol and cue lure are the effective tool for the management of *B. dorsalis* and *B. cucurbitae* respectively. Since the parapheromones are sex biased, synthetic, posing problem in biodegradation (Sankaram, 1999) and not accessible to farmers due to high cost and/or lack of availability (Sookar *et al*., 2002), there is a need for low cost fruit fly trap. The present paper deals with evaluation of the low cost fruit fly trap and food bait used in gourds in the field.

A low cost trap was designed to keep food attractants for attracting fruit flies in gourds. Two used plastic water bottle of 1 litre capacity were used. The bottle 'A' was cut at 23cm from top. The top portion served as fly collecting chamber. The bottom portion was given 6-8 entry holes for attracted flies. A square cut of 3 cm^2 foldable bait window was provided just above the entry holes to facilitate manual bait placement. The bottle 'B' was cut 10 cm from top. The top portion was inserted into the top portion of bottle 'A' and fastened using Fevicol SR® after placing the bottom portion of bottle A. The trap was closed with the lid after fastening with nylon wire to suspend the unit in the field. The

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whole set up measured 33 cm (Plate 1 and Fig. 1).

Food bait is kept inside the trap at the base plate using a spoon through the foldable window, which can be closed after keeping bait. The fly entry holes above the base plate allow volatile dispersion which results in attraction of fruit flies. The trap was tied in between the crops from the roof of the pandal with the help of wire at canopy level. Attracted fruit flies enter into trap via fly's entry holes and move into the transparent collecting chamber (which mimics the sky) through fly gate and get trapped (Plate 2). The traps were placed in field at the rate of 10 traps/ acre and fruit flies collected in the trap were killed within the trap by using chloroform/ ethyl acetate dipped cotton. Once all the flies died, flies were collected with the help of camel hair brush by removing lid and transferred to plastic tray with size 25 X 20 cm. The adults collected, were identified using taxonomical keys (David and Ramani, 2011) and counted and sexed on a daily basis and preserved. After a preliminary screening with other food baits including pumpkin, sapota, snake gourd for their attractiveness, a combination of 30 g banana pulp with 3 ml food grade alcohol was finalized. Traps were replaced with same composition of food bait for every 4 days (10-11 replacements for 45 days).

In large scale experiments at two locations @ 10 traps/acre, revealed that the combination of 30 g banana pulp with 3 ml food grade alcohol, attracted significantly more number (139.23 flies/trap/day) of *B. cucurbitae* in snake gourd and was followed by bitter gourd (135.42 flies/trap/day) (51.31females and 84.11 males) and in ridge gourd 133.44 flies/ trap/day with 61.02 females and 78.21 males in Coimbatore. The highest female to male ratio was recorded in ridge gourd with 0.78:1.The combination significantly attracted more number of fruit flies in snake gourd ecosystem with 141.6 fruit flies/trap/ day (56.16 females and 85.44 males) followed by bitter gourd, 139.33 flies/trap/day (55 females and 84.33 males) and in ridge gourd the catches were 137.66 flies/trap/day (55.56 females and 82.1 males) at Dharmapuri district. Maximum female to male ratio 0.67:1 was recorded in ridge gourd (Table 1).

The combination attracted 40% of female and 60% of male *B. cucurbitae* in gourds and has an added advantage that it lessens oviposition of female fruit flies on the fruits resulting in reduced egg load and lesser infestation. Fruit flies were attracted to banana because of its high sugar content (Bose and Mitra, 1990). Several workers reported the added effect of sugar/fermented sugar in food baits (Thomas and Mangan, 2005; Stone house *et al*., 2007; McPhail, 1937; Jiji *et al.,* 2005).

The cost of methyl eugenol and cue lure per acre was Rs 450/- and Rs 600/- respectively, while the low cost trap and food bait cost was only Rs 43/- acre (Table 2). Further, the food bait based traps have competitive advantage of attracting both males and females as against only male counterparts in case of commonly available lures. Besides cost, the food bait based trap attracts the target species *B. cucurbitae* while parapheromoes attract only *B. 'dorsalis* and *B. correcta* which are not the pest species of cucurbits. Thus the food based trap

Table 1. Field evaluation of banana pulp (30g) + food grade alcohol (3ml) attractant against fruit flies in gourds

