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Review Paper

Biology, host range and management options for Papaya mealybug in Africa

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Abstract

Papaya mealybug (Paraccocus margnatus) is a destructive insect pest with varied range of host plant species of economic importance to human worldwide. Management of the mealybug is commonly synthetic chemicals, however, the method is challenged by the ability of the insect to excrete a heavy white waxy that covers its body, environmental safeness on humans and non-target organisms and resistance by the pest. Other pest management options including cultural, biological and application of natural botanical extracts options are available in the literature but have not been fully tested in Africa. This review discusses besides biology and host range, some potential pesticidal plants that can be used in managing papaya mealybug in Africa.

Keywords: Mealybug, Ocimum sanctum, Argemone mexicana, Piper capensis, Pesticidal plants.

Introduction

Paracoccus margnatus (Papaya mealybug) is the agricultural crop pest which belongs to the family Pseudococcidae[1,2]. This species originates from Mexico and some adjacent nations[3,4]. It was reported for the first time in Florida in 1998[5]. Later on, the pest extended its invasion to St. Barthélémy, St. Martin and Antilles[6]. Papaya mealybug is currently widely spread in Guam, Palau, Hawaiian Islands in the specific islands, Southeast Asia, Indian subcontinents and other parts of the world[3]. In Africa, it was first reported in Ghana, Togo, Benin and Nigeria in the year of 2009 and 2010[7,8]. The pest has continued to spread to other countries such as Mauritius[8], Reunion in Indian Ocean and Tanzania[9,10]. Recent records show that Papaya mealybug is now found in more than 35 tropical countries around the globe[11]. The papaya mealybug infects negatively vegetables, weeds, ornamental and fruits[13].

The plant parts infested are seem with whitish masses of cotton like on the parts infected and its uses it's the young and adult female as the most effective stages of its parasitism in plants[3,14]. The insect sucks the sap of the host plant and weakens it[12]. In addition to a white cotton masses, the Papaya mealybug secretes honey dew that provide suitable environment for its association with some ants species[15].

It has been reported that, mutual association of mealybug and ants facilitate movement of mealybug to different parts of the plant and sometimes in different host plant[16]. In addition, spread of the honey dew on the leaves create conducive environment for the black sooty mould formation which impairs photosynthetic efficiency of the affected plants[17].

The papaya mealybug causes destruction in wide range of agricultural crops which leads to significant crop losses to farmers[18]. As a result of hefty infestation about 65 percent yield has been lost in some of susceptible crops such as papaya[19-21]. In some African countries such as Ghana, the mealybug has been reported to cause a destruction of about 85% of horticultural plantations resulting into unemployment of 1734 people[22].

The affected plants usually result in no or fruits with a very low quality in terms of size, weight and color as a consequence, low value in market[23-26].

Managing Papaya mealybug by farmers in Africa has been based on synthetic pesticides. However, such pesticides have been reported to fail to manage the mealybug due to its ability to form a whitish cotton-like waxy materials that covers its body and a presence of a wide host range of plants for its habitat[27,28]. As a result, farmers do over-apply synthetic pesticides, an approach that not only affects humans but also impacts natural enemies, contaminates the environment and fastens possibilities for development of resistance by the pest[29,30]. This over application of chemicals increases cost to farmers to levels that small scale farmers cannot afford[2].

Attempts on use of other pest management options such as plant extracts are increasingly becoming popular due to their easy availability and fast degradation[18]. It is based on this view that, this review critically discusses the insect biology and host range with emphasis on identifying the gaps and potential of botanical pesticide that can be used for sustainable management of Papaya mealybug in Africa.

Morphology and Biology of Papaya mealybug

The morphological features of Papaya mealybug differ in female and male. The female adult is oval with the length ranging from 1.5 to 2.7mm and 0.9 to 1.7mm wide[13]. The diagnostic characters of slide mounted adult female are the appearance of tube-shaped dusts limited to marginal areas of the body, absence of translucent pore on the hind tibia and the presence of pores on the hind coxae[13]. Females characterized by greenish-yellow in colour with yellowish body fluid. No dorsal stripes are present on females and mealy waxes dusted on dorsum is not thick enough to hide their body colour[15]. The mealybug-ovisacs are produced beneath or sometime behind the body of female. The body is rounded with many short waxy filaments whereby the caudal filaments are about one fourth of the body length[13,15].

