

Occurrence of cassava mealybug, *Phenacoccus manihoti* Matile-Ferrero (Pseudococcidae: Hemiptera), a new invasive pest on cassava in India and prospects for its classical biological control

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Increased globalization and trade have made India a target for entry of many new alien insect pests. One such unintentional recent introduction is the cassava mealybug (CMB), *Phenacoccus manihoti* on cassava. Monitoring on the occurrence and damage potential of CMB on cassava was undertaken during 2020. Among the places surveyed, maximum damage score (4–5) and density of the mealybug (>1000/shoot tip) were recorded in Salem and Namakkal districts of Tamil Nadu and Thrissur district of Kerala. In the absence of effective native natural enemies and other methods of control, CMB might pose a major crisis to the cassava industry in India. The prospects of its suppression by classical biological control are quite vibrant and the initiative to import the parasitoid wasp, *Anagyrus lopezi* from Thailand and the Republic of Benin is already being taken by ICAR-NBAIR, Bengaluru, India.

Keywords: Biological control, damage, invasive, monitoring, *Phenacoccus manihoti*.

CASSAVA, also called tapioca (*Manihot esculenta* Crantz), is an important industrial crop native to North-East Brazil. India occupies fifth place in world's cassava cultivation, and exports around 3563 tonnes of value-added cassava byproducts and flour to nearly 18 countries with an export revenue generation of Rs 200 million for 2019–20 (<http://agriexchange.apeda.gov.in/>). Cassava crop is cultivated predominantly in the southern states of which

Tamil Nadu and Kerala are responsible for 51.9% and 31.7% of area and 57.8% and 34.9% of production respectively¹. It is also grown in Andhra Pradesh, Karnataka, Madhya Pradesh, North Eastern States and to some extent in Pondicherry and Andaman and Nicobar group of Islands.

Cassava was relatively free of any serious pest till the accidental introduction of papaya mealybug (PMB), *Paracoccus marginatus* Williams & Granara de Willink (Hemiptera: Pseudococcidae) in 2008 (ref. 2). Papaya mealybug might have been introduced into India from Sri Lanka³. Since the introduced pests are always amenable to classical biological control, the encyrtid parasitoids *Acerophagus papayae* Noyes & Schauff, *Anagyrus loecki* Noyes and Menezes and *Pseudleptomastix mexicana* Noyes & Schauff were imported from Puerto Rico through USDAAPHIS by ICAR-NBAIR, Bengaluru and introduced in India during 2010 (ref. 4). *A. papayae* established very well under field conditions and continues to suppress the *P. marginatus* populations on many crops⁵.

The recent most serious biological invasion is the cassava mealybug (CMB), *Phenacoccus manihoti* Matile-Ferrero (Hemiptera: Pseudococcidae) on cassava. In India, occurrence of this pest was first noticed on cassava in Thrissur, Kerala during April 2020. Identity of the mealybug samples was established by ICAR-NBAIR⁶. The CMBs are pinkish in colour and covered with mealy coating, and usually infest the shoot tips and under surface of the leaves. All the stages of mealybug, viz. eggs, nymphs and adults (Figure 1) were observed on the plant parts

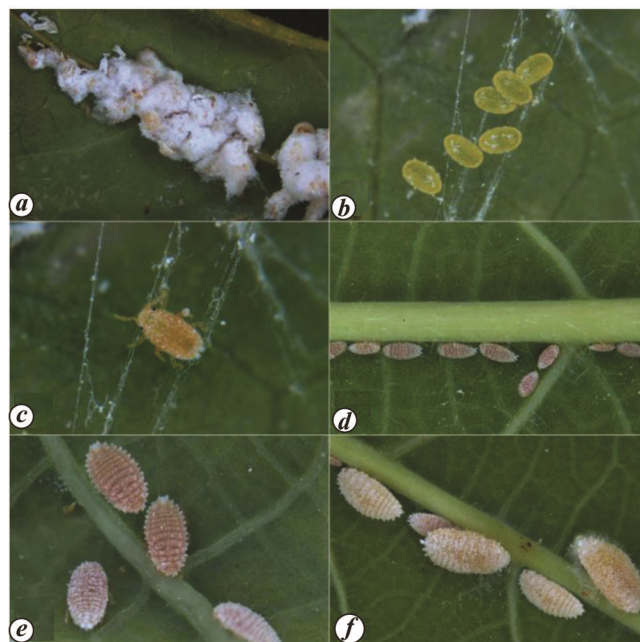


Figure 1. Life stages of *Phenacoccus manihoti* Matile-Ferrero. *a*, Ovisacs; *b*, Eggs; *c*, First instar (crawler); *d*, Second instar females beginning infestation around leaf veins; *e*, Third instar females exhibiting typical pink colour of the species; *f*, Grown up females turning yellow and initiating oviposition.

