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Studies on evaluation of some adjuvants against *Phenacoccus solenopsis* under laboratory conditions

Rajesh Illathur, R Philip Sridhar and JS Kennedy

Abstract
Mealybugs (Hemiptera: Pseudococcidae) are important insect pests in worldwide. Among different organic solvents tested for wax removal of *P. solenopsis*, hexane at 20 ml per litre recorded the highest per cent of wax removal (52.27 per cent) and among the natural oils, lemongrass oil at 20 ml per litre recorded the highest per cent of wax removal (63.58 per cent) followed by citronella oil (59.12 per cent of wax removal). After combining these oils (lemongrass oil and citronella oil, sweet flag oil), castor soap and custard apple powder with hexane against *P. solenopsis*, revealed that lemongrass oil combined with hexane at 20.0 ml per litre recorded the highest per cent removal of wax (71.36 per cent), followed by citronella oil mixed with hexane at 20.0 ml per litre recorded the highest per cent removal of wax (69.90 per cent).

Keywords: *Phenacoccus*, *Lecanicilium*, lemongrass oil, citronell oil

Introduction
Mealybugs are small, soft-bodied, plant sucking insects, which embrace the second largest family of scale insects (Pseudococcidae) with approximately 2000 species belonging to 300 genera and common name is due to the waxy material which covers the bodies of adult females (Miller and Williams 1997; Downie and Gullan 2004). The mealy bug, *Phenacoccus solenopsis* (Tinsley) (Hemiptera: Pseudococcidae) has been observed, damaging cotton crop very seriously from 2004-05 in Gujarat (Jhala *et al*., 2008). Chemical pesticides are generally used to protect crops and to kill pests. Use of synthetic pesticides causes some unfortunate consequences like environmental pollution, pest resistance and toxicity to other non-target organisms. Microbial control is a powerful pest management tactic, which involves the purposeful manipulation of pathogenic microorganisms to ensure a reduction in pestilence of a pest. This approach is a part of applied biological control in which the role of human agency is quite imperative. *Lecanicillium lecanii* (= *Verticillium lecanii*) (Zimm.) Zare & W. Gams is one of the most promising fungal species for control of whiteflies, aphids and other insect pests.

Materials and Methods
2. Evaluation of synergism / antagonism in the efficacy of entomopathogenic fungi against selected mealybugs through co-administration with some adjuvants under both laboratory and pot conditions

2.1 Estimation of different solvents and chemicals to dissolve the wax of mealybugs
Laboratory experiments were carried out to identify the suitable agent for removing the waxy coat from mealybug. 36 different adjuvants *viz.*, chloroform, hexane, absolute alcohol, acetone, soap (detergent) solution, clove oil (*Syzygium aromaticum* L.), Sheekai (*Acacia concinna* (Wlll) D.C., lemongrass oil (*Cymbopogon citratus* L.), citronella oil (*Cymbopogon nardus* L. Rendle), peppermint oil (*Mentha pipperia* L.), castor oil (*Ricinus communis* L.), neem oil (*Azadirachta indica* L.), eucalyptus oil (*Eucalyptus globus*), soap oil, pungam oil (*Pongamia* pinnata L.), coconut oil (*Cocos nucifera* Linn.), mustard oil (*Brassica nigra* L.), mahua oil (*Madhuca indicum* L.), Gingelly oil (*Sesamum indicum* L.), rose water, sunflower oil (*Helianthus annuus* L.), Tutuvalai (*Solanum trilobatum* L.) powder, hibiscus powder (*Hibiscus rosa sinensis L.)*, Amla (*Phyllanthus emblica* L.) powder, *cynodon* powder, arappu Thool (*Albizia amara* L.*)* powder, limonene powder, multani powder, poduthalai (*phyla nodiflora* L.) powder, vallarai (*Centella asiatica* L.) powder, avaaram poo (*Senna auriculata* L.) powder, Sweet flag (*Acarus calamus)* oil, *Smilax chinensis powder*, nilavembu