The adult male is small than female and its long ranged from 0.9 – 1.1mm and 0.2- 0.3 mm. wide at thorax. The first instar is coloured yellow and later to turn pink colour[13,31]. Male Papaya mealybug is characteristically distinct and different from females with their well-developed wings and flight1[12,13,32].

The Papaya mealybug feeds on tissue of the plant through its stylet [33-36]. The infestation initially occurs in the ventral surface of the leaf and later on to the branches and stems[15].The Papaya mealybug reproduces sexually[15]. Seni and Chongtham[32] reported that, most females Mealybug lay eggs in ovisacs and the number of eggs laid ranges from 150 to 600. The duration for egg laying is about one to two weeks[34].

Stages for development differ between female and male, for instance, while female goes through four instars (in approximately about 24 to 26 days), a male goes through five instars (in approximately 27 to 30 days) at favorable conditions[12,32]. Female has three instar nymphs with the first instars known as crawlers while male has four instars nymphs with the fourth instar known as a pupa[34]. Adult females have no wings and the movement is by means of wind or through crawling. The male possesses wings in the fifth instar and has the ability to fly[15].

The Papaya mealybug prefer dry and hot environmental conditions[34]. Temperature determines the duration of female mealybug to complete its development. Its proliferation rate is high during warm season and low during the rainy seasons[12].

Considering the African tropical environments, there is a high possibility that, papaya mealy bug can real be a big problem due to favorable tropical conditions throughout the year. Nevertheless, the key focus for Africa will be on designing management options. To do so it is of crucial importance to conduct research to determine the life history of Papaya mealybug for effective designing of management option[37]. In addition there is need to understand the abundance, distribution and factors for rapid spread and development of the insect in Africa.

Host range and mechanism of damage by Papaya mealybug

Papaya mealybug has a variety of host plants including, fruits, vegetables, and ornamental crops[3,13,38-40]. Different host plants commonly preferred by Papaya mealyburg include plumeria[14], papaya, cassava, jatropha, hibiscus plants[41] beans, eggplant, tomatoes, pepper, avocado, citrus, cotton, cherry, sweet potato, mango, citrus, peas, rubber and pomegranate[13,31,42]. In other some countries outside Africa such as India, papaya mealybug has been associated with 60 plant species belonging to 29 families[16]. In Sri lanka, Walker *et al*. (2003) identified about 40 host plants[43].

For instance, a number of host plants from different countries as presented in Table-1. In this table, it is apparent that hosts of papaya ranges from 10 to 133. The plant families preferred as host of Papaya mealybug are Euphorbiaceae, Malvaceae, Solanaceae, Asteraceae and Fabaceae[20].

In Africa however, limited information is available on the host range of Papaya mealybug. Future studies should explore more on the distribution and host range of Papaya mealybug as it varies in different ecological zones and therefore proper understanding of its host plant in different region might have an implication in the long run to effectively manage of the pest.

Papaya mealybug is a destructive pest of the aerial parts of most of plants due to its polyphagous nature and its dispersal mechanisms[44]. According to Galanihe *et al*. and Singh & Kaur[14,15] the infestation of the mealybug on plant host appear as oozing of milky sap like colonies of cotton masses which can result into the destruction of the whole plant. The insect is capable of inserting its stylet into the epidermis of plants and sucks the fluid content from different part of the plant[12,14,45].

The insect also can secrete honeydew for its survival however, this secretion provides suitable medium for the growth and development of sooty mould which consequently results into interfering photosynthetic process of the plants[12]. The molds turns the infected plant surfaces black causing the crinkles and curls thus blocking the plant ventilation and respiration pathways[32, 45, 46]. Thus, the toxic substance released by Papaya mealybug while feeding on host plant, resulted in chlorosis, leave deformation, plant stunting, premature fruit and leaf drop, and sometime death of host plants[41,45,47- 49].

Management strategies of Papaya mealybug

For any pest management option, details of the life history and infection cycle are required. For Papaya mealybug, one of the most important stage recommended to be managed is larval stage[51]. In this section a number of management options have been discussed and areas for further research towards managing papaya mealybug have been highlighted for interventions in Africa.

