Pest Management in Horticultural Ecosystems,
Vol. 16, No. 2 pp 108-119 (2010)

MANAGEMENT OF ROOT MEALYBUGS, *Geococcus* spp. IN BANANA *CV*. NENDRAN

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ABSTRACT : Soil ameliorants, botanicals, chemical insecticides and fungal bio-agents were screened against banana root mealybug, *Geococcus* spp. Among the soil ameliorants, application of sodium silicate and calcium oxide at the time of planting effectively reduced the population of root mealybug. Drenching of neem seed kernel extract (NSKE) @ 3 % at monthly intervals was superior to neem cake, neem oil and pongamia oil. The entomopathogenic fungus, *Cephalosporium lecanii* Zimmerman was the best among the three fungi screened. At five months after planting, *C. lecanii* recorded 1.95 colonies per sample followed by *Hirsutella* sp. (2.25 / sample) and the control recorded 5.70 per sample. Among the synthetic chemicals, drenching chlorpyriphos (0.05%) at monthly intervals @ 2.5 ml l^{-1} effectively reduced the root mealybug population and was found to be the best treatment. Field experiment conducted with the best treatment in each of the category and their combinations revealed that, almost all treatment combinations containing chlorpyriphos caused maximum reduction of root mealybug. Among the combinations without synthetic insecticides, sodium silicate (S) alone and its combination with NSKE and *C. lecanii* (SNV) were effective in reducing the mealybug population at sixth and seventh month of the crop. Application of chlorpyriphos gave the highest benefit cost ratio of 2.46 followed by sodium silicate (2.30).

Keywords : Banana, *Geococcus* spp., root mealybug, botanicals, bioagents, soil ameliorants

INTRODUCTION

Two species of root mealybugs *viz*., G*eococcus citrinus* Kuwana and *Geococcus coffeae* Green were found infesting the roots of different banana cultivars in Kerala (Smitha *et al*., 2005). The adults and crawlers suck sap from the lateral roots and as a result, the roots turn brown at the site of colonization and later dry up. Such roots cannot absorb water and nutrients from the soil. In severe case, the plants will topple down in wind due to destruction of anchoring roots. The bunch size is reduced and filling of fingers is adversely affected. Usually the infestation goes unnoticed as it occurs below the soil surface. This mealybug infestation was also observed in the roots of weeds seen in the banana field. *Cyperus kyllinga* Endlicher, *C. pangorei* Kunth, *Ludwigia parviflora* Roxb., *Centella asiatica* (L.), *Axonopus compressus* (Swartz), *Commelina* *bengalensis* L., *Colocasia antiquorum* Schott are recorded as collateral hosts for this mealy bug (Smitha *et al*., 2005). Considering the wide occurrence of the pest and damage caused to the commercial cultivation of Nendran banana in Kerala, a detailed study was conducted on the management of this pest.

MATERIALS AND METHODS

The investigation on the management of root mealybug was carried out in a farmers' field at Mannarkkad, Palakkad district, Kerala during the period from October 2004 to February 2006. The treatment materials under different category were screened under field condition. After the initial field screening, a field trial was laid out selecting the best treatment from each category and these treatments were evaluated individually and in all possible combinations.

Screening experiments

Four each of soil ameliorants, botanicals and chemical insecticides and three fungal bioagents (Table 1) were evaluated under field conditions against root mealybug. The experiment was laid out in Randomized Block Design with four replications except for the bio-agents where five replications were maintained. Control plots were maintained separately where plants were drenched with water. Six plants were maintained per replication. The trials were conducted during the period from June 2005 to December 2005. The observations on mealybug population from a soil block of size $15\times15\times15cm^3$ from the root zone of the plant were recorded for five months at monthly intervals. The colony count before the application of the treatments was also recorded. The quantity of the solution used was five litres per plant.

Soil ameliorants

Calcium carbonate, Calcium oxide, Sodium silicate and Salicylic acid (Table 1) were used in this study. Calcium carbonate shells were ground for the purpose of application as such, and heated to obtain fresh calcium oxide. All the soil ameliorants except salicylic acid were applied once, as basal application, at the time of planting of suckers. Salicylic acid was drenched at monthly intervals for five months beginning from one month after planting of suckers.

