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Efficacy of Organophosphorus Insecticides against *Rhizoecus amorphophalli*-Infested Tubers of *Amorphophallus paeoniifolius* Under Laboratory Conditions

R. S. Sreerag • C. A. Jayaprakas*

Division of Crop Protection, Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram 695017, Kerala, India

***Corresponding author*: * prakashcaj@gmail.com**

ABSTRACT

Elephant foot yam, *Amorphophallus paeoniifolius* is an edible aroid widely cultivated in tropical countries. Upon harvest, the tubers are either marketed directly as a vegetable or stored as seed material. Infestation by the mealy bug, *Rhizoecus amorphophalli* is a serious problem during its long-term storage. This sap-sucking insect pest attacks the stored tubers and sucks the juice leading to desiccation and shriveling of tubers. Mealy secretions from the insect disfigure the tubers affecting their acceptability and marketability. Proper management of this noxious pest plays a crucial role in avoiding storage damage inflicted by mealy bugs. The present study aimed to check the efficacy of six locally available organophosphorus insecticides against mealy bug under laboratory conditions. All the 1st instars sprayed with 0.001% malathion were completely killed whereas 0.005% of quinalphos and methyl parathion was required to produce the same effect. Malathion, chlorpyrifos, dimethoate and methyl parathion at 0.5% effectively controlled adult females but other insecticides resulted in only 90% mortality and were less effective. Dipping the mealy bug-infested tubers in chlorpyrifos and methyl parathion at 0.5% completely controlled this pest on the first day but malathion and dimethoate produced a similar effect only on the second day after treatment. Dipping the infested tubers for 10 min in any of these insecticides is recommended for the management of this pest. To achieve better results, the strategy has to be aimed at controlling the establishment of young crawlers by dipping the tubers several times until crawler production ceases, thereby controlling the mealy bug population.

Keywords: mealy bug, Elephant foot yam, insecticides, treatment
Abbreviations: DAT, days after treatment

INTRODUCTION

Insect pests have been a menace to man since they started cultivating and often severe pest out breaks minimize the crop production and reduce agricultural outcome. Climate change has paved the way for transformation of hitherto known minor pests to the status of major pests especially the mealy bugs (Homoptera: Pseudococcidae) which are highly polyphagous and gregarious in nature (Suresh and Kavitha 2008). Being a sucking pest, they feed on plant juices from most agricultural crops including the stored products and also act as a vector of several plant diseases (Ben Dov 1994). The genus *Rhizoecus* encompasses more than 120 world species widely reported, including root mealy bugs (Williams 1985; Danzig *et al*. 2008). *Rhizoecus amorphophalli* Betrem is the noxious pest infesting the stored tubers of major yams and aroids, especially elephant foot yam (Palaniswami *et al*. 1999; Rajamma *et al*. 2002). They are white, slow-moving, oval, soft bodied insects with a white waxy coating over their body.

Elephant foot yam, *Amorphophallus paeoniifolius* (Dennst.) Nicolson is an edible aroid cultivated in the tropical countries and in India it is traditionally cultivated in West Bengal, Andhra Pradesh, Tamil Nadu, Bihar, Gujarat, Kerala and Jharkhand (Nedunchezhiyan 2008) with a production potential of 50-80 t/ha (Ravi *et al*. 2009). The tubers are rich in starch and a good source of minerals and vitamins, therefore used as a vegetable after cooking (Misra 2002). Moreover, many indigenous Ayurvedic and unani medicinal preparations were also made using these tubers (Srinivas and Ramanathan 2005). On harvest, the tubers were either marketed or stored as seed materials for the next planting season and the mealy bug infestation is prevalent during this storage period. They suck and desap the cell content of the tubers and severely infested tubers shriveled, adversely affecting their cooking quality (Palaniswami 1994). In addition, mealy substance secreted by this insect disfigures the tuber, which affects their acceptability and marketability (Hegde and Jayaprakas 2011).