Table-1: Number of host plant species reported as host to Papaya mealybug in some countries.

Country /region	No. of host plant species	Reference
Florida	>55	43
Thailand	10	50
Ghana	50	20
Tamil Nadu-India	133	42
Kerela	95	48
South Karnataka- India	60	16
Sri lanka	>40	43

Chemical pesticide control: Chemical pesticides have been commonly used in pest management by most of farmers in Africa. A summary of commonly used synthetic chemicals for managing papaya mealybug is shown in Table-2. Some of these chemical are sprayed on the plant however, for large trees, Thiamethoxam 25%WG can be applied in-soil[15]. Muniappan *et al*.[52] reported that the use of insecticides has not been successful and this calls for other sustainable methods for the control of the pest.[53] carried out the investigation on the efficiency of some insecticides on third instars nymph of papaya mealybug and verified that chlorpyriphos exhibited high toxicity on the pests after 24 and 48hrs of the treatment time.

In addition the farmers' dosage for application of the formulations on the mealybug is usually twice the normal dose due to the waxy covering of the mealybug body[44]. This increases chances of resistance by the insect pest[12,51,54].

Being a polyphagous insect thus, it has been challenging to manage the pest using synthetic pesticides[27]. Therefore, the use of chemicals as the control measure has been associated by a number of negative impact including environmental contamination, killing of non-targeted insests and among others[43,55]. In this regards chemical pesticides are recommended as the last option towards managing papaya mealybug[3]. Galanihe *et al*. recommended biological control as preferred method of pest management. Use of biological methods for papaya mealybug management is considered ecofriendly as it is non-chemical method that can be used for papaya mealybug management. Thus there is need for studies aimed at searching for more promising sustainable environmental friendly techniques including the biological or botanical based options to suppress this papaya meal bug.

Cultural methods: Cultural practices such as the use sharp cutting tools (machete), removing and burning of affected leaves or any other infested plant materials as well as removing of alternative host plant and weeds nearby farm[3] have been employed in the control of Papaya mealybug [3].Other cultural practices includes physical remove of the mealybug by the use of high pressure hose to wash and clean the mealybugs from the host plants[3,17,52]. However the cultural methods are not successful in management of Papaya mealybug due to the fact that, is more physical and time consuming. Use of cultural control is suitable for initial mealybug infestation and single host though may be challenging when the mealybug attack several host plant at the same time[32]. Hence, it is crucial to integrate cultural practices with other bio-pesticides approaches which are environmentally friendly.

Table-2: Common synthetic chemical pesticides used for papaya mealybug control.

Name of chemical	Reference
Thiamethoxam 25%WG, Mineral oil (Sparrow oil) and Imidacloprid	15
Imidacloprid, lamda-cyhalothrin ,Spirotetramat and Dimethoate	53
Imidachloprid, Thiomethoxam, Thiocyclin and Hydrogen Oxalate	44
Malathion, Acephate, Carbaryl, Dimethoate, Chlorpyrifos and Diazinon	34
Acetamiprid, Clothianidin, Dinotefuran, Imidacloprid, Thiamethoxam, Pyriproxyfen and Buprofezin	28
Acephate 75 WP, Dichlorvos and Profenophos 50EC	56

Biological control: Biological approach that involves the use of parasitoid and predator as natural enemies played an important role in the management of Papaya mealybug under natural environment [57-61] It was revealed that predator and parasitoid have been used for long time and have proven to be effective in biological control of pests and therefore recommended as an integral technique in the sustainable control of pests. For instance, the scientific findings have unveiled that the parasitoids have been found to significantly reduce pest populations attacking mostly the second and third instar larva of Papaya mealybug[62,63]. Worldwide it was reported that, parasitoids caused Papaya mealybug population decrease for about 97-99 and some of these parasitoids and predators are available commercially as mealybug destroyers[63,64]. Ladybird beetles, lacewings, and hover flies are among of the commercially destroyers that have been reported to have potential impact on mealybug populations[65]. A summary of common used parasitoids and predators for managing of Papaya mealybug is shown in Table-3.