Botanical insecticides

Four botanical insecticides *viz.*, neem cake, neem seed kernel extract, neem oil and pongamia oil (Table 1) were evaluated. All the botanical insecticides except neem cake were drenched at monthly intervals for five months beginning from one month after planting of suckers. Neem cake was applied as basal application at one month after planting.

Fungal bioagents

Three fungal bio-agents, *viz.*, *Beauveria bassiana* Balsamo, *Cephalosporium lecanii* and *Hirsutella* sp. (Table 1) were evaluated. The pure culture of *B. bassiana* and *Hirsutella* sp. multiplied in the Entomology laboratory, College of Horticulture, Vellanikkara were used for the experiment. They were mass multiplied in half-cooked sorghum grains in 250g packets. The sterilized grains were inoculated with ten days old fungal culture grown in PDA medium. For the fungus, *Cephalosporium lecanii*, a formulated product, Ecocil was used. Spore count was assessed using Haemocytometer and the required concentration was prepared in 0.1 per cent teepol solution. Before screening, pathogenicity of the entomopathogenic fungi was tested under laboratory conditions and LD_{50} values were worked out. In the field, the fungal suspension was drenched around the plant and the basin was covered with top soil.

Chemical insecticides

Four chemical insecticides, *viz.*, malathion, quinalphos, triazophos and chlorpyriphos (Table 1) were screened. The insecticide solutions were drenched in the basin of the plant at monthly intervals.

Table 1. Treatments tested against root mealybug

Type of material	Treatments	Concentration/ Quantity	Mode of application	Frequency of application
Soil ameliorants	1. Calcium carbonate	500g/plant	Soil application	Once at planting
	2. Calcium oxide	280g/plant	Soil application	Once at planting
	3. Sodium silicate	200g/plant	Soil application	Once at planting
	4. Salicylic acid	0.4 %	Drench	Monthly
Botanicals	1. Neem cake	1 kg/plant	Soil application	Once at planting
	2. Neem Seed Kernel Extract	3%	Drench	Monthly
	3. Neem Oil	3%	Drench	Monthly
	4. Pongamia Oil	3%	Drench	Monthly
Fungal bioagents	1. *Beauveria bassiana*	$1x10^7$ spores ml^{-1}	Drench	Monthly
	2. *Hirsutella thompsonii*	$1x10^7$ spores ml^{-1}	Drench	Monthly
	3. *Cephalosporium lecanii*	7g/litre	Drench	Monthly
Synthetic chemicals	1. Malathion	1ml $litre^{-1}$ (0.05%)	Drench	Monthly
	2. Quinalphos	2ml $litre^{-1}$ (0.05%)	Drench	Monthly
	3. Triazophos	1.25ml $litre^{-1}$ (0.05%)	Drench	Monthly
	4. Chlorpyriphos	2.5ml $litre^{-1}$ (0.05%)	Drench	Monthly
Control	Water	5 litre $plant^{-1}$	Drench	Monthly

Field experiment

A field trial was conduced in a root mealybug infested banana field at Thannerpanthal area of Palakkad district with the best treatments selected from the screening experiment. Fifteen combinations (Table 2) were designed and the experiment was laid out in a Randomized Block Design. Two replications were maintained for each treatment combination and nine plants were maintained per replication. Calcium oxide was applied to all plants at the rate of 500g per pit. Sodium silicate was applied as basal application at one month after planting and all the other treatments were applied as soil drenching at bimonthly intervals for seven months commencing from one month after planting of suckers. Five litres of solution was applied per plant. One control plot was also maintained, which was drenched with five litres of water at bimonthly intervals. Observations on mealybug intensity, growth and yield parameters and bunch weight were recorded. Observations on colony count were made for six months and per cent reduction in population over control was calculated. The colony count before the application of the treatments was also recorded. The average of nine plants gave the intensity for one replication.

Data recording and Statistical analysis

Mealybug intensity was recorded by counting the number of colonies per unit sample. Sampling was started from one month after application onwards. The average of five plants gave the intensity for one replication of a treatment. The intensity was recorded as number of colonies per sample. The data on population were transformed and subjected to Randomized Block Design (RBD) ANOVA and means were separated by Fisher's Least Significant Difference Test. Data on growth and yield parameters and bunch weight were subjected to ANOVA test and Duncan's Multiple Range Test separated the means.