Initially, the infestation cannot be noticed as the crawlers are microscopic, but while infestation develops, colonies build up quickly and consequently the tuber will be totally covered by this insect. Relentless infestation results in vast crop failure and consequently severe economic loss to the farmers. Large quantities of stored tubers were rendered unfit for human consumption as a result of insect attack (Adesuyi 1973). Even though the intensity of infestation by this pest and its economical loss to farmers are indisputable, not much work has been reported on their management. Nedunchezhiyan *et al*. (2011) determined the effect of six low cost and environmentally safe management practices including salt solution, cow urine and cow dung slurry on the mealy bug *R. amorphophalli* which were found effective in reducing mealy bug numbers and associated corm damage. Even though pesticides are perilous to human health and their environment, mealy bug outbreaks require the use of insecticides due to the rapid multiplication of this insect when compared with other pests (Bartlett and Clancy 1972). Adverse effect of insecticide treatments on the mealy bug population density is characterized by the frequent use of non-selective insecticides (Franco *et al*. 2004) and non-timely application of these chemicals. The present study aims to screen the efficacy of six locally available organophosphorus insecticides on the mealy bug *R. amorphophalli* under laboratory conditions.

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MATERIALS AND METHODS

Maintenance of insect culture

Medium sized tubers of elephant foot yam, *A. paeoniifolius* (700-2000 g), totally devoid of any insect infestation were selected and procured from farm office, Central Tuber Crop Research Institute (CTCRI), Sreekariyam. These tubers were cleaned, washed with water and shade dried for 4-5 h. The adult females of amorphophallus mealy bug, *R. amorphophalli* was obtained from the mother culture maintained on tubers of elephant foot yam in the bio-pesticide laboratory, CTCRI and insects were transferred to uninfested tubers using a sable haired brush for maintaining pure culture for laboratory assay. These tubers were kept inside wooden cages (60 cm × 60 cm × 60 cm) having the door in the front and other sides covered with wire mesh supplied with a 15-W fluorescent light for 8 h per day. The insect culture was transferred to the fresh set of tubers according to the decay or damage of infested tubers.

Preparation of insecticidal solutions

Locally available synthetic insecticides belonging to organophosphate groups were purchased and used for the assay (**Table 1**). The concentrations used were 0.5, 0.1, 0.05, 0.01, 0.005 and 0.001% for all the insecticides selected for the treatment.

Treatment method

First instars (freshly emerged crawlers) and adult females were carefully collected from the tubers with the aid of sable haired brush and were transferred to separate Petri dishes. Freshly prepared insecticidal solutions were taken in atomiser and sprayed on the insects.

In another experiment, scoops having 3 cm^3 diameter were taken from the fully infested tubers using cork borer. These scoops were observed under stereo zoom binocular microscope (Leica M10, Leica Microsystems, Weltzar, Germany - magnification of 80-800X) to confirm that these scoops contain a good population of live insects. These scoops were dipped for 10 min in the freshly prepared insecticidal solutions taken in a 100-ml plastic container. Then using forceps these pieces of tubers were transferred to filter paper kept in small Petri dishes so that the excess solution was removed. Three replicates were maintained and water was used as control in both experiments.

Observation of mortality

Under the microscopic view, mortality count was observed continuously for three days after treatment (1, 2, and 3 DAT). For the dipping method the mortality percentage was calculated as follows:

Mortality percentage (%) = (Number of dead insects - number of live insects) × 100

Statistical analysis

Statistical analysis was done by analysis of variance (ANOVA) in a random block design and pair-wise comparison was carried out by Duncan's multiple range test (DMRT, $P \leq 0.05$) using SPSS 17.0.

Table 1 List of locally available oraganophosphorus insecticides used for the study.

Name of insecticide	Chemical name	Emulsified concentration, EC (%)
Killer	Malathion	50
Ekalux	Quinalphos	25
Rogor	Dimethoate	30
Nuvan	Dichlrovos	79
Regichlo	Chlorpyrifos	20
Metacil	Methyl parathion	50

RESULTS

Effect of insecticides on the 1st instars

Mortality percentage of 1st instars treated with locally available organophosphorus insecticides were depicted on **Table 2-4**. One day after treatment, all insecticides at the concentration of 0.05% resulted in 100% mortality. Methyl parathion even at 0.005% produced same effect. Whereas, only 73.3% instars treated with chlorpyrifos at this concentration were killed and gave the least effect among the insecticides treated. Quinalphos gave 100% effect till 0.005% which declined significantly to 70% at 0.001%. Chlorpyrifos at 0.01% gave 86% mortality at one day after treatment whereas lower concentrations gave significantly less mortality. Methyl parathion at 0.001% killed 90% instars and showed significantly less mortality than the high concentrations. All the control batches recorded no mortality in the first day observation and differed significantly from all the treated batches.

