Host range and distribution pattern of papaya mealy bug, *Paracoccus marginatus* Williams and Granara de Willink (Hemiptera : Pseudococcidae) on selected Euphorbiaceae hosts in Kerala

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Abstract

Papaya mealy bug, *Paracoccus marginatus* Williams and Granara de Willink (Hemiptera: Pseudococcidae) has a wide host range. In Kerala, during 2010 – 12 periods, 95 host plants were recorded belonging to 39 plant families. Highest number of host plants of *P. marginatus* was recorded under the family Euphorbiaceae. Heavy population build up was recorded on 44 host, moderate incidence on 27 plants and on 21 hosts, the infestation severity was low. Spatial distribution studies showed that the variance to mean ratio was the highest on *Manihot esculenta* Crantz (>100) and lowest on *Phyllanthus amarus* Schumach & Thonn. (0.63). Members of the same genus had variation in different indices owing to the plant architecture.

Keywords : *Paracoccus marginatus*, Papaya mealybug, Host range, Spatial distribution.

Introduction

Papaya mealy bug, *Paracoccus marginatus* Williams and Granara de Willink (Hemiptera: Pseudococcidae) is an exotic sucking insect pest that attacks several genera of host plants (Miller and Miller, 2002). It has a wide host range (Miller et al., 1999; Meyerdirk et al., 2004; Muniappan et al., 2008; ManiChellappan, 2010; Cham et al., 2011; Selvaraju and Sakthivel 2011). First described by Williams and Granara de Willink (1992) and later re-described by Miller and Miller (2002), the mealybug is believed to be native to Mexico and Central America (Miller et al., 1999). In India, occurrence of the pest had been reported first from Coimbatore area of Tamil Nadu in 2008 on papaya (Muniappan et al., 2008) and later in Kerala (Krishnakumar and Rajan, 2009; Lyla and Philip, 2010), Karnataka, Andhra Pradesh, Maharashtra, Tripura and Orissa.

Papaya mealy bug infestation causes clusters of cotton – like masses of the insect on the above ground portion of plants. The bug sucks plant sap by inserting its stylets into the epidermis of the leaf, stem and fruit and while feeding on the plant fluid, it injects its toxic saliva into the host which ultimately leads to the death of the plant. The overall symptoms of *P. marginatus* infestation are chlorosis, stunting of plants, deformation of leaves, early leaf and fruit drop, a heavy build up of honey dew and finally death of the host plant. Distribution and host range of *P. marginatus* varies and proper understanding of the spatial distribution might help in the long run to effectively manage the pest.

In the present study the dispersion pattern of *Paracoccus marginatus* on different host plants with particular reference to the Euphorbiaceae has been worked out.

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Materials and Methods

Sample collection

The distribution and degrees of *Paracoccus marginatus* infestation on different host plants were studied through a field survey in eleven districts (excluding Kollam, Pathanamthitta and Alapuzha) of Kerala. The study was carried out from January 2010 to May 2012 between 9 am – 1 pm at periodical intervals. The sampling method was random collection so that every sampling unit had an equal chance to be chosen (Pedigo and Buntin, 1994). As different stages of papaya mealy bug colonized on the under-surface of leaves, one leaf was selected as a sampling unit. A total of six leaves (two from bottom, two from middle and two from top) were sampled. The leaves were randomly selected using a sharp knife to prevent damage to the specimen. The leaves collected from one portion of the plant (top, middle or bottom) were placed in plastic carry bags labeled with collection number, the locality, date of collection, name of collector and notes about the host plant, its habitat and the portion of the plant where the leaves were collected. Plastic bags containing specimens were then placed in a large card board box to prevent damage to leaves and mealy bugs. The sample specimens were then brought to the laboratory with extreme care.

Laboratory analysis

In the laboratory, using a camel hair brush, mealy bugs were brushed onto a counting tray. Number of third instars, adult females and adult females with ovisac was recorded using a hand lens (10 X magnification) to get an unbiased estimate of the population mean. All other stages *viz.*, first and second instars, pupae and adult males were counted using a stereo-binocular microscope in the laboratory. The mealy bug specimens were then transferred into well labeled vials containing alcohol (70%) for further study.