(*Andrographis paniculata* L.) Powder, custard apple (*Annona reticulate* L.) powder, green gram (*Vigna radiate* L.) powder, adatoda (*Justica adhatoda* L.) powder and castor soap were used. Treatments were imposed for removal of wax by measuring the weight of wax for respective chemical and placed in a respective petridish (Plate 1). The treatment details and concentrations used are as follows

Treatment No.	Concentration (ml per litre)		
	Chloroform, hexane, ethane and acetone, and Soap (detergent)	**Tutuvalai powder, hibiscus powder, sheekai, amla powder, *Cynodon* powder, arapatul powder, limonene powder, multani powder, *Phyla nodiflora* powder, vallarai powder, avaaram poo powder, *Smilax chinensis powder*, nilavembu powder, green gram powder, adatoda powder**	**Clove oil, lemongrass oil, citronella oil, peppermint oil, castor oil, neem oil, eucalyptus oil, soap oil, pungam oil, coconut oil, mustard oil, mahua oil, gingelly oil, rose water, sunflower oil, *and* sweetflag oil**
T1	0.5	0.5	0.5
T2	1.0	1.0	1.0
T3	1.5	1.5	1.5
T4	2.0	2.0	2.0
T5	Water	Water	Water

The concentrations of various solvents (1% solvent, 1% surfactant and emulsified with 2% Tween) were applied into the petridish containing the wax particles and kept for one hour. After one hour, the solvents were dried and taken the weight of the wax dissolved and in case of oils (1% oil, 1% surfactant, 4% citric acid and emulsified with 2% Tween) after one hour, oils were filtered through muslin cloth and taken the weight of the wax remained and calculated the per cent wax removed by the respective chemical as follows:

$$\text{Per cent wax removal} = \frac{\text{Weight of wax dissolved after treatment}}{\text{Total weight of wax (Boopathi, 2015)}} \times 100$$

Table 1: Effect of solvents on removal of *Phenacoccus solenopsis* wax

Concentration (ml per litre)	Weight of wax (mg) from 20 adults*											
	Chloroform			Hexane			Ethanol			Acetone		
	Before solvent	After solvent	Wax removal (%)	Before solvent	After solvent	Wax removal (%)	Before solvent	After solvent	Wax removal (%)	Before solvent	After solvent	Wax removal (%)
5	2.236	1.466	34.41^{d} (36.22)	2.173	1.336	38.37^{d} (38.56)	2.303	1.683	27.05^{d} (31.66)	2.283	1.673	26.70^{d} (31.43)
10	2.166	1.360	37.19^{c} (37.87)	2.165	1.276	41.09^{c} (40.16)	2.190	1.482	32.38^{c} (34.99)	2.172	1.473	32.07^{c} (34.80)
15	2.112	1.276	39.12^{b} (39.00)	1.993	1.126	43.41^{b} (41.50)	2.106	1.363	35.44^{b} (36.83)	2.086	1.356	35.09^{b} (36.62)
20	2.313	1.196	48.29^{a} (44.30)	2.393	1.143	52.27^{a} (46.59)	2.376	1.443	39.32^{a} (39.12)	2.356	1.436	39.11^{a} (39.00)
Water	2.153	1.993	7.45^{e} (16.38)	2.182	2.023	7.02^{e} (15.92)	2.083	1.914	8.130^{e} (17.08)	2.061	1.916	5.47^{e} (14.14)
Mean	-	-	34.76	-	-	36.55	-	-	31.94	-	-	31.2030
SEd	-	-	0.4078	-	-	0.5477	-	-	0.1943	-	-	0.3274
CD (P = 0.05)	-	-	0.9087	-	-	1.2204	-	-	0.4329	-	-	0.7295

*Mean of four replications; significant at 1%; figures in parentheses are arc sin transformed value; in a column, means followed by a common letter(s) are not significant different by DMRT (P=0)