Locations	Snake gourd				Ridge gourd				Bitter gourd			
	Mean no. of flies/trap/day				Mean no. of flies/trap/day				Mean no. of flies/trap/day			
	M	F	Total*	F:M	M	F	Total*	F:M	M	F	Total*	F: M
Coimbatore	85.43	53.80	139.23	0.62:1	78.21	61.02	133.44	0.78:1	84.11	51.31	135.42	0.61:1
Dharmapuri	85.44	56.16	141.6	0.65:1	82.1	55.56	137.66	0.67:1	84.33	55	139.33	0.65:1

M= Male, F= Female, *Mean catches from 10 traps

Table 2. Economics of commonly available parapheromonal traps versus food baited traps

Sl. No.	Particulars	Total cost (in Rs)		
		Methyl eugenol trap	Cue lure trap	Food baited trap
A	Cost of trap @ 6 nos./ acre	300	300	20*
B	Lure cost/ trap for 3 replacements from 45 DAS to 90 days.	150	300	33**
	Total cost/ac (A+B)	450	600	43

*Traps recommended at10/acre;
** Food baits replaced once in 4 days necessitating 10-11 replacements

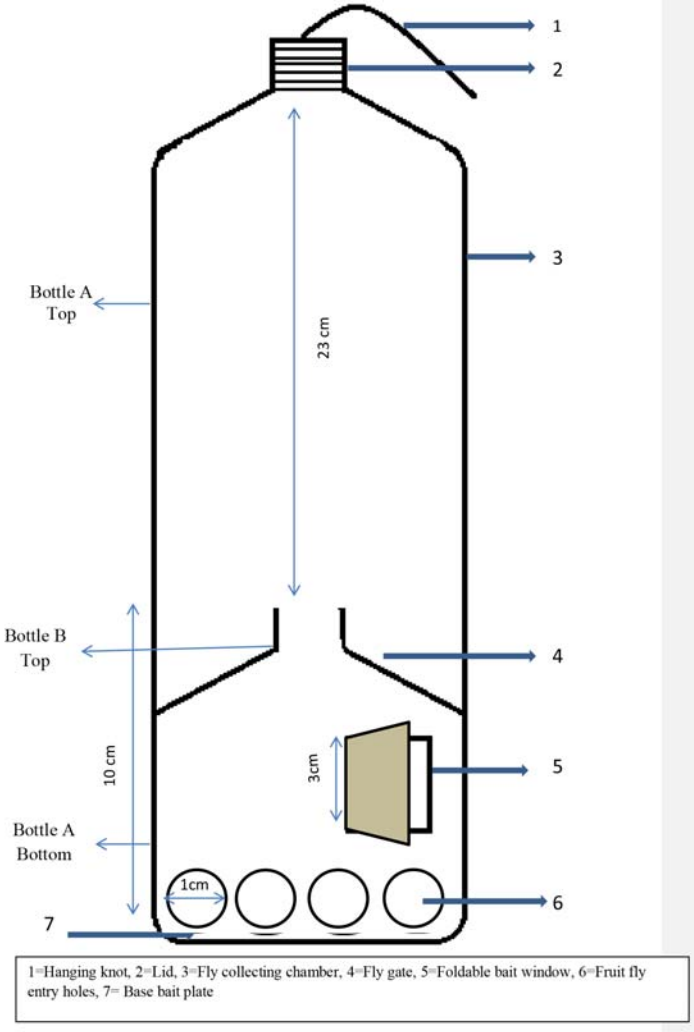

Fig 1. Design - low cost food attractant based fruit fly trap

Plate 1. Low cost fruit fly trap

banana pulp (30g) + food grade alcohol (3ml) suspended in used plastic bottles @10/acre is cost effective, attractive to both sexes and serve the real purpose of attracting the intended target pests.

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Plate 2. Fruit flies collection in the trap in the field

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Mating status of brinjal shoot and fruit borer *Leucinodes orbonalis* Guenee (Crambidae: Lepidoptera) male adults caught in sex pheromone traps

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ABSTRACT: Brinjal Shoot and Fruit Borer, *Leucinodes orbonalis* , is a major constraint in brinjal production. Investigation was taken up to understand the mating status of *L. orbonalis* male adults caught in sex pheromone trap. The genetalia of the male moths were examined for the presence of sperm cells and sperm bundles. The results indicated that 55.38 per cent of males caught in the trap were unmated whereas 26.15 per cent of them are partially mated and 18.40 per cent males are spent ones. The study indicated presence of *L orbonalis* male moths of different mating status in the pheromone catches.