In Africa, management of Mealybug with use of natural enemies is not common. In addition, smallholder farmers are not accustomed to the use of biological control in management of Papaya mealybug. Although predators and parasitoids are essential in management of Mealybug pest, their use may be considerably underestimated particularly for biological control

of Papaya mealybug in Africa. Therefore, identification and assessment of biological control using natural enemies as an integrated pest management programs is of highly importance in Africa.

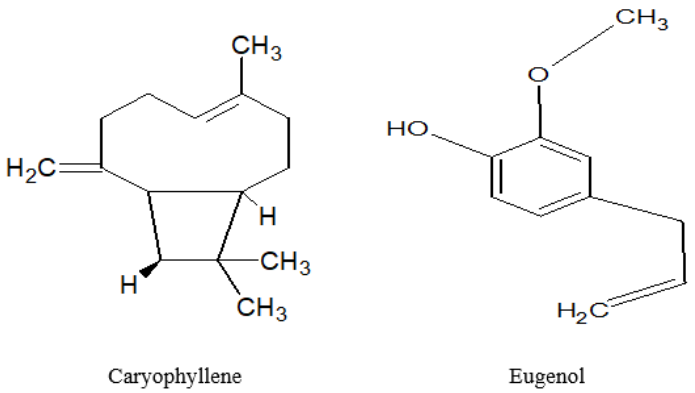
Table-3: Potential Predators and parasitoids used in the management of Papaya mealybug (PMB).

Biological control of PMB	Used organisms	Reference
Lacewing *Apertochrysa* sp (green lacewing) and *Cryptolaemus montrouzieri* (ladybird beetle)	Predators	15
Ladybird beetles *Anegleis cardoni* and *Brumoides suturalis* and *Phintella vittata*	Predators	41
Anegleis cardoni, *Brumoides suturalis*, *Chilocorus nigrita*, *Nephus quadrimaculatus*, *Chrysoperla carnea*, *Cyrtopeltis* sp	Predators	3,17,66,67
Anagyrus loecki, *Acerophagus papaya* and *Pseudleptomastix Mexicana, Acerophagus papaya Acerophagus loecki*	Parasitoids	52,68

Insecticidal potential of *Ocimum sanctum*, *Piper sp* and *Argemone Mexicana* in controlling Papaya mealybug

Ocimum sanctum: This herb belongs to the family Lamiaceae, and has been reported to have medicinal properties since ancient times[69]. Phytochemical analysis of *Ocimum sanctum* revealed that major components of *O. sanctum* are Eugenol and Caryophyllene (Figure-1)[70-72]. Based on the chemistry of the compounds isolated from this plant species, it is postulated that they may also be tested in the control of Papaya mealybug. This is due to the fact that studies have reported ethanolic extract of *O. sanctum* seeds were efficient in the control of the aphid and at 4% concentration whereby there was complete mortality of all aphids after 48hrs. Since Papaya mealybug and aphids are both scaled insect thus, it essential to test the efficacy of *O.sunctum* against Papaya mealybug. In addition, a study by Prishanthini and Vinobaba in 2014 found that the *Ocimum sanctum* has potential control against cotton mealybug under laboratory setting and field conditions[18]. Their results revealed that *O. sanctum* was efficient in the control of cotton mealybug.

Whilst *O. sanctum* has been explored for its use in different pest in different areas. There is less work done for the control of Papaya mealybug in most of African countries. It is therefore of utmost importance to determine the efficacy of this plant in the management of Papaya mealybug in Africa for maximizing the survival of Papaya.



Caryophyllene Eugenol

Figure-1: Chemical structures[71,72].

Argemone Mexicana: *Argemone mexicana* (prickly poppy) belongs to family Papaveraceae is a weed plant to mostly African, Australian and Asian cropping systems[73]. The plant is potential for agricultural crop insect pest management. Its bioactive ingredients are richly available in roots, leaves, seeds and flowers[73]. Some of active compounds present in *Argemone mexicana* are saponins, alkaloids, flavonoids, glycosides, lignin tannins and phenol[74,75]. These compounds contribute to the insecticidal properties of *Argemone mexicana* against diverse of insect pests[76]. Among these compounds, L-dopa has been reported as the most active ingredients in the management of various insect pests (Figure-2). For example, a practical experiment by Granados-echegoyen *et al*. has demonstrated positive results aganst *Bactericera cockerelli*. Also, similar results was reported by Sharma *et al*. where 100% mortality of young *B.cockerelli* was recorded[77]. Likewise, organic solvent extracts of *A. mexicana* suppressed, repelled and killed *T. castaneum* from cereal grains[73]. Also the leaf extracts of *A. mexicana* have shown effects on problematic termites significantly[78].