Table 2: Effect of oils on removal of *Phenacoccus solenopsis* wax

Concentration (ml per litre)	Weight of wax (mg) from 20 adults*											
	Clove oil			Peppermint oil			Lemongrass oil			Citronella oil		
	Before solvent	After solvent	Wax removal (%)	Before solvent	After solvent	Wax removal (%)	Before solvent	After solvent	Wax removal (%)	Before solvent	After solvent	Wax removal (%)
5	1.740	1.613	7.31^{d} (16.23)	1.743	1.530	12.20^{d} (20.88)	1.910	1.043	45.37^{d} (42.63)	2.447	1.435	41.35^{d} (40.31)
10	2.123	1.936	8.81^{c} (17.77)	2.053	1.646	19.81^{b} (26.79)	2.032	0.976	51.89^{c} (46.37)	2.398	1.319	44.96^{c} (42.39)
15	1.903	1.550	18.56^{a} (25.88)	1.876	1.566	16.57^{c} (24.40)	2.073	0.866	58.15^{b} (49.98)	2.450	1.228	49.86^{b} (45.21)
20	1.913	1.626	15.07^{b} (23.24)	1.913	1.503	21.47^{a} (27.95)	2.023	0.736	63.58^{a} (53.18)	2.479	1.013	59.12^{a}m (50.55)
Water	1.776	1.696	4.43^{e} (12.83)	1.743	1.656	4.90^{e} (13.44)	1.763	1.670	5.14^{e} (13.73)	2.016	1.843	8.48^{e} (17.44)
Mean	-	-	19.19			22.69	-	-	41.18	-	-	39.18
SEd	-	-	0.1943			0.2591	-	-	0.5476	-	-	0.6353
CD (P = 0.05)	-	-	0.4330			0.5774	-	-	1.2201	-	-	1.4156

*Mean of four replications; significant at 1%; figures in parentheses are arc sin transformed value; in a column, means followed by a common letter(s) are not significant different by DMRT (P=0.05)

Table 3: Effect of oils on removal of *Phenacoccus solenopsis* wax

Concentration (ml per litre)	Weight of wax (mg) from 20 adults*											
	Orange oil			Castor oil			Neem oil			Eucalyptus oil		
	Before solvent	After solvent	Wax removal (%)	Before solvent	After solvent	Wax removal (%)	Before solvent	After solvent	Wax removal (%)	Before solvent	After solvent	Wax removal (%)
5	1.733	1.530	11.72^{d} (20.46)	2.276	1.410	38.11^{d} (38.12)	2.363	1.493	36.81^{d} (37.65)	2.346	1.526	34.93^{d} (36.53)
10	2.030	1.633	19.54^{c} (26.59)	2.263	1.286	43.11^{c} (41.04)	2.280	1.363	40.18^{c} (39.63)	2.260	1.353	40.02^{c} (39.53)
15	1.923	1.556	18.85^{b} (26.10)	2.233	1.196	46.48^{b} (42.98)	2.266	1.273	43.80^{b} (41.73)	2.246	1.306	41.81^{b} (40.57)
20	1.916	1.493	22.33^{a} (28.54)	2.363	1.086	54.01^{a} (47.30)	2.283	1.133	50.32^{a} (45.47)	2.263	1.153	49.00^{a} (44.71)
Water	1.763	1.670	5.14^{e} (13.73)	2.166	1.983	8.49^{e} (16.95)	2.210	1.953	11.60^{e} (20.35)	2.190	1.973	9.88^{e} (18.79)
Mean	-	-	23.09	-	-	37.28	-	-	36.97	-	-	36.03
SEd	-	-	0.1965	-	-	0.4153	-	-	0.4039	-	-	0.5786
CD (P = 0.05)	-	-	0.4379	-	-	0.9252	-	-	0.8999	-	-	1.2891