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Table 1. Survey on the occurrence and damage potential of cassava mealybug (CMB) on cassava crop in the cassava growing states

District (Block)	Village name	% infested plants	% plants with bunchy top	<i>P. manihoti</i> density scale*	Shoot tip damage scale**
Tamil Nadu					
Salem (Edappadi)	Vellarivelli	26.5–73.4	14.3–56.2	4	4–5
Salem (Pethanaickanpalayam)	Ethapur	21.2–36.5	22.5–29.6	4	3–4
Namakkal (Vennandur)	Mallur	19.0–28.2	1.8–13.2	3	3–4
Namakkal (Rasipuram)	Murungapatti, Bodinayakkanpatti	7.0–33.6	2.2–23.5	2	2–3
Namakkal (Namagiripettai)	Oduvankurichi, Ariyagoundampatti, Thoppapatti, Tho. Pachudaiampalayam, T. Jedarpalayam, Kullandikadu	9.2–86.7	1.2–74.3	4	5
Namakkal (Senthamangalam)	Kalkurichi, Rootupudur, Vellalapatti, Valayapatti, Pallipatti, Eachampatti	36.4–81.3	13.1–72.4	4	5
Erode (Modakurichi)	Avalpoondurai	8.5–11.0	0.0	1	2
Dharmapuri (Palacode)	Agaram	0.0	0.0	1	1
Dharmapuri (Morappur)	Annamalai Halli, Kellavalli	0.0	0.0	0	1
Dharmapuri (Pappireddipatti)	Avarangkattur,	0.0	0.0	0	1
Kerala					
Thrissur	Kannara, Punnamparambu, Mukkattukkara, Cathankkulam, Meppadam, Talikkode, Thannikkudam, Peruvallur, Vellanikkara, Kachithode	6.7–46.7	2.3–39.8	3	2–4
Karnataka					
Dakshina Kannada, Chikmagalur, Udipi, Mysore, Hassan, Madikeri, Chamarajanagar	–	Nil	Nil	Nil	Nil
Andhra Pradesh					
East Godavari	Peddapuram, Jaggampeta and Rangampeta Mandals	Nil	Nil	Nil	Nil

*0, No mealybug; 1, 1–9 mealybugs/shoot tip; 2, 10–99 mealybugs/shoot tip; 3, 100–999 mealybug/shoot tip; 4, ≥ 1000 mealybugs/shoot tip.

**1, No damage; 2, Slight curling of leaf margins; 3, Slight bunching of the tip; 4, Pronounced distortion of the tip (bunchy top); 5, Severe defoliation.

causing curling of the leaves at growing tip of the plant leading to formation of bunchy tops and adventitious buds on almost all the internodes. Heavy population resulted in drying of the leaves and complete defoliation. Initially it was presumed that the invasion by *P. manihoti* was restricted to a small area in Kerala until the present survey was undertaken in cassava growing districts of Tamil Nadu. The cassava plants in Edappadi (Salem district), Namagiripettai and Senthamangalam (Namakkal district) blocks were found severely damaged by *P. manihoti* (https://www.nbair.res.in/sites/default/files/2020-06/Cassava_mealybug_monitoring.pdf). It is soon expected to spread to other cassava growing areas of the country.

In the present study, morphological identification of the samples was further compared to the DNA based identification. All the life stages of mealybug collected from the field were subjected for DNA extraction as per OEPP/EPPO guidelines⁷ with essential modifications according to Pacheco da Silva *et al.*⁸

The extracted DNA was used for polymerase chain reaction (PCR) amplification of partial mitochondrial cytochrome c oxidase 1 (CO1) gene using the forward (LCO 1490 5'-GGTCAACAAATCATAAAGATATTGG-3') and reverse primer (HCO 2198 5'-TAAACTTC-AGGGTGACCAAAAATCA-3') as per the standard

protocol⁹. The sequences (NCBI accession numbers MT895817 and MW039322) showed 100% identity with GenBank accession numbers of *P. manihoti*, KY611349, KY611348, KY611347 and KY611346 submitted from China.