However, the *A. mexicana* is used locally as pesticidal plants in various places in Tanzania particularly in Kilimanjaro and Tanga regions to variety of insect pests such mealybug. But it remains unclear on the right concentrations which couple with the accepted standards. Also the mechanism behind is not known and what happens when applied to the fields. Therefore, practical researches are needed to identify the standard concentrations and the mechanisms induced by extracts of *A. Mexicana* against insect pests.

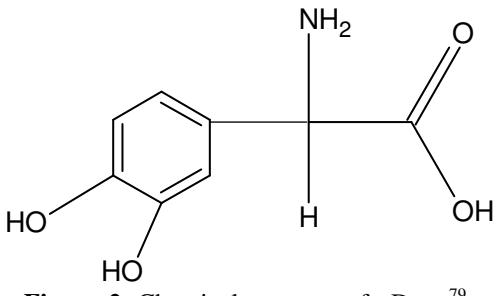


Figure-2: Chemical structure of $_{L}$-Dopa[79].

Piper capenses: *Piper capenses* is classified under family Piperaceae[68]. The plant is characterized as flowering shrub[68]. Four types of species of Piper their essential oils have been investigated and found that have bioactive constitutes such as β-pinene and α-pinene (Figure-3)[80,81,85]. These compounds possess pesticidal properties to variety of agricultural crop insect pests[68]. For instance, according to study of François *et al*. identified that essential oil extracts had significant effects towards stored product insect pests, *S. zeamais*[68,82,83]. This is in line with the research findings which concluded that essential oils of *Piper capenses* can cause up to 80% mortality in *Anopheles gambiae* larvae[82, 84].

The field observation in Moshi rural area, Northern Tanzania was noticed that farmers used pesticidal plant known as Mnongonongo, a Chagga name for *Piper capensis* to control Papaya mealybug. Papaya grower use extract of fresh leaves of *P. capensis* then mixed with ashes and water ready for applying in management of PMB. Regardless of being used locally in management of PMB, there are limited previous studies that have explored its potential for suppression of Papaya mealybug. Thus, its potential in for managing Papaya mealybug should first be evaluated prior to the recommendation for the use in Africa.

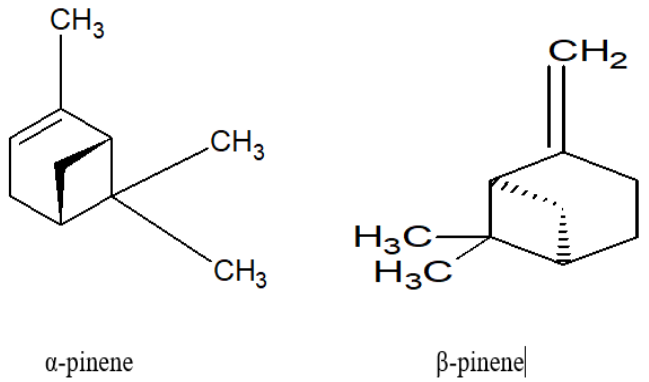


Figure-3: Chemical structures[85].

Conclusion

This review paper has demonstrated that mealybugs are the crop destructive species of which many reports have shown failure in their management. To overcome this challenge, more practical researches especially integrated pest management (IPM) are needed. The IPM techniques emphasized in this paper are biological control and use of pesticidal plants so that to alleviate negative effects caused by synthetic pesticides to human health and environments. Although, large body of knowledge on biological control and use of pesticidal plants (*Ocimum sanctum*, *Argemone mexicana* and *Piper capense*) in the management of mealybugs is not known in many parts of Africa. Therefore, this information gap calls for many more researches to justify the potentiality of biological methods, pesticidal plants such as *Ocimum sanctum*, *Argemone mexicana* and *Piper capensis* in the management of mealy bugs.

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