*Mean of four replications; significant at 1%; figures in parentheses are arc sin transformed value; in a column, means followed by a common letter(s) are not significant different by DMRT (P=0.05)

Table 4: Effect of surf and plant products on removal of *Phenacoccus solenopsis* wax

Concentration (gm per litre)	Weight of wax (mg) from 20 adults*											
	Surf (detergent)			Sheekai			Custard apple powder			Castor soap		
	Before solvent	After solvent	Wax removal (%)	Before solvent	After solvent	Wax removal (%)	Before solvent	After solvent	Wax removal (%)	Before solvent	After solvent	Wax removal (%)
5	2.066	1.743	15.64^{c} (23.68)	1.650	1.513	8.22^{d} (17.18)	2.391	1.733	27.47^{c} (31.93)	2.346	1.633	30.39^{c} (33.76)
10	2.033	1.686	16.96^{b} (24.70)	1.813	1.620	10.65^{c} (19.50)	2.210	1.523	31.03^{b} (34.16)	2.243	1.437	35.99^{b} (37.16)
15	2.056	1.763	14.21^{d} (22.55)	1.856	1.611	13.29^{b} (21.80)	1.973	1.266	35.80^{a} (37.05)	2.136	1.373	35.72^{b} (37.00)
20	2.067	1.496	27.62^{a} (32.02)	1.736	1.443	16.77^{a} (24.55)	2.306	1.456	36.86^{a} (37.67)	2.230	1.336	40.06^{a} (39.56)
Water	2.016	1.923	4.64^{e} (13.11)	1.733	1.666	3.85^{e} (12.04)	2.220	2.056	7.40^{d} (16.33)	2.093	1.870	10.64^{d} (19.50)
SEd	-	-	0.2298	-	-	0.1842	-	-	0.3101	-	-	0.2568
CD (P = 0.05)	-	-	0.5120	-	-	0.4104	-	-	0.6909	-	-	0.5723

*Mean of four replications; significant at 1%; figures in parentheses are arc sin transformed value; in a column, means followed by a common letter(s) are not significant different by DMRT (P=0.05)

Table 5: Effect of oils on removal of *Phenacoccus solenopsis* wax

Concentrations (ml per litre)	Weight of wax (mg) from 20 adults*					
	Sweet flag oil			Concentrations (ml per litre)	Soap oil		
	Before solvent	After solvent	Wax removal (%)		Before solvent	After solvent	Wax removal (%)
	2.343	1.746	25.45^{c} (30.62)	5	2.046	1.450	29.21^{d} (33.03)
10	2.190	1.553	29.08^{b} (32.95)	10	2.183	1.423	34.81^{c} (36.45)
15	1.933	1.293	33.09^{a} (35.42)	15	2.110	1.306	38.02^{b} (38.36)
20	2.320	1.540	33.63^{a} (35.75)	20	2.252	1.307	41.83^{a} (40.59)
water	2.283	2.112	7.52^{d} (16.45)	water	2.063	1.910	7.15^{e} (16.06)
SEd	-	-	0.3610	SEd	-	-	0.5788
CD (P=0.01)	-	-	1.1443	CD (P=0.01)	-	-	1.9420

*Mean of four replications; significant at 1%; figures in parentheses are arc sin transformed value; in a column, means followed by a common letter(s) are not significant different by DMRT (P=0.05)

Table 6: Effect of oils, plant products and detergents in hexane on removal of *Phenacoccus solenopsis* wax