Host range and distribution of Paracoccus marginatus

The observed plant species were categorized into herbs, shrubs and trees. A minor grouping of these plants into ornamental plants, vegetables and fruit crops, spices, medicinal plants, forest trees, and weed plants was also done. The extent of damage was calculated by placing all the host plants into three categories *viz.*, category I – low (1 – 15% plant area damaged), category II – moderate (16 – 50% plant area damaged) and category III – high (>50% plant area damaged) (Selvaraju and Sakthivel, 2011). Host plant status was also studied to find most susceptible plant species for *P. marginatus* infestation.

Spatial distribution of Paracoccus marginatus

The spatial distribution of *P. marginatus* on different host plant species of Euphorbiaceae family was determined by following four methods:

a. Variance to mean ratio (S^2/m) (Southwood, 1978): If the value of (S^2/m) <1 - uniform dispersion, (S^2/m) =1 - random dispersion, and (S^2/m) >1 - an aggregated dispersion where S^2 is variance and m is mean of the population.

b. Lloyd's mean crowding (X*):

$$X^* = m + (S^2/m) - 1$$

Lloyd's patchiness index (X*/m): expressed as the ratio of mean crowding to the mean. As with the variance to mean ratio, the index of patchiness is dependent upon quadrate size, X*/m = 1 – random dispersion, <1 – regular dispersion and >1 – aggregated dispersion (Lloyd, 1967).

c. David and Moore index of clumping (I) (David and Moore, 1954):

$$I = (S^2/m) - 1$$

David and Moore index of clumping values increase with increasing aggregation. If the index value = 0,

the distribution is random, positive value for negative binomial (aggregated) and negative value for positive binomial (regular).

d. Green's index (C_x) (Green, 1966):

$C_x = [(S^2/m) - 1] / n - 1$

where n is the number of samples. If $C_x < 0$ – regular or uniform dispersion, $C_x = 0$ - random dispersion and $C_x > 0$ - aggregated dispersion.

Results and Discussion

The field survey conducted in eleven districts of Kerala could identify a total of 95 plant species (Table 1) belonging to 39 plant families as hosts of *P. marginatus*. Of the recorded, 30 (31.57%) plant species were vegetable, food and fruit crops, belonging to 17 different plant families. There were 3 (3.16%) species of spices, (Myristicaceae,