Sampling for the occurrence of mealybug and its natural enemies was done in unsprayed cassava crop in farmers' fields. The number of plants showing bunchy top symptoms was estimated by counting the total plants and plants with bunchy top in a fixed area of 100 sq. m at different fields. Twenty-five randomly collected shoot tips from the infested plants were used for assessing the CMB population density.

The average number of *P. manihoti* per shoot tip was assigned to one of the following categories as per Neuenschwander *et al.*¹⁰ as 0, 1–9, 10–99, 100–999 and ≥ 1000 . The log ($X + 1$) transformed upper values of mealybugs under these categories were assumed as 0, 1, 2, 3 and 4 respectively. The same shoot tip samples were used for scoring the damage scale as described by Nwanze¹¹ and Pronam¹² as 1, no damage; 2, slight curling of leaf margins; 3, slight bunching of the tip; 4, pronounced distortion of the tip (bunchy top); 5, severe defoliation.

Cassava varieties namely, Mulluvadi, white Thailand, Sree Athulya and Sree Vijaya cultivated during 2020 at

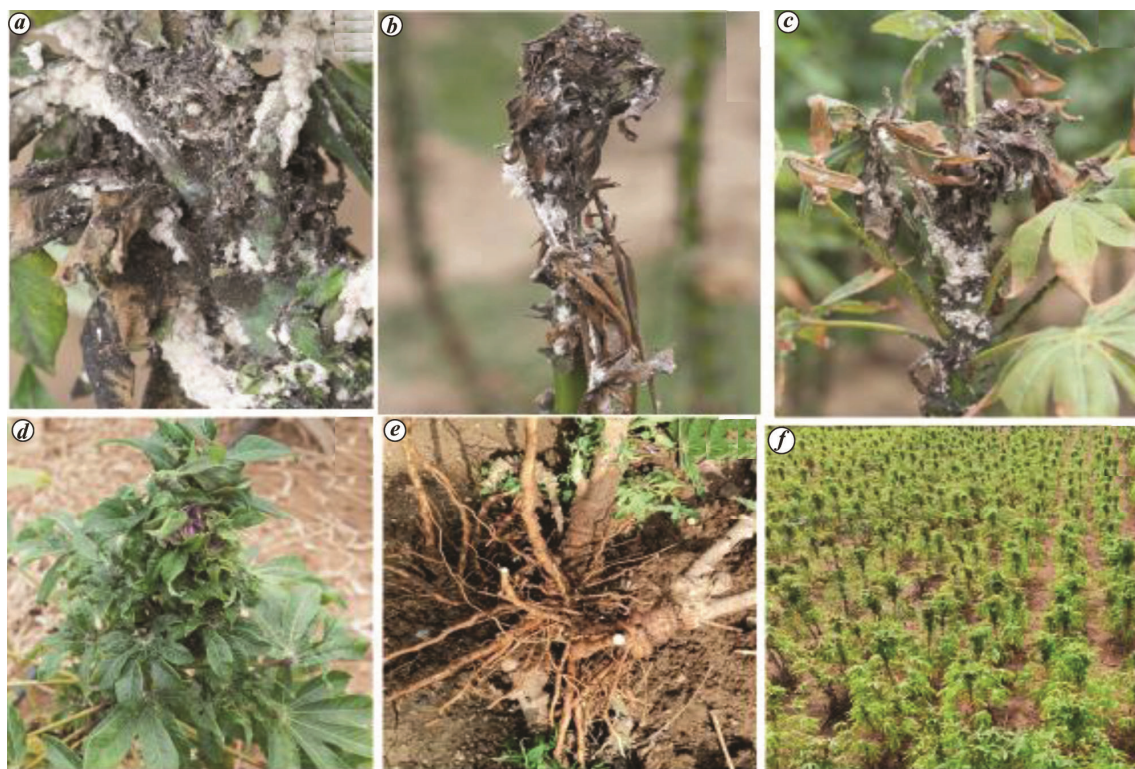


Figure 2. Symptoms on cassava due to cassava mealybug damage. *a*, Severely infested twig; *b*, Dried twig; *c*, Drying of leaves and shoot tip; *d*, Cassava plant with bunchy top appearance; *e*, Cassava plant with no tuber formation; *f*, Stunted cassava plants in the field.