Concentration (ml per litre)	Weight of wax (mg) from 20 adults*														
	Lemongrass oil + Hexane			Citronella oil + Hexane			Sweet Flag oil + Hexane			Custard apple powder (gm) + Hexane (ml)			Castor soap (gm) + Hexane (ml)		
	Before solvent	After solvent	Wax removal (%)	Before solvent	After solvent	Wax removal (%)	Before solvent	After solvent	Wax removal (%)	Before solvent	After solvent	Wax removal (%)	Before solvent	After solvent	Wax removal (%)
Oil (5 ml) + Hexane (5 ml)	2.156	1.006	53.28^{c} (47.1)	2.136	1.013	52.57^{c} (46.7)	2.440	1.730	29.10^{c} (32.9)	2.303	1.573	31.68 (34.5)	2.356	1.493	36.91^{c} (37.7)
Oil (10 ml) + Hexane (10 ml)	2.043	0.950	53.50^{c} (47.2)	2.047	0.980	52.13^{c} (46.5)	2.253	1.526	32.25^{b} (34.9)	2.134	1.383	35.15^{b} (36.6)	2.283	1.363	42.33^{b} (40.8)
Oil (15 ml) + Hexane (15 ml)	2.156	0.783	63.66^{b} (53.2)	2.133	0.786	63.16^{b} (52.9)	1.921	1.100	42.70^{a} (41.0)	2.046	1.130	44.78^{a} (42.2)	2.243	1.273	43.68^{b} (41.6)
Oil (20 ml) + Hexane (20 ml)	2.083	0.596	71.36^{a} (57.9)	2.106	0.633	69.90^{a} (57.0)	2.203	1.246	43.44^{a} (41.5)	2.186	1.193	45.45^{a} (42.6)	2.296	1.133	53.16^{a} (47.1)
water	1.793	1.640	8.31^{d} (17.2)	1.805	1.643	8.60^{d} (17.5)	2.352	2.110	10.05^{d} (18.9)	2.247	2.056	8.45^{d} (17.1)	2.106	1.953	11.35^{d} (20.1)
SEd	-	-	0.6533	-	-	0.6017	-	-	0.5545	-	-	0.2789	-	-	0.4815
CD (P = 0.05)	-	-	1.4556	-	-	1.3407	-	-	1.2356	-	-	0.6213	-	-	1.0728

*Mean of four replications; significant at 1%; figures in parentheses are arc sin transformed value; in a column, means followed by a common letter(s) are not significant different by DMRT (P=0.05)

3. Results & Discussions

3.3 Evaluation of synergism / antagonism in the efficacy of entomopathogenic fungi against selected mealybugs through co-administration with some adjuvants under both laboratory and pot conditions

3.1.1 Estimation of different solvents and oils, plant products and detergents to dissolve the wax of Mealybugs

Eighteen different organic solvents, oils, plant products and detergents with different concentrations were evaluated in dissolving the wax coat present in the body of *P. solenopsis*.

3.1.1.1 Chloroform

Among different concentrations of chloroform tested, 20.0 ml per litre recorded the highest per cent removal of wax (48.29 per cent) followed by 15.0 ml per litre that recorded 39.12 per cent of wax removal, 37.19 per cent of wax removal at 10.0 ml per litre and 34.41 per cent of wax removal at 5.0 ml per litre (Table 1). The per cent wax removal of chloroform ranged from 34.41 to 48.29 per cent (one hour after treatment).

3.1.1.2 Hexane

Among different concentrations of hexane tested, 20.0 ml per litre recorded the highest per cent removal of wax (52.27 per cent) followed by 15.0 ml per litre that recorded 43.41 per cent of wax removal, 41.09 per cent of wax removal at 10.0 ml per litre and 38.37 per cent of wax removal at 5.0 ml per litre (Table 1). The per cent wax removal of hexane ranged from 38.37 to 52.27 per cent (one hour after treatment).

3.1.1.3 Ethanol

Among different concentrations of ethanol tested, 20.0 ml per litre recorded the highest per cent removal of wax (39.32 per cent) followed by 15.0 ml per litre that recorded 35.44 per cent of wax removal, 32.38 per cent of wax removal at 10.0 ml per litre and 27.05 per cent of wax removal at 5.0 ml per litre (Table 1). The per cent wax removal of ethanol ranged from 27.05 to 39.32 per cent (one hour after treatment).