KEY WORDS: *L orbonalis,* Sex pheromone , Mating status

Brin-jal shoot and fruit borer, *Leucinodes orbonalis* Guenee (Crambidae: Lepidoptera) is a serious and destructive pest on brinjal crop cultivated in South and Southeast Asia. The larvae of *L. orbonalis* cause extensive damage both in vegetative and reproductive stages of the crop (Banerjee *et al.*, 2009). According to Rahman *et al.* (2009), among the different Integrated Pest Management (IPM) options available, the use of sex pheromone is a one of the prospective alternative to the sole use of chemical pesticides in brinjal crop. Sex pheromone is being widely used in *L. orbonalis* across different parts of the world (Peter *et al*., 2010). Information on the mating status of the male moths that are being attracted and trapped into sex pheromone trap either mated or virgin is not known. Keeping the above aspect in mind the present investigation was carried out in evaluating the mating status of *L. Orbonalis* male moths attracted to the sex pheromone lures.

For ascertaining the mating status of male adults caught in sex pheromone traps, the live moths trapped in the pheromone trap were dissected out for the spermatozoa content. The dissection and staining procedure reported by Mohmood and Reisen (1982) was followed. The live active male moth were killed with ether and dissected at under

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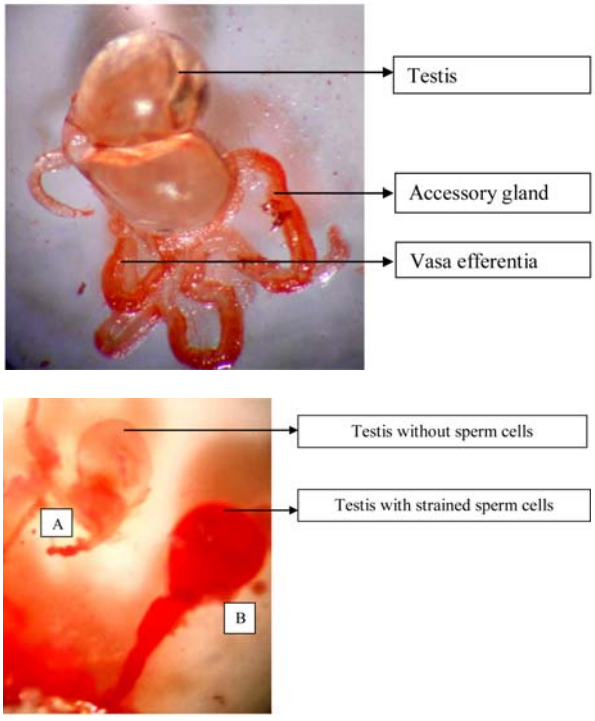
stereo-zoom microscope in magnification of 20-30X using minute nadelin inserted into wooden applicator sticks. The male internal genetalia was dissected out in saline (0.9 g NaCl/ litre) solution on a microscope cavity slides. The entire reproductive system was excised with one motion and care was taken not to break the vasa efferentia, while remaining the fatty tissues surrounding the reproductive system. The male moth collected from the trap catches were segregated as mated and unmated based on the presence or absence of sperm cells in sperm bundles in the genetalia. For better visualization of sperm bundles various strains like Congo red and Phenolphthalein were tried. The Congo red at 0.2 per cent was found most suitable (Figure 1).



A) Genetalia of spend male; B) Genetalia of unspend male

Fig. 1. Male reproductive system and matting status of *L. orbonalis*

Studies carried out on ascertaining mating status of the *L. orbonalis* male moth catches revealed presence of *L. orbonalis* male having different mating status besides 55.38 per cent unmated male. It is interesting to note that 26.15 per cent moths are partially mated and 18.46 per cent of moth completely spent (Table 1). The mating status to the male moths attracted to the pheromone trap revealed attraction of male maths of different mating status *viz*., unmated, partially mated and spent. The attraction of spent and partially spent male in the trap catches is the first kind of such report in *L. orbonalis*.

Table 1. Mating status of *L. orbonalis* male adults caught in traps

Male adults	No.	%
Total number of moth dissected	130	-
Moth having no sperm bundle	24	18.46
Moth having partially intact sperm bundles	34	26.15
Moth having sperm bundles intact	72	55.38

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First report of the invasive South American pinhole borer *Euplatypus paralellus* (F) (Coleoptera: Curculionidae: Platypodinae) on arecanut

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ABSTRACT: The invasive South American pinhole borer *Euplatypus paralellus* (F) is reported for the first time on arecanut palms from Kasaragod, Kerala, India.