Mortality of malathion at 0.01 and 0.005% increased in the second day and all instars treated were totally killed. Similar results were recorded in insects treated with quinalphos. Whereas, other insecticides did not recorded much increase in mortality and showed same results as in the first day observation. Mortality of insects treated with dimethoate at 0.001% increased to 90% and showed similar mortality with that of higher concentrations (0.005 and 0.001%). Second day mortality observations revealed that malathion and quinalphos at 0.005% also gave complete control over the instars.

In the third day also mortality percentage of malathion increased and cent percentage mortality was recorded for all concentrations tested. For quinalphos, complete instars treated with 0.005% were killed on the third day and varied significantly with the lower concentration (0.001%) and the control batch. Mortality increased from 90 to 100% for dichlorovos at 0.01% on the third day which differed significantly from the lower concentrations. Maximum effect was obtained for instars treated with chlorpyrifos till 0.05% and the lower concentrations showed significantly less mortality. Chlorpyrifos at 0.01% recorded 90% mortality and differed significantly from the lower concentrations of 0.005 and 0.001% which showed similar mortality. Treatment with dimethoate till 0.01% killed all the instars but lower concentrations 0.005 and 0.001% showed significantly less mortality (90%) on the third day. In case of methyl parathion there was no increase in mortality according to the days. There was no mortality for the instars of the control batch even third day after treatment.

Effect of insecticides on the adult females

Mortality percentage of adult females treated with insecticides (1 DAT) is given in **Table 5**. On the first day observation, malathion, chlorpyrifos and methyl parathion at 0.5% recorded similar mortality (100%). Quinalphos at 0.5% recorded 90% mortality followed by dimethoate and dichlorovos with 66.6 and 56.6%, respectively. Malathion, quinalphos and chlorpyrifos recorded almost similar mortality at 0.1% concentration ranging from 73-80% whereas other insecticides at this concentration gave less effect (60%). Treatment with dichlorovos produced only less effect when treated with concentrations below 0.05% which ranged from 13.3-30%. Similarly, least mortality (30%) was shown by dimethoate even at 0.1% and the lower concentrations failed to kill much female mealy bugs and showed no variation in mortality according to the concentration tested. Even though 0.5% of methyl parathion killed all females in the first day itself, the mortality significantly varied from lower concentrations tested.

There was no appreciable increase in the mortality percentage of adult mealy bugs treated with malathion and quinalphos on the second day observation (**Table 6**). But prominent increase in mortality was observed in treatment

Table 2 Mortality (%) of 1st instars of mealy bug one day after treatment.

Insecticides	Percentage mortality						
	0.5%	**0.1%**	**0.05%**	**0.01%**	**0.005%**	**0.001%**	**Control**
Malathion	100 ± 0 g	100 ± 0 g	100 ± 0 g	90 ± 10 ef	90 ± 0 ef	93.33 ± 5.7 fg	0 ± 0 a
Quinalphos	100 ± 0 g	100 ± 0 g	100 ± 0 g	90 ± 10 ef	100 ± 0 g	70 ± 10 bcd	0 ± 0 a
Dichlorovos	100 ± 0 g	100 ± 0 g	100 ± 0 g	90 ± 0 ef	90 ± 0 ef	90 ± 0 ef	0 ± 0 a
Chlorpyrifos	100 ± 0 g	100 ± 0 g	100 ± 0 g	86.6 ± 5.7 def	73.3 ± 5.7 b	76.6 ± 5.7 bc	0 ± 0 a
Dimethoate	100 ± 0 g	100 ± 0 g	100 ± 0 g	90 ± 0 ef	90 ± 0 ef	83.3 ± 5.7 cde	0 ± 0 a
Methyl parathion	100 ± 0 g	100 ± 0 g	100 ± 0 g	100 ± 0 g	100 ± 0 g	90 ± 0 ef	0 ± 0 a

Means with the same letters in are not significantly different by Duncan's multiple range test

Table 3 Mortality (%) of 1st instars of mealy bug two days after treatment.