3.1.1.4 Acetone

Among different concentrations of acetone tested, 20.0 ml per litre recorded the highest per cent removal of wax (39.11 per cent) followed by 15.0 ml per litre that recorded 35.09 per cent of wax removal, 32.07 per cent of wax removal at 10.0 ml per litre and 26.70 per cent of wax removal at 5.0 ml per litre (Table 1). The per cent wax removal of acetone ranged from 26.70 to 39.11 per cent (one hour after treatment).

3.1.1.5 Clove oil

Among different concentrations of clove oil tested, 15.0 ml per litre recorded the highest per cent removal of wax (18.56 per cent) followed by 20.0 ml per litre that recorded 15.07 per cent of wax removal, 8.81 per cent of wax removal at 10.0 ml per litre and 7.31 per cent of wax removal at 5.0 ml per litre (Table 2). The per cent wax removal of clove oil ranged from 7.31 to 18.56 per cent (one hour after treatment).

3.1.1.6 Peppermint oil

Among different concentrations of peppermint oil tested, 20.0 ml per litre recorded the highest per cent removal of wax (21.47 per cent) followed by 10.0 ml per litre that recorded 19.81 per cent of wax removal, 16.57 per cent of wax removal at
15.0 ml per litre and 12.20 per cent of wax removal at 5.0 ml per litre (Table 7).
The per cent wax removal of peppermint oil ranged from 12.20 to 21.47 per cent (one hour after treatment).

3.1.1.7 Lemongrass oil

Among different concentrations of lemongrass oil tested, 20.0 ml per litre recorded the highest per cent removal of wax (63.58 per cent) followed by 15.0 ml per litre that recorded 58.15 per cent of wax removal and 51.89 per cent of wax removal at 10.0 ml per litre and 45.37 per cent of wax removal at 5.0 ml per litre (Table 2). The per cent wax removal of lemongrass oil ranged from 45.37 to 63.58 per cent ((one hour after treatment) (Plate 14).

3.1.1.8 Citronella oil

Among different concentrations of citronella oil tested, 20.0 ml per litre recorded the highest per cent removal of wax (59.12 per cent) followed by 15.0 ml per litre that recorded

49.86 per cent of wax removal, 44.96 per cent of wax removal at 10 ml per litre and 41.35 per cent of wax removal at 5 ml per litre (Table 2). The per cent wax removal of citronella oil ranged from 41.35 to 59.12 per cent ((one hour after treatment).

3.1.1.9 Orange oil

Among different concentrations of orange oil tested, 20.0 ml per litre recorded the highest per cent removal of wax (22.33 per cent) followed by 10.0 ml per litre that recorded 19.54 per cent of wax removal, 18.85 per cent of wax removal at 15.0 ml per litre and 11.72 per cent of wax removal with 5.0 ml per litre (Table 3). The per cent wax removal of orange oil ranged from 11.72 to 22.33 per cent ((one hour after treatment).

3.1.1.10 Castor oil

Among different concentrations of castor oil tested, 20.0 ml per litre recorded the highest per cent removal of wax (54.01 per cent) followed by 15.0 ml per litre that recorded 46.48 per cent of wax removal, 43.11 per cent of wax removal was recorded at 10.0 ml per litre and 38.11 per cent of wax removal at 5.0 ml per litre (Table 3). The per cent wax removal of castor oil ranged from 38.11 to 54.01 per cent ((one hour after treatment).

3.1.1.11 Neem oil

Among different concentrations of neem oil tested, 20.0 ml per litre recorded the highest per cent removal of wax (50.32 per cent) followed by 15.0 ml per litre that recorded 43.80 per cent of wax removal, 40.18 per cent of wax removal at 10.0 ml per litre and 36.81 per cent of wax removal at 5.0 ml per litre (Table 3). The per cent wax removal of neem oil ranged from 36.81 to 50.32 per cent ((one hour after treatment).