KEY WORDS: *Euplatypus paralellus*, Arecanut, Kerala, India

Arecanut is an important commercial crop in India, Karnataka, Kerala and Assam being the leading producers in the country. Twenty nine out of 180 plants of Mohitnagar variety of arecanut planted in 2014 were found attacked by an insect at Kalichamaram, Kasaragod District, Kerala (12.2557° N, 75.1341° E) in December, 2018. Attacked plants exhibited massive discolouration of the trunk (Fig. 1) that extends into deeper layers (Fig. 2), pinholes with gummy exudation (Fig. 3) as well as pin holes with powdery frass. Pinholes were observed with gummy exudation on the green part of the tree trunk as well as between the leaf axils. Live beetles were found inside the pinhole (Fig. 4). The attacked plants showed yellowing and wilting and subsequent death. The insect was identified as the invasive South American pinhole borer *Euplatypus paralellus* (F.) (Coleoptera: Curculionidae: Platypodinae).

It is a widely distributed (Wood and Bright, 1992; Beaver, 2013) polyphagous ambrosia beetle reported on 82 species in 25 families of trees (Gümüº and Ergün, 2015), including rubber in Brazil (Silva *et al*., 2013). Li *et al*. (2018) reported its occurrence in China. Most ambrosia beetles infest stressed, dying or recently felled trees, while *E. parallelus* is capable of attacking healthy trees (Silva *et al*., 2013). Maruthadurai (2013) and Maruthadurai *et al*. (2014) reported its incidence on cashew from Goa. It has also been recorded on coconut (Bark and Ambrosia beetles data base, 2018). Sangamesh and Prathapan recorded it on rubber in Kannur, Kerala in 2018 (Personal communication). Infestation of *E. parallelus* on healthy arecanut palms (*Areca catechu* L.) is reported for the first time, from Kerala, India.

This invasive beetle, being recorded on four most important cash crops of Kerala such as arecanut, cashew, coconut and rubber, poses a serious threat to the agrarian economy of the state.

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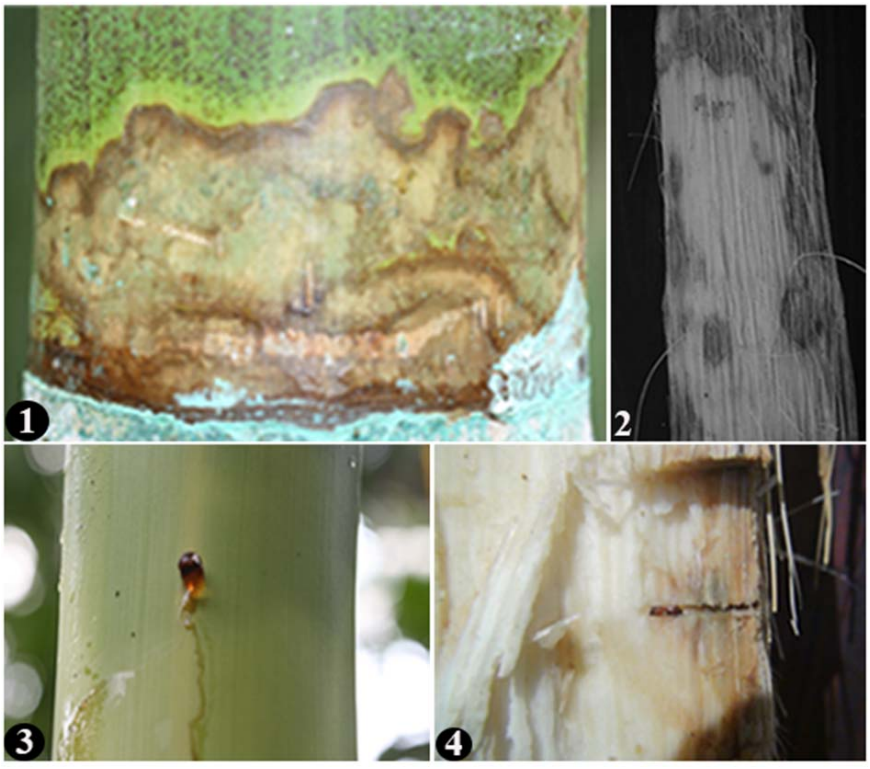

Figs 1 – 4. Symptoms of infestation of *Euplatypus parallelus* on arecanut. 1. discoloration of bark, external view, 2. discoloration in deeper layers of stem, 3. pin-hole with gummy exudation, 4. live beetle inside gallery.

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