Table 1. Host range of *Paracoccus marginatus* in Kerala

Family Name	Botanical Name	Common Name	Plant Category	Infestation level	Host Status
Acanthaceae	*Adhatoda vasica* Nees	Malabar nut (vasaka)	Medicinal	L	Secondary
Amaranthaceae	*Alternanthera brasiliana* (L.) Kuntze	Brazilian joyweed	Weed	H	Most Favoured
	Amaranthus cruentus L.	Blood amaranth	Ornamental	H	Most Favoured
	Amaranthus dubius Mart. ex Thell.	Red spinach	Vegetable crop	H	Most Favoured
Anacardiaceae	*Anacardium occidentale* L.	Cashew	Cash crop	L	Secondary
	Mangifera indica L.	Mango	Fruit crop	L	Secondary
Anonaceae	*Annona squamosa* L.	Custard - apple	Fruit crop	M	Favoured
Apocynaceae	*Allamanda cathartica* L.	Golden trumpet	Ornamental	M	Favoured
	Alstonia scholaris (L.) R. Br.	Indian devil's tree	Medicinal	M	Favoured
	Nerium indicum Mill.	Common oleander	Ornamental	M	Favoured
	Plumeria obtusa L.	Frangipani (white)	Ornamental	H	Most Favoured
	Plumeria rubra L.	Frangipani (red)	Ornamental	H	Most Favoured
	Rauvolfia serpentina (L.) Benth. Ex. Kurz	Snakeroot	Medicinal	L	Secondary
Araceae	*Amorphophallus paeoniifolius* (Dennst.) Nicolson	Elephant foot yam	Food crop	L	Secondary
	Anthurium andraeanum Linden ex Andre.	Flemingo lilli	Ornamental	L	Secondary
	Colocasia esculenta (L.) Schott	Colocasia	Food crop	L	Secondary
Arecaceae	*Cocos nucifera* L.	Coconut	Cash crop	L	Secondary
Asclepiadaceae	*Asclepias syriaca L.*	Common milk weed	Weed	M	Favoured
Asteraceae	*Ageratina altissima* (L.) R.M King & H. Rob.	White snake root	Weed	H	Most Favoured
	Chromolaena odorata (L.) R. M King & H.Rob.	Eupatorium	Weed	H	Most Favoured
	Cyanthillium cinereum (L.) H. Rob.	Little iron weed	Medicinal	L	Secondary
	Mikania micrantha Kunth	Mile- a-minute	Weed	H	Most Favoured
	Parthenium hysterophorus L.	Congress weed	Weed	H	Most Favoured
	Synedrella nodiflora (L.) Gaertn.	Cindrella weed	Weed	H	Most Favoured
	Tagetes erecta L.	Aztec mari gold	Ornamental	H	Most Favoured
	Zinnia peruviana (L.) L.	Peruvian zinnia	Ornamental	L	Secondary
Bigoniaceae	*Tecoma stans* (L.) Juss. ex Kunth	Yellow bells	Ornamental	M	Favoured
Caesalpiniaceae	*Bauhinia variegata* L.	Mountain ebony	Medicinal	M	Favoured
Caricaceae	*Carica papaya* L.	Papaya	Fruit crop	H	Most Favoured

Table 1. contd.....

Family Name	Botanical Name	Common Name	Plant Category	Infestation level	Host Status
Cucurbitaceae	*Benincasa hispida* (Thunb.) Cogn.	Winter melon	Vegetable crop	L	Secondary
	Coccinia grandis (L.) Voigt	Ivy gourd	Vegetable crop	L	Secondary
	Cucumis sativus L.	Garden cucumber	Vegetable crop	L	Secondary
	Momordica charantia L.	Bitter gourd	Vegetable crop	L	Secondary
	Trichosanthes cucumerina L.	Snake gourd	Vegetable crop	L	Secondary
Cyperaceae	*Cyperus polystachyos* Rottb.	Sedge	Weed	M	Favoured
Euphorbiaceae	*Acalypha indica* L.	Indian acalypha	Weed	H	Most Favoured
	Codiaeum peltatum (Labill.) P. S. Green	Croton	Ornamental	L	Secondary
	Codiaeum variegatum (L.) Rumph. ex A. Juss.	Garden croton	Ornamental	M	Favoured
	Datura stramonium L.	Jimson weed	Medicinal	M	Favoured
	Euphorbia hirta L.	Asthma weed	Weed	H	Most Favoured
	Euphorbia heterophylla L.	Mexican fireplant	Weed	H	Most Favoured
	Euphorbia neriifolia L.	Indian spurge tree	Weed	M	Favoured
	Hevea brasiliensis (Willd. Ex A. Juss.) Müll.Arg.	Rubber	Cash crop	H	Most Favoured
	Jatropha curcas L.	Physic nut	Ornamental	H	Most Favoured
	Jatropha gossypiifolia L.	Bellyache bush	Weed	H	Most Favoured
	Manihot esculenta Crantz	Cassava (Tapioca)	Food crop	H	Most Favoured
	Phyllanthus amarus Schumach. & Thonn.	Jar amla	Medicinal	M	Favoured
	Phyllanthus fraternus G. L. Webster	Gulf leaf flower	Medicinal	M	Favoured
Fabaceae	*Cajanus cajan* (L.) Millsp.	Pigeon pea	Vegetable crop	H	Most Favoured
	Cassia occidentalis L.	Coffee senna	Medicinal	L	Secondary
	Cyamopsis tetragonoloba (L.) Taub.	Cluster bean	Vegetable crop	M	Favoured
	Gliricidia sepium (Jacq.) Walp.	Gliricidia	Forest tree	H	Most Favoured
	Indigofera tinctoria L.	True indigo	Medicinal	M	Favoured
	Lablab purpureus (L.) Sweet	Dolichos bean	Vegetable crop	M	Favoured
	Mimosa pudica L.	Touch - me - not	Weed	H	Most Favoured
	Vigna unguiculata (L.) Walp.	Cow pea	Vegetable crop	M	Favoured
Gramineae	*Polytrias indica* (Houtt.) Veldkamp	Indian muraina grass	Weed	M	Favoured
Lamiaceae	*Clerodendrum infortunatum* L.	Hill glory bower	Weed	H	Most favoured
	Ocimum sanctum L.	Holy basil (Tulsi)	Medicinal	H	Most favoured
Lecythidaceae	*Couroupita guianensis* Aubl.	Cannonball tree	Medicinal	H	Most favoured
Magnoliaceae	*Michelia champaca* L.	Joy perfume tree	Ornamental	H	Most Favoured
Malvaceae	*Abelmoschus esculentus* (L.) Moench	Okra	Vegetable crop	M	Favoured
	Hibiscus rosa-sinensis L.	Chinese rose	Ornamental	H	Most Favoured
	Hibiscus mutabilis L.	Cotton rose mallow	Ornamental	H	Most Favoured
	Sida acuta Burm. f.	Common wireweed	Weed / Medicinal	H	Most Favoured
	Sida rhombifolia L.	Cuban jute	Weed / Medicinal	H	Most Favoured
Meliaceae	*Azadirachta indica* A.Juss.	Neem tree	Medicinal	L	Secondary
Moraceae	*Artocarpus heterophyllus* Lam.	Jack fruit	Fruit crop	L	Secondary
	Ficus exasperata Vahl.	Bhrahma's banyan tree	Medicinal	M	Favoured
	Morus alba L.	Mulberry	Fruit crop	H	Most Favoured
Moringaceae	*Moringa oleifera* Lam.	Drum stick tree	Food crop	M	Favoured