RESULTS AND DISCUSSION

Soil ameliorants

The screening of four soil ameliorants/ chemicals *viz*., calcium carbonate, calcium oxide, sodium silicate and salicylic acid, revealed that application of sodium silicate (200g/plant) and calcium oxide (280g/plant) at the time of planting, brought down the root mealybug population effectively. Significantly less number of root mealybug colonies (1.06 / sample) was recorded in plots where, sodium silicate was applied at banana root zone at two months after planting (MAP). The treatments calcium carbonate (1.19 colonies) and calcium oxide (1.25 colonies) were on par with sodium silicate. Salicylic acid drenching recorded 1.88 colonies, which was significantly less effective compared to the above three ameliorants but was superior to control (3.69 colonies) (Table 3). Sodium silicate maintained the superiority at all intervals of observation. Many workers reported the effect of sodium silicate in pest management. Field and laboratory studies carried out in the German Federal Republic revealed that a foliar application of one per cent sodium silicate to spring wheat reduced the population of aphids, *Sitobion avenae* (F.) and *Metopolophium dirhodum* (Wlk.) by varying degrees depending on the wheat variety, degree of infestation and environmental factors (Kleber, 1983). Warnhjelm (1985) also reported that spraying the plants with solutions of sodium silicate or silicic acid could enhance the defense of plants against insect pest.

Botanical insecticides

Neem seed kernel extract (NSKE) @ 3% was the most effective treatment among botanicals with 1.38 per sample at four months of planting followed by neem oil (1.88/15 cm^3 soil) as against 4.94/15 cm^3 soil in control plants (Table 4). There is no information on the effect of botanicals on root mealybugs but the effectiveness of NSKE at 5 and 2.5 per cent on first instar nymphs of *Maconellicoccus hirsutus* Green after 24 and 48 hours of treatment was reported by Verghese

Table 2. Details of treatments imposed in the field experiment for the management of root mealybug

S. No.	Treatment
T_1	Sodium silicate @ 200g per plant at the time of planting **(S)**
T_2	Drenching 5 l of NSKE 3% **(N)**
T_3	Drenching 5 l of chlorpyriphos 0.05% **(C)**
T_4	Drenching 5 l *Cephalosporium lecanii* @ 1 x 10^7 spores ml $^{-1}$at bimonthly intervals **(V)**
T_5	Sodium silicate @ 200g per plant at the time of planting + drenching 5 l of NSKE 3% **(SN)**
T_6	Sodium silicate @ 200g per plant at the time of planting + drenching 5 l of Chlorpyriphos 0.05% **(SC)**
T_7	Sodium silicate @ 200 per plant at the time of planting + drenching 5 l of *Cephalosporium lecanii* @ 1x 10^7 spores ml^{-1} at bimonthly intervals **(SV)**
T_8	Drenching 5 l each of NSKE 3%, and Chlorpyriphos 0.05% **(NC)**
T_9	Drenching 5 l each of NSKE 3% and *Cephalosporium lecanii* @ 1x10^7 spores ml^{-1} at bimonthly intervals **(NV)**
T_{10}	Drenching 5 l each of Chlorpyriphos 0.05% and *Cephalosporium lecanii* @ 1x 10^7 spores ml^{-1} at bimonthly intervals **(CV)**
T_{11}	Sodium silicate @ 200g per plant at the time of planting + drenching 5 l each of NSKE 3%, Chlorpyriphos 0.05% at bimonthly intervals (SNC)
T_{12}	Sodium silicate @ 200g per plant at the time of planting + drenching 5 l each of NSKE 3% and *Cephalosporium lecanii* @ 1x10^7 spores ml^{-1} at bimonthly intervals **(SNV)**
T_{13}	Sodium silicate @ 200g per plant at the time of planting + drenching 5 l each of Chlorpyriphos 0.05% and *Cephalosporium lecanii* @ 1x 10^7 spores ml^{-1} at bimonthly intervals **(SCV)**
T_{14}	Drenching 5 l each of NSKE 3%, Chlorpyriphos 0.05% and *Cephalosporium lecanii* @ 1x10^7 spores ml^{-1} at bimonthly intervals **(NCV)**
T_{15}	Sodium silicate @ 200g per plant at the time of planting + drenching 5 l each of NSKE 3%, Chlorpyriphos 0.05% and *Cephalosporium lecanii* @ 1x10^7 spores ml^{-1} at bimonthly intervals **(SNCV)**
T_{16}	Drenching 5 l of water **(Control)**