Insecticides	Percentage mortality						
	0.5%	**0.1%**	**0.05%**	**0.01%**	**0.005%**	**0.001%**	**Control**
Malathion	100 ± 0 e	100 ± 0 e	100 ± 0 e	100 ± 0 e	100 ± 0 e	93.33 ± 5.7 d	0 ± 0 a
Quinalphos	100 ± 0 e	100 ± 0 e	100 ± 0 e	100 ± 0 e	100 ± 0 e	70 ± 10 c	0 ± 0 a
Dichlorovos	100 ± 0 e	100 ± 0 e	100 ± 0 e	90 ± 0 d	90 ± 0 d	90 ± 0 d	0 ± 0 a
Chlorpyrifos	100 ± 0 e	100 ± 0 e	100 ± 0 e	90 ± 0 d	73.3 ± 5.7 b	76.6 ± 5.7 bc	0 ± 0 a
Dimethoate	100 ± 0 e	100 ± 0 e	100 ± 0 e	90 ± 0 d	90 ± 0 d	90 ± 0 d	0 ± 0 a
Methyl parathion	100 ± 0 e	100 ± 0 e	100 ± 0 e	100 ± 0e	100 ± 0 e	90 ± 0d	0 ± 0 a

Means with the same letters in are not significantly different by Duncan's multiple range test

Table 4 Mortality (%) of 1st instars of mealy bug three days after treatment.

Insecticides	Percentage mortality						
	0.5%	**0.1%**	**0.05%**	**0.01%**	**0.005%**	**0.001%**	**Control**
Malathion	100 ± 0 d	100 ± 0 d	100 ± 0 d	100 ± 0 d	100 ± 0 d	100 ± 0 d	0 ± 0 a
Quinalphos	100 ± 0 d	100 ± 0 d	100 ± 0 d	100 ± 0 d	100 ± 0 d	70 ± 10 b	0 ± 0 a
Dichlorovos	100 ± 0 d	100 ± 0 d	100 ± 0 d	100 ± 0 d	90 ± 0 c	90 ± 0 c	0 ± 0 a
Chlorpyrifos	100 ± 0 d	100 ± 0 d	100 ± 0 d	90 ± 0 c	80 ± 0 b	76.6 ± 5.7 b	0 ± 0 a
Dimethoate	100 ± 0 d	100 ± 0 d	100 ± 0 d	100 ± 0 d	90 ± 0 c	90 ± 0 c	0 ± 0 a
Methyl parathion	100 ± 0 d	100 ± 0 d	100 ± 0 d	100 ± 0 d	100 ± 0 d	90 ± 0 c	0 ± 0 a

Means with the same letters are not significantly different by Duncan's multiple range test

Table 5 Mortality (%) of adult females one day after treatment.

Insecticides	Percentage mortality						
	0.5%	**0.1%**	**0.05%**	**0.01%**	**0.005%**	**0.001%**	**Control**
Malathion	96 ± 5.7 m	76 ± 20.8 jkl	53.3 ± 5.7 fgh	40 ± 10 def	40 ± 10 def	40 ± 10 def	0 ± 0 a
Quinalphos	90 ± 0 l m	80 ± 0 kl	56.6 ± 15.27 fghi	30 ± 10 bcde	30 ± 17.3 bcde	26.6 ± 5.7 bcde	0 ± 0 a
Dichlorovos	56.6 ± 11.54 fghi	40 ± 10 def	30 ± 10 bcde	16.6 ± 11.54 abc	16.66 ± 15.27 abc	13.33 ± 5.7 ab	0 ± 0 a
Chlorpyrifos	96.6 ± 5.7 m	73.3 ± 5.7 ijk	60 ± 10 ghij	66.6 ± 5.7 hijk	53.3 ± 5.7 fgh	43.3 ± 5.7 efg	0 ± 0 a
Dimethoate	66.6 ± 15.27 hijk	30 ± 17.32 bcde	33.3 ± 5.7 cde	26.6 ± 5.7 bcde	23.3 ± 5.7 bcd	20 ± 10 bc	0 ± 0 a
Methyl parathion	100 ± 0 m	60 ± 0 ghij	63.3 ± 5.7 hijk	40 ± 10 def	43.3 ± 11.54 efg	30 ± 10 bcde	0 ± 0 a

Means with the same letters are not significantly different by Duncan's multiple range test

Table 6 Mortality (%) of adult females two days after treatment.