Table 1. contd.....

Family Name	Botanical Name	Common Name	Plant Category	Infestation level	Host Status
Musaceae	*Musa* sp. (AB Genome) 'Koompillakannan'	Koompillakannan (Musa)	Fruit crop	L	Secondary
Myristicaceae	*Myristica fragrans* Houtt.	Nut meg	Spices	L	Secondary
Myrtaceae	*Psidium guajava* L.	Guava	Fruit crop	H	Most Favoured
Oleaceae	*Jasminum multiflorum* (Burm. f.) Andrews	Star jasmine	Ornamental	M	Favoured
Phyllanthaceae	*Phyllanthus emblica* L.	Indian gooseberry	Fruit crop	H	Most Favoured
	Phyllanthus niruri L.	Stone breaker	Medicinal	H	Most Favoured
Piperaceae	*Piper nigrum* L.	Black pepper	Spices	L	Secondary
Polygonaceae	*Persicaria perfoliata* (L.) H. Gross	Asiatic terathumb	Weed	H	Most Favoured
Rosaceae	*Rosa x alba* L.	Common white rose	Ornamental	M	Secondary
Rubiaceae	*Mussaenda erythrophylla* Schumach. & Thonn.	Red flag bush	Ornamental	H	Most Favoured
	Mussaenda frondosa L.	Flag bush	Forest tree	H	Most Favoured
	Ixora coccinea L.	Scarlet jungleflame	Ornamental	H	Most Favoured
Rutaceae	*Citrus aurantiifolia* (Christm.) Swingle	Lime	Fruit crop	M	Favoured
	Murraya koenigii (L.) Spreng.	Curry leaf	Food crop	H	Most Favoured
Santalaceae	*Santalum album* L.	Sandalwood	Forest tree	L	Secondary
Sapotaceae	*Manilkara zapota* (L.) P.Royen	Sapodilla	Fruit crop	M	Favoured
Solanaceae	*Capsicum annuum* L.	Green chilli	Food crop	M	Favoured
	Physalis minima L.	Pygmi ground cherry	Weed	M	Favoured
	Solanum melongena L.	Egg plant (Brinjal)	Vegetable crop	H	Most Favoured
	Solanum lycopersium L.	Tomato	Vegetable crop	H	Most Favoured
	Solanum tuberosum L.	Potato	Vegetable crop	H	Most Favoured
Verbenaceae	*Lantana camara* L.	West Indian lantana	Ornamental	H	Most Favoured
	Tectona grandis L. f.	Teak	Forest tree	H	Most Favoured
Zingiberaceae	*Curcuma longa* L.	Turmeric	Spices	L	Secondary