Table 3. Effect of soil ameliorants on the population of root mealy bug infesting banana

Treatment	* Root mealy bug population (No. of colonies / 15 cm³ soil)						
	Pre-count	**2 MAP**	**3 MAP**	**4 MAP**	**5 MAP**	**6 MAP**	**Mean** population
Calcium carbonate| @ 500 g plant^{-1}	6.69[a] (2.68)	1.25[c] (1.32)	1.38[c] (1.37)	1.85[c] (1.52)	1.81[c] (1.52)	1.69[c] (1.48)	1.59[c] (1.40)
Calcium oxide @ 280 g plant^{-1}	6.63[a] (2.61)	1.19[c] (1.30)	0.81[d] (1.15)	1.38[d] (1.32)	0.94[d] (1.19)	1.00[d] (1.22)	1.10[d] (1.29)
Sodium silicate @ 200 g plant^{-1}	6.06[a] (2.55)	1.06[c] (1.25)	0.44[d] (0.97)	1.00[d] (1.23)	0.69[d] (1.09)	0.63[e] (1.06)	0.76[e] (1.12)
Salicylic acid @ 0.4 %	6.00[a] (2.54)	1.88[b] (1.54)	2.06[b] (1.59)	2.63[b] (1.75)	2.38 [b] (1.69)	2.31[b] (1.68)	2.25[b] (1.66)
Control (Water drench)	6.25[a] (2.59)	3.69[a] (2.05)	3.44[a] (1.98)	4.06[a] (2.14)	3.94[a] (2.10)	3.88[a] (2.09)	3.80[a] (2.07)

MAP- Months after planting
* Mean of four replications
Figures followed by the same alphabets did not differ significantly (P=0.05)
Figures in parentheses are square root transformed (x+0.5) values

Table 4. Effect of botanical insecticides on the population of root mealy bug infesting banana

Treatment	* Root mealy bug population (No. of colonies / 15 cm³ soil)						
	Pre count	**2 MAP**	**3 MAP**	**4 MAP**	**5 MAP**	**6 MAP**	**Mean population**
Neem cake @1 kg plant $^{-1}$	9.63 [a] (3.18)	2.38[c] (1.69)	2.56 [c] (1.78)	2.06 [b] (1.60)	2.25 [b] (1.66)	2.19 [b] (1.68)	2.29[b] (1.67)
NSKE @ 3 %	9.25[a] (3.12)	1.94[c] (1.55)	1.19[d] (1.29)	1.56 [c] (1.43)	1.38[d] (1.36)	1.38[d] (1.39)	1.49[d] (1.41)
Neem oil emulsion @ 3%	9.50 [a] (3.16)	2.38[c] (1.69)	1.56 [b] (1.43)	1.63[c] (1.46)	1.88 [c] (1.54)	1.81[c] (1.56)	1.85[c] (1.53)
Pongamia oil emulsion @ 3%	9.38[a] (3.13)	3.56 [b] (2.04)	2.50[b] (1.73)	2.00[c] (1.58)	2.50[b] (1.73)	2.50[b] (1.73)	2.61[b] (1.76)
Control (Water drench)	9.38[a] (3.14)	5.94[a] (2.54)	4.25[a] (2.18)	4.69[a] (2.28)	4.94[a] (2.34)	4.75[a] (2.29)	4.91[a] (2.33)

MAP- Months after planting
* Mean of four replications
Figures followed by the same alphabets did not differ significantly (P=0.05)
Figures in parentheses are square root transformed (x+0.5) values

(1997). Mourier (1997) in a laboratory test in Denmark also reported that the cassava leaves treated with NSKE were less attractive to first instar nymphs of cassava mealybug, *Phenacoccus manihoti* (Mat. Ferr.) and those, which fed on the treated leaves, died during the second instar stage. They also reported that in green house studies, the application of NSKE at weekly intervals protected cassava against established early instar nymphs of cassava mealybug. There was no significant difference in concentrations *viz*., 1, 10 and 25 per cent. Satyanarayana *et al*. (2003) also reported the efficacy of five per cent NSKE on *Maconellicoccus hirsutus* in Karnataka. Observations on mortality recorded at 6, 12, 24 and 36 hours after treatment (30 ml of 5 per cent extract) showed that NSKE recorded the highest per cent mortality (68.50%).