Insecticides	Percentage mortality						
	0.5%	**0.1%**	**0.05%**	**0.01%**	**0.005%**	**0.001%**	**Control**
Malathion	100 ± 0 n	76.6 ± 20.8 ijkl	56.6 ± 5.7 fgh	46.6 ± 5.7 def	40 ± 10 cde	40 ± 10 cde	0 ± 0 a
Quinalphos	90 ± 0 l mn	83.33 ± 5.7 jklm	56.6 ± 15.27 fgh	40 ± 0 cde	30 ± 17.3 bc	26.6 ± 5.7 bc	0 ± 0 a
Dichlorovos	70 ± 17.3 hij	50 ± 10 defg	36.66 ± 5.7 bcd	40 ± 10 cde	26.66 ± 5.7 bc	23.33 ± 11.54 b	0 ± 0 a
Chlorpyrifos	100 ± 0 n	83.3 ± 11.54 jklm	73.3 ± 11.54 ijk	70 ± 0 hij	53.3 ± 5.7 efg	50 ± 0 defg	0 ± 0 a
Dimethoate	96.6 ± 5.7 mn	53.3 ± 11.54 efg	46.6 ± 5.7 def	30 ± 10 bc	30 ± 10 bc	26.6 ± 5.7 bc	0 ± 0 a
Methyl parathion	100 ± 0 n	86.6 ± 5.7 klmn	63.3 ± 5.7 ghi	63.3 ± 5.7 ghi	43.3 ± 11.54 defg	50 ± 0 defg	0 ± 0 a

Means with the same letters are not significantly different by Duncan's multiple range test

Table 7 Mortality (%) of adult females three days after treatment.

Insecticides	Percentage mortality						
	0.5%	**0.1%**	**0.05%**	**0.01%**	**0.005%**	**0.001%**	**Control**
Malathion	100 ± 0 n	76.6 ± 20.81 jklm	56.6 ± 5.7 efg	46.6 ± 5.7 bcde	40 ± 10 bcd	40 ± 10 bcd	0 ± 0 a
Quinalphos	90 ± 0 mn	83.33 ± 5.7 klm	60 ± 10 efgh	40 ± 10 bcd	30 ± 17.3 b	30 ± 0 b	0 ± 0 a
Dichlorovos	83.33 ± 5.7 klm	60 ± 10 efgh	36.6 ± 5.7 bc	40 ± 10 bcd	30 ± 0 b	30 ± 0 b	0 ± 0 a
Chlorpyrifos	100 ± 0 n	83.3 ± 11.54 klm	73.3 ± 11.54 ijkl	70 ± 0 hijk	53.3 ± 5.7 def	50 ± 0 bcdef	0 ± 0 a
Dimethoate	100 ± 0 n	53.3 ± 11.54 def	46.6 ± 5.7 bcde	30 ± 10 b	30 ± 0 b	26.6 ± 5.7 b	0 ± 0 a
Methyl parathion	100 ± 0 n	86.6 ± 5.7 lmn	63.3 ± 5.7 fghi	63.3 ± 5.7 fghi	50 ± 10 bcdef	50 ± 0 bcdef	0 ± 0 a

Means with the same letters are not significantly different by Duncan's multiple range test

with dichlorovos, chlorpyrifos and dimethoate.

Mortality percentage of adult females treated with insecticides (3 DAT) is depicted in **Table 7**. All insecticides except quinalphos and dichlorovos tested in this study produced cent percentage mortality at 0.5% after the third day observation. At 0.1% concentration, methyl parathion showed 86.96% mortality followed by quinalphos and chlorpyrifos with 83.3% mortality. But dimethoate at the same concentration killed only 53.3% adult females and showed less effect. On the third day, malathion and quinalphos recorded no appreciable increase in mortality and mortality percentage remained almost same as in the second

Table 8 Mortality percentage of mealy bugs on the infested tubers dipped in insecticides.