L- Low infestation level; M- Medium infestation level; H- High infestation level

Piperaceae and Zingiberaceae). Three cash crops (Anacardiaceae – cashew, Euphorbiaceae – rubber, and Arecaceae - coconut) were infested by *P. marginatus*. Twenty plant species (21.05%) were weeds, comprising 11 plant families, while four (4.21%) were wild plants and trees and the rest thirty four (35.79%) were ornamental and medicinal plants. The highest number of host plants of *P. marginatus* was recorded in the family Euphorbiaceae (13 plant species) followed by Fabaceae (8 plant species), Asteraceae (8 plant species), Apocynaceae (6 plant species), Malvaceae (5 plant species) and Solanaceae (5 plant species). The rest of the families had just four or less than four representatives. This result was in confirmation with the host range study done by Meyerdirk (1999), Miller and Miller (2002), ManiChellappan (2010), Narendrakumar and Shekhar (2010), Tanwar et al., (2010), Cham et al., (2011) and Selvaraju and Sakthivel (2011).

Among the plant families, Euphorbiaceae had the highest number of host plants for *P. marginatus*. The high host preference for Euphorbiaceae family by the mealybug might be due to the presence of latex (Hodgkiss, 2010; Cham et al., 2011). As in the present study, high host preference was noticed by Selvaraju and Sakthivel (2011) on plants

belonging to the family Euphorbiaceae and Fabaceae followed by Malvaceae, Solanaceae, Apocynaceae and Amaranthaceae. Besides the members of Euphorbiaceae many other plants identified as hosts of *P. marginatus* were also found to contain latex *viz.*, *Carica papaya* L. (Caricaceae), *Mangifera indica* L. (Anacardiaceae), *Artocarpus heterophyllus* Lam. (Moraceae), *Ficus exasperate* Vahl. (Moraceae), *Nerium indicum* Mill., *Plumeria* sp., *Allamanda cathartica* L. (all Apocynaceae), etc. and it was in conformation with the study done by Cham et al., (2011).

Among the 95 observed plant species, 44 host plants recorded heavy population build up and severe damage (Category III) *viz.*, *Plumeria* sp., *Parthenium hysterophorus* L., *Carica papaya* L., *Euphorbia* sp., *Jatropha curcus* L., *Manihot esculenta* Crantz., *Hibiscus rosa-sinensis* L., *Sida* sp., *Morus alba* L., *Psidium guajava* L., etc. where infestation caused more than 51 per cent plant area damage. Selvaraju and Sakthivel (2011) and Mahalingam et al., (2010) in Tamil Nadu also observed that papaya, plumeria, mulberry, cassava and jatropha were damaged severely and the extent of damage was almost 100 per cent. The pest intensity and damage were found moderate on 27 host plant species whereas it was low on 21 plants.