Bioagents

Cephalosporium lecanii was superior among the three entomopathogenic fungi screened, by bringing down the mealybug population to 1.95 colonies at six months after planting followed by *Hirsutella* sp. (2.25) and *B. bassiana* (2.45) compared to control (5.70) (Table 5). The effectiveness of *C. lecanii* in the present study is in conformity with the findings of Kulkarni *et al*. (2003) against *Ferrisia virgata* and *Planococcus citri* on pomegranate. The better performance of *Hirsutella* sp. in the present study is in agreement with Garcia *et al*. (1990), who found that *Hirsutella cryptosclerotium* caused mortality to the fruit mealybug, *Rastrococcus invadens* on mango.

Chemical insecticides

Field screening of chemical insecticides revealed the superiority of chlorpyriphos against root mealybug. Quinalphos was also effective in controlling the mealybug. At three months after planting, significantly less number of colonies was observed in chlorpyriphos (1.06). Quinalphos was the next effective chemical with 1.69 colonies followed by triazophos (2.19) and these two treatments were on par. Though malathion supported higher number of colonies (2.81), it was superior to control (4.25 colonies). The present study on the effect of chlorpyriphos is in agreement with the report of Kumar and Prakasan (1992) that chlorpyriphos resulted in better control of root mealybugs in general. Hara *et al*. (2001) also reported that, drenching of chlorpyriphos twice at two weeks interval controlled root mealybugs in general. Rajagopal and Krishnamoorthy (2003) recommended the use of persistent insecticides like chlorpyriphos @ 2-3 ml^{-1} for the control of root mealybugs in general.

Field evaluation

Field evaluation against root mealybugs was done with the best treatment each from different screening experiments. Selected treatments were evaluated singly and in all possible combinations (Table 2). The per cent reduction in mealybug population over control showed that almost all combinations containing chlorpyriphos recorded higher per cent reduction of root mealybug during different intervals of observation. The treatment combinations which recorded higher per cent reduction of root mealybug were chlorpyriphos alone (C), sodium silicate + chlorpyriphos (SC), sodium silicate + chlorpyriphos + *C. lecanii* (SCV) and chlorpyriphos + *C. lecanii* (CV). At fifth month of the crop growth, two months after second treatment application, SCV had the highest per cent reduction of 65.63. However, SC and chlorpyriphos also gave the same per cent reduction (62.50) in population (Table 7). The treatments CV (59.38%) and NCV (50.00%) were statistically on par with SCV. This effect might be due to the fumigant action of chlorpyriphos. Several workers reported the use and effectiveness of chlorpyriphos in controlling root mealybugs (Kumar and Prakasan, 1992; Hara *et al*. 2001; Rajagopal and Krishnamoorthy, 2003).

Among the treatments without synthetic insecticides, sodium silicate alone and in combination with NSKE and *C. lecanii* was better

Table 5. Effect of fungal bioagents on the population of root mealybug, *Geococcus* spp. infesting banana

Treatment	* Root mealy bug population (No. of colonies/ 15 cm^3 soil)						
	Precount	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	Mean population
Beauveria bassiana 1x10 ^{7} spores ml^{-1}	5.05^a (2.36)	1.75^b (1.49)	2.60^b (1.76)	2.40^b (1.70)	2.40^b (1.69)	2.45^b (1.72)	2.30^b (1.67)
Hirsutella sp. 1x10^7 spores ml^{-1}	4.60^{ab} (2.25)	1.60^b (1.45)	2.15^{bc} (1.63)	2.00^{bc} (1.58)	2.15^b (1.63)	2.25^c (1.66)	2.05^c (1.59)
Cephalosporium lecanii 1x10^7 spores ml^{-1}	4.20^b (2.16)	1.05^c (1.24)	1.90^c (1.53)	1.65^c (1.46)	1.90^c (1.53)	1.95^d (1.56)	1.65^d (1.47)
Control (Water drench)	4.45^{ab} (2.23)	3.60^a (2.02)	4.35^a (2.20)	4.90^a (2.32)	5.20^a (2.37)	5.70^a (2.48)	4.35^a (2.20)