3.1.1.12 Eucalyptus oil

Among different concentrations of eucalyptus oil tested, 20.0 ml per litre recorded the highest per cent removal of wax (49.00 per cent) followed by 15.0 ml per litre that recorded 41.81 per cent of wax removal, 40.02 per cent of wax removal at 10.0 ml per litre and 34.93 per cent of wax removal at 5.0 ml per litre (Table 3). The per cent wax removal of eucalyptus oil ranged from 34.93 to 49.00 per cent ((one hour after treatment).

3.1.1.13 Sweet Flag oil

Among different concentrations of sweet flag oil tested, 20.0 ml per litre recorded the highest per cent removal of wax (33.63 per cent) followed by 15.0 ml per litre that recorded 33.09 per cent of wax removal, 29.08 per cent of wax removal at 10.0 ml per litre and 25.45 per cent of wax removal at 5.0 ml per litre (Table 5). The per cent wax removal of sweet flag oil ranged from 25.45 to 33.63 per cent ((one hour after treatment).

3.1.1.14 Soap oil

Among different concentrations of soap oil tested, 20.0 ml per litre recorded the highest per cent removal of wax (41.83 per cent) followed by 15.0 ml per litre that recorded 38.02 per cent of wax removal, 34.81 per cent of wax removal at 10.0 ml per litre and 29.21 per cent of wax removal at 5.0 ml per litre (Table 5). The per cent wax removal of soap oil ranged from 29.21 to 41.83 per cent ((one hour after treatment).

3.1.1.15 Castor soap

Among different concentrations of castor soap tested, 20.0 ml per litre recorded the highest per cent removal of wax (40.06 per cent) followed by 10.0 ml per litre that recorded 35.99 per cent of wax removal which is on a par with the per cent of wax
removal (35.72 per cent) at 15.0 ml per litre and 30.39 per cent of wax removal at
5.0 ml per litre (Table 4). The per cent wax removal of castor soap ranged from 30.39 to 40.06 per cent ((one hour after treatment).

4.4.1.16 Sheekai powder

Among different concentrations of sheekai powder tested, 20.0 gm per litre recorded the highest per cent removal of wax (16.77 per cent) followed by 15.0 gm per litre that recorded 13.29 per cent of wax removal, 10.65 per cent of wax removal at
10.0 gm per litre and 8.22 per cent of wax removal at 5.0 gm per litre (Table 4). The per cent wax removal of sheekai powder ranged from 8.22 to 16.77 per cent (one hour after treatment)**.**

3.1.1.17 Custard apple powder

Among different concentrations of custard apple powder tested, 20.0 gm per litre recorded the highest per cent removal of wax (36.86 per cent) followed by 15.0 gm per litre that recorded 35.80 per cent of wax removal, 31.03 per cent of wax removal at
10.0 gm per litre and 27.47 per cent of wax removal at 5.0 gm per litre (Table 4). The per cent wax removal of custard apple powder ranged from 27.47 to 36.86 per cent
(one hour after treatment).

3.1.1.18 Surf (detergent)

Among different concentrations of surf (detergent) tested, 20.0 gm per litre recorded the highest per cent removal of wax (27.62 per cent) followed by 10.0 gm per litre that recorded 16.96 per cent of wax removal, 15.64 per cent of wax at 5.0 gm per litre and 14.21 per cent of wax removal at 15.0 gm per litre (Table 4). The per cent wax removal of surf (detergent) ranged from 14.21 to 27.62 per cent (one hour after treatment).