Results revealed that *C. papaya* L., *M. esculenta* Crantz., *Jatropha* sp., *Plumeria* sp., *P. hysterophorus* L., *Euphorbia* sp., *Hibiscus* sp., *Sida sp., Tectona grandis* L.f., *Alternanthera brasiliana* (L.) Kuntze, *Amaranthus* dubius Mart. ex Thell., *M. alba* L., *Phyllanthus* sp., *Lantana camara* L., *P. guajava* L., *Ixora coccinia* L., *Mussanda* sp. *and Solanum* sp. were the most preferred host plants of *P. marginatus*. According to the works of Cham et al., (2011) *C. papaya* L., *Plumeria sp., Solanum melongena* L., *J. curcus* L. *Jatropha multifida* L., *M. esculenta* Crantz. and *Hibiscus sp.* were the preferred hosts of *P. marginatus*. Meyerdirk et al., (2004) reported on *C. papaya* L. and *P. hysterophorus* L., while Muniappan et al., (2008) listed *C. papaya* L., *M. esculenta* Crantz., *Euphorbia sp*. and *I. batatas* (L.) Lam. as being suitable hosts of *P. marginatus*. Caraphin News (2001) listed *Jatropha* sp., *Acalypha* sp., *Hibiscus* sp. and *A. muricata* (L.) Dostál as being suitable hosts.

The spatial distribution studies (Table 2) showed values of distribution indices for *P. marginatus* on 13 host plant species of Euphorbiaceae family. Insects seemed spatially distributed in uniform, random, or aggregated patterns primarily in response to the environment in which they live (Southwood, 1984). Taylor (1984) inferred that spatial distribution pattern of an organism was one of its most important ecological characteristics, because it tends to be more stable than the population density among generation and/ or seasons.

Variance to mean ratio was an important parameter in the spatial distribution pattern of *P. marginatus*. It was found that the highest 'variance to mean ratio' was on *Manihot esculenta* Crantz. (>100) while *Phyllanthus amarus* L. had the lowest ratio (0.63). The difference in the 'variance to mean ratio' corresponds to the degree of infestation of papaya mealy bug. Higher values of 'variance to mean ratio' indicated higher mean density of *P. marginatus* on these host plants. Hence, *Manihot esculenta* Crantz. being the most favoured host plant and *Phyllanthus amarus* Schumach. & Thonn. was the least favoured for *P. marginatus* in Euphorbiaceae family. Result of this study supported the view of Southwood (1978) that the higher the variance to mean ratio, the greater the extent of aggregation.

According to Lloyd (1967) when the patchiness value or mean crowding was less than 1, equal to, or more than 1, the distribution would be dispersed, random or clumped respectively. The value of mean crowding increased with the increase in mean density. In this present study Lloyd's index of patchiness was more than one in ten cases which further confirmed the clumped or aggregated nature

Table 2. Spatial distribution pattern of *P. marginatus* in thirteen host plant species of Euphorbiaceae family

Scientific name	Variance to mean ratio (S^2/m)	Lloyd's index of patchiness (X^*/m)	David & Moore index of clumping (I)	Green's index (C_x)
Acalypha indica L.	4.24	1.07	3.24	0.65
Codiaeum peltatum (Labill.) P. S. Green	4.14	1.48	3.14	0.63
Codiaeum variegatum (L.) Rumph. ex A. Juss.	20.00	1.32	19.00	3.80
Datura stramonium L.	14.66	1.13	13.66	2.73
Euphorbia hirta L.	2.24	1.04	1.24	0.25
Euphorbia heterophylla L.	15.57	1.22	14.57	2.91
Euphorbia neriifolia L.	1.04	1.00	0.04	0.00
Hevea brasiliensis (Wild. ex A. Juss.) Müll.Arg	4.37	1.04	3.37	0.68
Jatropha curcus L.	3.14	1.01	2.14	0.43
Jatropha gossypiifolia L.	1.90	1.02	0.90	0.18
Manihot esculenta Crantz.	186.07	1.83	185.07	37.01
Phyllanthus amarus Schumach. & Thonn..	0.63	0.98	-0.37	-0.07
Phyllanthus fraternus G. L. Webster	0.80	0.98	-0.20	-0.04