MAP- Months after planting
* Mean of five replications
Figures followed by the same alphabets did not differ significantly (P=0.05)
Figures in parentheses are square root transformed (x+0.5) values

Table 6. Effect of synthetic insecticides on the population of root mealybug, *Geococcus* spp. infesting banana

Treatment	* Root mealy bug population (No. of colonies/ 15 cm^3 soil)						
	Precount	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	Mean population
Malathion @ 0.05 %	6.19^a (2.58)	4.13^b (2.15)	2.81^b (1.82)	1.63^b (1.46)	3.06^b (1.88)	2.75^b (1.80)	2.88^b (1.84)
Quinalphos @ 0.05 %	6.00^a (2.53)	3.31^{bc} (1.94)	1.69^c (1.48)	1.00^c (1.23)	1.35^c (1.36)	1.25^c (1.32)	1.72^d (1.49)
Triazophos @ 0.05 %	7.69^a (2.84)	3.75^b (2.06)	2.19^{bc} (1.64)	1.38^b (1.37)	1.75^c (1.48)	1.44^c (1.39)	2.10^c (1.64)
Chlorpyrifos @ 0.05 %	7.94^a (2.90)	2.44^c (1.70)	1.06^d (1.25)	1.00^c (1.23)	0.88^d (1.17)	0.69^d (1.09)	1.21^e (1.31)
Control (Water drench)	7.13^a (2.76)	6.31^a (2.60)	4.25^a (2.17)	4.19^a (2.16)	4.80^a (2.30)	4.50^a (2.24)	4.31^a (2.30)

MAP- Months after planting
* Mean of four replications
Figures followed by the same alphabets did not differ significantly (P=0.05)
Figures in parentheses are square root transformed (x+0.5) values

Table 7. Per cent reduction in the population of root mealybug, *Geococcus* spp. infesting banana in different treatments

Treatment		* Per cent reduction over control					
	1MAT	**2MAT**	**3MAT**	**4MAT**	**5MAT**	**6MAT**	**7MAT**
S	28.82^{def} (0.559)	27.44^{cdef} (0.551)	46.53^{ab} (0.750)	46.88^{bcd} (0.754)	31.43^{d} (0.589)	52.94^{abc} (0.815)	54.89^{abc} (0.835)
N	20.88^{ef} (0.465)	15.04^{fg} (0.398)	34.72^{bcd} (0.627)	34.38^{def} (0.623)	24.29^{d} (0.514)	32.65^{de} (0.608)	39.93^{cd} (0.684)
C	58.97^{a} (0.876)	42.73^{abc} (0.712)	61.46^{a} (0.902)	62.50^{ab} (0.913)	58.45^{ab} (0.871)	60.68^{ab} (0.8930)	66.52^{ab} (0.955)
V	15.88^{f} (0.407)	12.66^{g} (0.361)	20.14^{d} (0.458)	25.00^{f} (0.524)	26.79^{d} (0.544)	26.37^{e} (0.539)	31.54^{d} (0.596)
SN	38.09^{bcd} (0.665)	22.43^{defg} (0.493)	32.29^{bcd} (0.604)	43.75^{cde} (0.722)	33.93^{cd} (0.619)	53.14^{abc} (0.817)	58.12^{abc} (0.868)
SC	58.97^{a} (0.876)	54.89^{ab} (0.834)	64.58^{a} (0.934)	62.50^{ab} (0.913)	58.45^{ab} (0.871)	62.35^{a} (0.910)	64.79^{ab} (0.937)
SV	26.32^{def} (0.533)	24.81^{defg} (0.520)	31.94^{bcd} (0.594)	37.5^{def} (0.6580)	29.05^{d} (0.564)	51.47^{abc} (0.800)	58.01^{abc} (0.867)
NC	41.03^{abcd} (0.695)	37.72^{bcd} (0.661)	38.19^{bc} (0.666)	40.63^{def} (0.691)	38.81^{cd} (0.671)	52.00^{abcd} (0.785)	51.56^{bc} (0.801)
NV	24.27^{def} (0.515)	20.05^{efg} (0.464)	22.92^{cd} (0.488)	28.13^{ef} (0.558)	29.17^{d} (0.570)	35.59^{cde} (0.638)	41.55^{cd} (0.700)
CV	56.03^{ab} (0.847)	37.22^{bcd} (0.655)	61.46^{a} (0.902)	59.38^{abc} (0.881)	60.83^{a} (0.895)	60.88^{ab} (0.895)	63.29^{ab} (0.920)
SNC	48.09^{abc} (0.766)	39.35^{bcd} (0.674)	46.53^{ab} (0.750)	46.88^{bcd} (0.752)	58.45^{ab} (0.871)	62.55^{a} (0.912)	65.13^{ab} (0.940)
SNV	26.32^{def} (0.533)	22.18^{defg} (0.486)	28.82^{cd} (0.561)	34.38^{def} (0.623)	31.55^{d} (0.594)	43.33^{bcde} (0.718)	58.12^{abc} (0.868)
SCV	58.53^{a} (0.874)	57.52^{a} (0.861)	61.46^{a} (0.902)	65.63^{a} (0.945)	60.95^{a} (0.896)	63.82^{a} (0.926)	71.47^{a} (1.009)
NCV	48.09^{abc} (0.766)	34.59^{cde} (0.626)	49.65^{ab} (0.782)	50.00^{abcd} (0.785)	41.19^{bcd} (0.694)	52.94^{abc} (0.815)	53.28^{bc} (0.818)
SNCV	34.27^{cde} (0.621)	32.46^{cde} (0.606)	37.85^{bc} (0.661)	43.75^{cde} (0.722)	51.07^{abc} (0.796)	59.02^{ab} (0.877)	61.57^{ab} (0.902)