Among different organic solvents tested for wax removal of *P. solenopsis*, hexane at 20 ml per litre recorded the highest per cent of wax removal (52.27 per cent) and among the natural oils, lemongrass oil at 20 ml per litre recorded the highest per cent of wax removal (63.58 per cent) followed by citronella oil (59.12 per cent of wax removal). So, an attempt was made by combining these oils (lemongrass oil and citronella oil) with the organic solvent, hexane. In addition to these oils, sweet flag oil, castor soap and custard apple powder were tested by mixing with hexane against *P. solenopsis.*

3.1.1.19 Lemongrass oil combined with hexane

Among different concentrations of lemongrass oil combined with hexane,
20.0 ml per litre recorded the highest per cent removal of wax (71.36 per cent) followed by 15.0 ml per litre that recorded 63.66 per cent of wax removal, 53.50 per cent of wax removal at 10.0 ml per litre, which is on a par with the wax removal (53.28 per cent) at 5.0 ml per litre (Table 6). The per cent wax removal of lemongrass oil combined with hexane ranged from 53.28 to 71.36 per cent (one hour after treatment) (Plate 14).

3.1.1.20 Citronella oil combined with hexane

Among different concentrations of citronella oil mixed with hexane, 20.0 ml per litre recorded the highest per cent removal of wax (69.90 per cent) followed by 15.0 ml per litre that recorded 63.16 per cent of wax removal, 52.57 per cent of wax removal at 5.0 ml per litre, which is on a par with wax removal (52.13 per cent) at 10.0 ml per litre (Table 6). The per cent wax removal of citronella oil mixed with hexane ranged from 52.13 to 69.90 per cent (1 hour after treatment).

3.1.1.21 Sweet flag oil combined with hexane

Among different concentrations of sweet flag oil combined with hexane, 20.0 ml per litre recorded the highest per cent removal of wax (43.44 per cent) followed by
15.0 ml per litre that recorded 42.70 per cent of wax removal, 32.25 per cent of wax removal at 10.0 ml per litre and 29.10 per cent of wax removal at 5.0 ml per litre (Table 6). The per cent wax removal of sweet flag oil combined with hexane ranged from 29.10 to 43.44 per cent (1 hour after treatment).

3.1.1.22 Custard apple powder combined with hexane

Among different concentrations of custard apple powder combined with hexane, 20.0 gm per litre recorded the highest per cent removal of wax (45.45 per cent) followed by 15.0 gm per litre that recorded 44.78 per cent of wax removal, 35.15 per cent of wax removal at 10.0 gm per litre and 31.68 per cent of wax removal at 5.0 gm per litre (Table 6). The per cent wax removal of custard apple powder combined with hexane ranged from 31.68 to 45.45 per cent (1 hour after treatment).

4.4.1.23 Castor soap combined with hexane

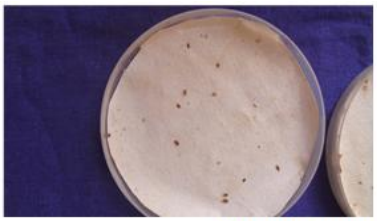
Among different concentrations of castor soap combined with hexane, 20.0 gm per litre recorded the highest per cent removal of wax (53.16 per cent) followed by
15.0 gm per litre that recorded 43.68 per cent of wax removal, 42.33 per cent of wax removal at 10.0 gm per litre and 36.91 per cent of wax removal at 5.0 gm per litre (Table 11).
The per cent wax removal of castor soap combined with hexane ranged from 36.91 to 53.16 per cent (1 hour after treatment).
After taken in to the consideration of results of oils and solvents, another experiment was conducted by combining these treatments with *Lecanicillium lecanii* (LlMO2) to assess the synergistic or antagonistic effect of these wax dissolving agents on the efficacy of *L. lecanii* both in laboratory and pot culture.
In laboratory experiment, along with these eighteen treatments, twenty two new treatments were tested by combining with *Lecanicillium lecanii* (LlMO2) (1 x 10^8 spores per ml).

Solvents used against mealybugs

Measuring weight of mealybug

Experimental setup to evaluate wax dissolving agents

Plate: Experimental Setup to evaluate wax dissolving agent on mealybug ugh



Mealybugs without wax coating after treatment

Plate: Condition of mealybugs after treatment with lemongrass oil

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