Table 2. Severe reduction of harvest index due to CMB infestation in ruling varieties of cassava at the study sites (Senthamangalam and Namagiripettai blocks of Namakkal district in Tamil Nadu)

Cassava variety	Harvest index	
	CMB infested fields	Uninfested fields
Mulluvadi	0.06	0.68
	0.03	0.47
	0.02	–
	0.06	–
White Thailand	0.04	0.61
	0.03	0.58
	0.06	–
	0.00	–
Sree Athulya	0.00	0.63
	0.09	0.58
	0.24	–
Sree Vijaya	0.12	0.57
	0.30	0.60
	0.29	–

Edappadi and Pethanaickenpalayam blocks of Salem district and Rasipuram, Senthamangalam and Namagiripettai blocks of Namakkal district of Tamil Nadu were severely infested with CMB. The sets of the above varieties planted between November 2019 and January 2020 were found severely infested during the dry summer months (March–June 2020) (Table 1). The pinkish oval mealybugs were commonly noticed on tender shoots, and at the

under surface of the top leaves. Due to extreme sucking of plant sap by the mealybug, symptoms such as drying of leaves, distortion of stem, clumping of leaves, shortening of internodes and bunchy top were observed in highly infested and unsprayed fields (Figure 2). The per cent infested plants in the sampled villages varied from 7.0 to 86.7, whereas the bunchy top symptoms appeared on up to 74.3% of the infested plants in certain locations especially in Edappadi, Senthamangalam and Namagiripettai blocks of Salem and Namakkal districts. The CMB density collected from these locations reached a maximum scale of 4 (equivalent to ≥ 1000 mealybugs/shoot tip) with corresponding damage scales of 4 and 5, where, severe distortion and drying of shoot tip, stunting of the plant, defoliation and multiple tillering (bunchy top) occurred. Plants infested by *P. manihoti* were not only stunted, but also had lower harvest indices due to rudimentary or no tuber formation. The harvest index (HI) was estimated for the aforementioned four varieties at the time of harvest in different cassava fields at Namagiripettai and Senthamangalam blocks. The extremely infested Mulluvadi variety registered HI between 0.02 and 0.06 as against 0.47 and 0.68 under protected fields. In White Thailand variety, HI declined between 0.0 and 0.06 as against 0.58 and 0.61 under protected/uninfested condition. The cultivars Sree Athulya and Sree Vijaya registered decline in HI between 0.0 and 0.24 and 0.12 and 0.30 as against 0.58 and 0.63 and 0.57 and 0.60 of their respective protected/uninfested counterparts (Table 2).

The PMB, *P. marginatus* occurred during the initial stage of the crop was successfully controlled by the exotic parasitoid, *A. papayae*, whereas *P. manihoti* was not preferred by *A. papayae*. The absence of effective native natural enemies and the drought like situation have caused the CMB population to flare up. Though a fair population of *Spalgis epeus*⁶ Westwood (Lepidoptera: Lycaenidae) and predatory coccinellid beetle, *Hyperaspis maindroni* Sicard (Coleoptera: Coccinellidae) was found feeding on CMB in the unsprayed fields, the biocontrol potential of *H. maindroni* was severely hampered due to parasitization by a parasitoid, *Homalotylus turkmenicus* Myartseva (Hymenoptera: Encyrtidae)¹³.

Anagyrus lopezi (De Santis) (Hymenoptera: Encyrtidae), a parasitoid native to Central America, is being successfully used for the management of CMB in African and other Asian countries. *A. lopezi* is host-specific, and environmentally-adaptable¹⁴ and its parasitism levels were 10–57% in the mealybug affected fields in the released countries¹⁵. Host specificity studies conducted in other countries indicated that *A. lopezi* could develop only on CMB¹⁶. A large-scale biological control campaign by International Institute of Tropical Agriculture (IITA), Nigeria, in collaboration with numerous national and international organizations has led to the successful control of *P. manihoti* through the introduction and establishment of *A. lopezi*. Presently the parasitoid wasp has been established in 26 African and four Asian countries, imparting a substantial reduction in the population density of CMB in most farmers' fields¹⁷.

The introduction and release of the exotic parasitoid *A. papayae* by ICAR-NBAIR for the management of *P. marginatus* on cassava, mulberry and papaya was highly successful and reduced the pest incidence from 49% to 3% over a period of two years (2010–2012), and an annual saving of 1623 crores was accrued to the farmers in Tamil Nadu, Karnataka and Maharashtra (<https://www.nbaair.res.in/sites/default/files/2018-12/PMB%20Brochure.pdf>). ICAR-NBAIR has obtained import permit for importing *A. lopezi* from Thailand and Republic of Benin. The experience gained by ICAR-NBAIR will be used aptly for the management of the new invasive CMB by successful introduction of this exotic parasitoid after necessary quarantine studies at NBAIR QC-2 facility.

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