Concentrations	Malathion			Quinalphos		
(%)	1 DAT	2 DAT	3 DAT	1 DAT	2 DAT	3 DAT
0.5	98.48 ± 2.62 e	100 ± 0 e	100 ± 0 e	98.33 ± 2.58 e	98.33 ± 2.58 e	98.33 ± 2.58 e
0.1	74.33 ± 14.01 cd	79.33 ± 16.77 de	79.33 ± 16.77de	93.64 ± 5.52 e	93.64 ± 5.52 e	93.64 ± 5.52 e
0.05	73.96 ± 25.04 bcd	77.29 ± 20.54 de	77.29 ± 20.54 de	72.02 ± 11.06 d	72.02 ± 11.06 d	72.02 ± 11.06 d
0.01	59.22 ± 3.17 bcd	59.22 ± 3.17 bcd	59.22 ± 3.17 bcd	58.17 ± 10.69 bc	58.17 ± 10.69 bc	58.17 ± 10.69 bc
0.005	53.64 ± 11.02 bc	53.64 ± 11.02 bc	53.64 ± 1.02 bc	58.52 ± 2.56 c	58.52 ± 2.56 c	58.52 ± 2.56 c
0.001	50.41 ± 12.98 b	50.41 ± 12.98 b	50.41 ± 12.98b	46.16 ± 3.14 b	46.16 ± 3.14 b	46.16 ± 3.14 b
Control	0 ± 0 a	0 ± 0 a	0 ± 0 a	0 ± 0 a	0 ± 0 a	0 ± 0 a

Concentrations	Dichlorovos			Chlorpyrifos		
(%)	1 DAT	2 DAT	3 DAT	1 DAT	2 DAT	3 DAT
0.5	86.1 ± 12.7 e	86.1 ± 12.7 e	86.1 ± 12.7 e	100 ± 0 e	100 ± 0 e	100 ± 0 e
0.1	76.5 ± 6.1 de	76.5 ± 6.1 de	76.5 ± 6.1 de	95 ± 8.6 de	95 ± 8.6 de	95 ± 8.6 de
0.05	46.9 ± 6.6 b	68.1 ± 13.28 cd	68.1 ± 13.28 cd	91.1 ± 10.9 de	91.1 ± 10.9 de	91.1 ± 10.9 de
0.01	53.7 ± 11.6 bc	53.7 ± 11.6 bc	53.7 ± 11.6 bc	71.49 ± 19.6 bc	71.49 ± 19.6 bc	79.8 ± 8.3 cd
0.005	46.1 ± 4.17 b	46.1 ± 4.17 b	46.1 ± 4.17 b	62.6 ± 6.4 bc	62.6 ± 6.4 bc	67.9 ± 12.2 bc
0.001	37.42 ± 6.9 b	37.42 ± 6.9 b	37.42 ± 6.9 b	58.3 ± 7.2 b	58.3 ± 7.2 b	58.3 ± 7.2 b
Control	0 ± 0 a	0 ± 0 a	0 ± 0 a	0 ± 0 a	0 ± 0 a	0 ± 0 a

Concentrations	Dimethoate			Methyl parathion		
(%)	1 DAT	2 DAT	3 DAT	1 DAT	2 DAT	3 DAT
0.5	94.43 ± 4.83 ef	100 ± 0 f	100 ± 0 f	100 ± 0 e	100 ± 0 e	100 ± 0 e
0.1	82.73 ± 16.07 de	82.73 ± 16.08 de	82.73 ± 16.08 de	92.67 ± 6.42 e	92.67 ± 6.42 e	92.67 ± 6.42 e
0.05	79.8 ± 8.3 d	79.8 ± 8.3 d	79.8 ± 8.3 d	71 ± 12.71 d	71 ± 12.71 d	71 ± 12.71 d
0.01	45.5 ± 4.06 bc	52 ± 3.46 c	52 ± 3.46 c	55.33 ± 5.5 c	55.33 ± 5.5 c	55.33 ± 5.5 c
0.005	47.15 ± 9.33 bc	52.1 ± 3.6 c	52.1 ± 3.6 c	53.33 ± 5.7 c	53.33 ± 5.7 c	53.33 ± 5.7 c
0.001	36.31 ± 2.44 b	40.5 ± 4.7 bc	40.5 ± 4.7 bc	39.83 ± 2.02 b	39.83 ± 2.02 b	39.83 ± 2.02 b
Control	0 ± 0 a	0 ± 0 a	0 ± 0 a	0 ± 0 a	0 ± 0 a	0 ± 0 a

Means with the same letters are not significantly different by Duncan's multiple range test

day observation. Slight increase in mortality was observed for mealy bugs treated with dichlorovos and the percentage mortality increased to 83.3 and 60% for 0.5, 0.1%, respectively. Similarly, methyl parathion at same concentrations showed no significant variation in mortality. Chlorpyrifos and dimethoate showed similar mortality as in the second day observation. All the insecticides tested in the study at 0.005% were able to kill less number of females i.e., below 50%.