- (S^2/m) <1 - uniform dispersion, (S^2/m) =1 - random dispersion, and (S^2/m) >1 - an aggregated dispersion
- X^*/m = 1 – random dispersion, <1 – regular dispersion and >1 – aggregated dispersion
- David and Moore index value = 0, the distribution is random, positive value for negative binomial (aggregated) and negative value for positive binomial (regular).
- C_x<0 – regular or uniform dispersion, C_x = 0 - random dispersion and C_x> 0 - aggregated dispersion

of distribution of papaya mealybug. *Phyllanthus amarus* Schumach. & Thonn and *Phyllanthus fraternus* G. L. Webster showed value less than one i.e., 0.98, in each case which indicated dispersed or regular pattern of distribution of *P. marginatus* on these plants. However, the plant *Euphorbia neriifolia* L. showed a patchiness value equal to one which denoted random dispersion of papaya mealybug on this plant. This might be due to the presence of cactus like appearance of *Euphorbia neriifolia* L. leaves. The extent of occupying place played an important role in the distribution pattern of an organism. Lloyd's index of patchiness was highest (1.83) in *Manihot esculenta* Crantz., indicating clumped or aggregated distribution. This is in confirmation with the study of Ahmadi et al., (2005) suggesting that the presence of an individual at one point leads to an increased probability of another individual being nearby, and habitat occupation probability is not likely to be the same for all individuals.

Distribution analysis of *P. marginatus* on plant species belonging to Euphorbiaceae family using David and Moore index of clumping (I) and Green's index (C_x) also showed aggregated distributon. *Manihot esculenta* Crantz. showed the highest value for both David and Moore index of clumping (> 100) and Green's index (37.01) further indicating the tendency of *P. marginatus* to aggregate on this plant. However, *Phyllanthus amarus* Schumach. & Thonn. and *Phyllanthus fraternus* G. L. Webster showed negative value (-0.37, -0.20 respectively) for David and Moore index of clumping (I) which corresponds to regular pattern of distribution. Similarly, Green's index was also less than zero on these two plants again indicating regular distribution. *Euphorbia neriifolia* L. had a value equal to zero corresponding to regular or uniform pattern of dispersion of *P. marginatus* on that plant. Siswanto et al., (2008) suggested that when the population of *P. marginatus* was high, the insects tend to aggregate, meanwhile when the population

was low the insect tended to distribute randomly or regularly, a distribution common in insects. Poole (1974) stated that the most obvious cause of aggregation is probably habitat heterogeneity or an intrinsic part of the behaviour of a species. Similar spatial distributions were worked out for populations of *Frankliniella occidentalis* (Pergande) on greenhouse cucumber as aggregated (Cho et al., 2001), *Helopeltis antonii* Signoret on cashew as clumped or aggregated (Siswanto et al., 2008) and chilli thrips, *Scirtothrips dorsalis* Hood as aggregated on pepper (Seal et al., 2006).

The results of the study also revealed that a noticeable difference in values occurred among the plants of the same genus. *Codiaeum variegatum* (L.) Rumph. ex A. Juss. showed high values for all the indices as compared to those of *Codiaeum peltatum* (Labill.) P. S. Green. This might be due to the presence of larger broad leaves for *C. variegatum* (L.) Rumph. ex A. Juss. compared to the smaller narrow leaves of *C. peltatum* (Labill.) P. S. Green. As the occupying area increased the degree of infestation also increased. Similar trend was seen in case of genus *Euphorbia* also.

Papaya mealybug, *Paracoccus marginatus* has a wide host range of over 95 host plant species in 39 families and to cause severe damage to economically important fruits, vegetables and ornamental plants as well as weeds and wild trees. The plant family Euphorbiaceae had severe infestation due to the presence of its latex producing members. The host range studies showed that the papaya mealybug could infest any crop and wild plants which could serve as a reservoir for the mealybug even if the management measures taken on the cultivated plants. Spatial distribution is one of the most important ecological characters of a population that can be used in extended sampling programs for pest management. Distribution analysis using various indices of dispersion methods indicated aggregated distribution of *P. marginatus* when the population was high, and regular or random when the population was low. Therefore, understanding the host range and distribution pattern of the insect is very essential in the management of *P. marginatus*.

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