MAT- Months after treatment *Mean of two replications
Figures in parentheses are angular transformed values
S- Sodium silicate, N-Neem Seed Kernel Extract, C - Chlorpyriphos, V- *Cephalosporium lecanii*

Table 8. Effect of different treatments on yield and yield parameters of banana

Treatment	*Plant height (cm)	*Girth at 1 m height (cm)	*No. of leaves	*No. of hands	*No. of fingers/hand	*Finger length (cm)	*Finger girth (cm)	*Bunch weight (kg/plant)	Benefit Cost ratio
S	310.67_{abc}	42.54^{abcdef}	7.25^{a}	5.09^{de}	10.34^{g}	22.49^{ab}	14.69^{a}	10.11^{def}	2.30
N	308.42_{abc}	42.80^{abcdef}	6.34^{bcd}	5.42^{bcd}	11.84^{de}	22.69^{a}	13.32^{c}	9.83^{fg}	1.86
C	319.50_{a}	44.75^{a}	5.25^{ef}	5.59^{b}	13.84^{a}	20.75^{e}	12.72^{e}	11.43^{a}	2.46
V	320.67_{a}	44.29^{ab}	6.25^{bcd}	5.25^{bcde}	13.00^{abc}	20.81^{de}	13.19^{cd}	10.32^{de}	1.87
SN	308.58_{abc}	41.54^{bcdef}	6.44^{bcd}	5.25^{bcde}	10.50^{efg}	22.69^{a}	14.81^{a}	10.18^{de}	1.80
SC	312.87_{abc}	39.92^{f}	5.92^{d}	5.25^{bcde}	11.84^{de}	21.13^{de}	13.84^{b}	10.19^{de}	1.98
SV	304.59_{abc}	40.09^{f}	6.42^{bcd}	4.92^{e}	10.67^{fg}	22.00^{c}	13.32^{c}	9.88^{efg}	1.89
NC	317.25_{abc}	43.34^{abcde}	6.67^{bc}	5.59^{b}	12.50^{bcd}	22.25^{abc}	12.69^{e}	10.52^{cd}	1.80
NV	312.58_{abc}	42.25^{abcdef}	6.17^{cd}	5.00^{e}	12.00^{cde}	22.13^{bc}	12.13^{f}	10.25^{de}	1.66
CV	316.25_{abc}	43.50^{abcd}	4.84^{f}	5.92^{a}	13.50^{ab}	20.81^{de}	12.72^{e}	11.26^{ab}	2.03
SNC	298.33^{bc}	40.55^{ef}	6.29^{bcd}	5.17^{cde}	11.84^{de}	20.75^{e}	13.66^{b}	10.43^{cd}	1.69
SNV	297.84_{c}	40.67^{def}	6.75^{b}	5.50^{bc}	11.84^{de}	21.25^{d}	13.63^{b}	9.67^{fg}	1.62
SCV	302.30_{abc}	41.12^{cdef}	6.20^{bcd}	5.19^{cde}	11.50^{def}	19.44^{f}	14.63^{a}	10.19^{de}	1.73
NCV	319.24_{ab}	43.89^{abc}	6.17^{cd}	5.17^{cde}	13.00^{abc}	22.25^{abc}	11.69^{g}	10.82^{bc}	1.60
SNCV	298.08^{c}	40.46^{ef}	5.92^{d}	4.92^{e}	11.34^{efg}	20.81^{de}	13.81^{b}	9.54^{g}	1.35
Control	317.75_{abc}	43.50^{abcd}	5.40^{e}	5.47^{bc}	13.33^{ab}	20.75^{e}	12.94^{de}	7.88^{h}	1.93