Dipping of mealy bugs in insecticides

Mortality percentage of mealy bugs on the infested tubers dipped in insecticides was shown in **Table 8**. Malathion at 0.5% showed 100% mortality in all three observations followed by concentrations 0.1 and 0.05% which showed no significant increase in mortality after the second day observation. Quinalphos at 0.5 and 0.1% showed similar mortality which differed significantly from that of insects treated at 0.05% and the other lower concentrations. Almost cent percentage mortality was obtained at 0.5 and 0.1% but failed to achieve complete control over the insects.

Complete mortality of mealy bugs was not recorded in all tuber pieces treated with dichlorovos at 0.5% even after the third day observation. Mortality was 86.1 and 76.5% for 0.5 and 0.1%, respectively which showed no increase according to the day after treatment. Dichlorovos at 0.05% showed 46.9% on the first day and increased to 68% mortality 2 days after treatment. But lower concentrations (0.005 and 0.001%) showed no significant difference in the mortality which ranged from 37.42-46.1%.

Chlorpyrifos at 0.5 recorded 100% mortality followed by 95% and 91.1% mortality recorded at 0.1 and 0.05%. There was no increase in mortality of above treatments according to the days but showed high mortality percentage than other insecticides at this concentration. Chlorpyrifos at 0.01% recorded 71% mortality on the first day which increased to 79% on the second day and was more effective in this concentration compared with other insecticides. Mortality of insects treated with 0.005 and 0.001% recorded mortality of 62.6 and 58.3% on the first day but mortality increased from 62.6 to 67.9% on the second day; else there was no increase in the mortality according to the days.

Dimethoate at 0.5% showed 100% mortality on the second day observation where as 0.1% recorded only 82.73%. Mortality was 79.8% for the insects treated with 0.05% but lower concentrations (0.01, 0.005 and 0.001%) recorded significantly less mortality than higher concentrations. Mortality percentage increased from 45.5 to 52, 47.15 to 52.1 and 36.3 to 40.5 on the second day observation for the insects treated with 0.01, 0.005 and 0.001% respectively but there was no increase in mortality on the third day after treatment.

Methyl parathion showed no increase in mortality according to the days after treatment and all insects treated with 0.5% were killed on the first day itself. There was no significant variation in mortality between the concentrations 0.5 and 0.1% which showed 100 and 92.67% mortality, respectively. But there was a significant variation in mortality for insects treated with 0.05% when compared with its higher levels and 71% of insects were killed after the treatment. Lower concentrations (0.01 and 0.005%) recorded similar mortality ranging from 53-55.3%. But almost 61% of insects were alive when treated with methyl parathion at 0.001%. There was no mortality recorded for control batches in all treatments and proved to produce no effect on the mealy bugs.

DISCUSSION

Compared with other insect pests, management of mealy bug was not found easier and was labeled as "hard to kill pests" (Lower 1968). Even though many chemical pesticides were employed for the management of mealy bugs, selection of appropriate insecticides have a crucial role for achieving proper control. Organophosphate insecticides have been documented as effective control measures against most root mealy bug species including *Rhizoecus falcifer* Kunckel d' Herculais (Huang *et al*. 1983). Chemical control of insect pests is the most opted method by farmers and management of this insect pest is of great importance for better cropping of this precious crop. The present study revealed that all the locally available insecticides tested in the present study provide satisfactory control of mealy bugs.

Malathion at the least concentration tested was able to achieve complete control over the 1st instars on the third day after treatment. But, quinalphos and methyl parathion at 0.005% was required to produce the same effect. All other insecticides also produced cent percentage mortality, but only at 0.05%. Whereas these concentrations were not able to kill the adult females even three day after treatment. Malathion, chlorpyrifos, dimethoate and methyl parathion at 0.5% killed all females on the third day after treatment. But other insecticides made only 90% effect and proved to be less effective in the control of females when compared with the other insecticides. Dipping with chlorpyrifos and methyl parathion at 0.5% gave 100 per cent effect on the first day itself and proved to be most effective in the management of this insect. Malathion and dimethoate also produced similar effect two days after the treatment. Dipping infested tubers for ten minutes in any of these insecticides can be recommended for proper management of this pest. Quinalphos and dichlorovos even at the high concentration used in the study failed to achieve complete control over the insects even after the third day but probably can be made effective with repeated treatments or increasing the concentration.

Most of the insecticides selected for the study were previously employed in the management of mealy bugs, but the dose and concentrations varies according to the insecticides and different species of mealy bugs. In a laboratory study, Singh *et al.* (1991) observed that fensulfothion was the most toxic insecticide to adult females of mango mealy bug, *Drosicha mangiferae* Green followed by dimethoate, quinalphos and methyl demeton. Karar *et al.* (2010) treated mango mealy bug with chlorpyrifos 40EC 50 ml/L and recorded 77.68% and 52.99% mortality 168 h after treatment on first instars and adult females, respectively.

Chacko *et al.* (1976) tested seven insecticides with concentrations of 0.02% each, in the laboratory against the coffee mealy bug, *Pseudococcus liliacinus* Cockerell and found that fenthion, methyl parathion, cartap and fenitrothion gave better initial kill than quinalphos and carbaryl. The effectiveness of sprays of ten insecticides for the control of *Planococcus pacificus* Cox on custard apple was determined both in laboratory and field in Karnataka and the results showed that, dimethoate, phosphamidon, dichlorvos and monocrotophos at 0.05% gave the best control (Shukla and Tandon 1984). Butani (1978) recommended spraying with malathion (0.04%) against young nymphs and with diazinon or monocrotophos (0.1%) against older nymphs and adults. Rao *et al.* (1988) tested efficacy of three insecticides *viz*., dichlorvos, monocrotophos and dimethoate each at 0.05% against grape mealy bug, *Maconellicoccus hirsutus* Green on two varieties of grapes and found that the per cent knockdown in colonies 10 days after spraying was 51 and 52% by dichlorvos and dimethoate, respectively. Baskaran *et al.* (1999) reported that monocrotophos (0.072%), malathion (0.25%), dimethoate (0.06%) and phosalone (0.175%) were evaluated for *Ferrisia virgata* Cockerell control and found that dimethoate and malathion were most effective. Chlorpyrifos was found effective against enset root mealy bug, *Cataenococcus ensete* Williams and Matile-Ferrero (Bekele 2001) and spherical mealy bug, *Nipaecoccus viridis* Newstead (Gross *et al.* 2001). Suresh *et al.* (2010) recommended application of organophosphate insecticides like chlorpyriphos 20 EC 2 ml/l, dimethoate 2 ml/l and profenofos 50 EC 2 ml/l, against the cotton mealy bug, *Phenacoccus solenopsis* Tinsley. Similarly, Saeed *et al.* (2007) tested profenofos and chlorpyriphos against the mealy bug, *Phenacoccus gossipiphilous* on cotton and obtained satisfactory control over this pest. Nikam *et al.* (2010) tested the laboratory and field efficacy of selected insecticides against cotton mealy bug. The results showed that quinalphos and thiodicarb were inferior in controlling the mealy bug population. In the present study, high concentrations of insecticides were required to kill the females than the 1st instars. Similar observations were made by Yousuf *et al.* (2007) as they found difficult to obtain chemical control with contact insecticides on the adult females and the larger nymphs. But, first instar nymphs coming out from the mealy cocoon for settlement were easily controlled. Khushk and Mal (2006) worked on the effect of chemical pesticides on the mealy bugs infesting cotton plant and recommended profenofos and chorpyrifos at a dose of 1litre per acre for satisfactory control up to five days. They also opined that second application can suppress the mealy bug incidence at a maximum level. In case of mealy bugs on elephant foot yam, even though most insecticides were able to suppress the population to a maximum level, repeated application should be done according to the emergence of crawlers, if any. These pests are difficult to control with a single insecticide application as most mealy bugs are concealed and not hit by contact sprays and concealed females establish large colonies in a short while. Therefore, establishment of young mealy bugs has to be prevented by applying insecticides several times until crawler production ceases. Similar strategy has to be employed for the control of the amorphophallus mealy bug, *R. amorphophalli* and crawler population has to be controlled by multiple dipping treatments which require only lower concentrations of insecticides.

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