* Mean of two replications, S- Sodium silicate, N- Neem Seed Kernel Extract, C- Chlorpyriphos, V- *Cephalosporium lecanii*
Figures followed by the same alphabets did not differ significantly at P=0.05

than the other treatment combinations in reducing the mealybug population at sixth and seventh month of the crop. Sodium silicate might deposit silicon in the roots, which provide a mechanical barrier that interferes with feeding by mealybug. Similar results were reported by Jair *et al*. (2004) with *Schizaphis graminum* with sorghum plants treated with silicon. The effectiveness of NSKE on mealybugs was in agreement with the findings of Verghese (1997) and Mourier (1997).

Kulkarni *et al*. (2003) reported that *C. lecanii* at concentrations ranging from 2 to 6 g l^{-1} was effective against *F. virgata* and *P. citri* on pomegranate. However in the present study, the additive effect of *C. lecanii* was not obtained in treatment combinations. The laboratory experiment on the compatibility of *C. lecanii* with chlorpyriphos showed the inhibition of *C. lecanii*, which may be the reason for the non-additive effect. Manjunatha *et al.* (2006) also reported the inhibition in the growth of *C. lecanii* due to chlorpyriphos.

No significant association could be observed between per cent reduction in mealybug population and yield parameters in the field experiment. However all the treatments yielded significantly more than control (Table 8). Highest yield was recorded in the treatment, chlorpyriphos alone (11.43 kg /plant) followed by chlorpyriphos + *C. lecanii* (CV) (11.26 kg). Benefit: Cost (B:C) ratio for different treatments indicated chlorpyriphos as the most economical with the highest total benefit (Rs. 4, 88,633 ha^{-1}) and B:C of 2.46 followed by sodium silicate alone with total benefit 4, 35,195 and B:C of 2.30 and chlorpyriphos + *C. lecanii* (2.03) (Table 8). The high cost of *C. lecanii* in the combination, chlorpyriphos + *C. lecanii* was the reason for a low B:C ratio compared to sodium silicate alone irrespective of the high total benefit of Rs. 4, 81, 793 ha^{-1}. Sodium silicate was applied once and its cost was very less compared to *C. lecanii*. Though the treatments, NSKE + chlorpyriphos + *C. lecanii* (NCV), NSKE + chlorpyriphos (NC) and sodium silicate + neem seed kernel extract (NSKE) + chlorpyriphos (SNC) recorded high total benefits (Rs.4, 62,555ha^{-1} and Rs. 4,50,158 $ha^{-1}$and Rs.4, 45,883 ha^{-1} respectively), the B:C ratio was less (1.80:1,1.60:1 and 1.69:1 respectively) in these treatments compared to control (1.93:1). The labour cost for NSKE preparation and the material cost of *C. lecanii* increased the total cost in these treatment combinations. From the results obtained in this study, it can be concluded that the application of sodium silicate at the time of planting and monthly drenching of botanicals in rotation with chlorpyriphos can effectively and economically manage root mealybugs in banana cv. Nendran.

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