

Ecological Dynamics and Cultural Control of Eucalyptus Gall Wasp, *Leptocybe invasa* Fisher & La Salle

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Abstract

„*Leptocybe invasa*“ Fisher & La Salle (Hymenoptera: Eulophidae) has been recorded in many tropical and sub-tropical regions of the world as a gall wasp attacking „*Eucalyptus*“ species. It completes much of its life cycle inside eucalyptus tissue thus hampering chemical control. These investigations were done to gather ecological information needed to make „*L. invasa*“ amenable within eucalyptus agroecosystems:

(1) cues for „*L. invasa*“ oviposition in relation to olfaction and visual stimuli; (2) foraging and patch use by adult *L. invasa*; (3) plant host condition in relation to successful attack by „*L. invasa*“; and (4) variability of „*L. invasa*“ attack between major *Eucalyptus* species. Caged, infested „*E. saligna*“ seedlings

were used as sources of „*L. invasa*“ while caged healthy seedlings were used in „*L. invasa*“ ecological experiments with mean gall numbers per seedling as response variables. More eggs were laid by „*L. invasa*“ in response to oviposition cues in relation to olfaction stimuli than visual stimuli ($p < 0.05$) and patch residence time was greater than time spent in foraging from patch to patch ($p < 0.05$). Low nitrogen fertilization and moderate watering regime lowered the severity of attack by the pest (2.6 ± 0.9 galls per seedlings; $p < 0.05$). *E. „saligna“* was the most susceptible species to „*L. invasa*“ attack ($15.43 \pm$

0.29 galls per seedling) compared to *E. globulus* and „*E. citriodora*“, having only 0.86 ± 0.07 and 0.94 ± 0.07 galls per seedling respectively. The variability in „*L. invasa*“ attack between the major *Eucalyptus* species was significant ($p < 0.05$). Use of resistant *Eucalyptus* species like, „*E.*

camaldulensis“; having polycultures; and low application of N-fertilizers and moderate watering regimes have been recommended as cultural control strategies against „*L. invasa*“ gall wasp.

Keywords: *Eucalyptus*, *Leptocybe invasa*, gall wasp.

Introduction

Leptocybe invasa Fisher & La Salle (Hymenoptera: Eulophidae), commonly known as the blue-gum chalcid, is an invasive, gall-inducing insect pest of *Eucalyptus* trees (Myrtaceae), particularly *E. saligna*, *E. grandis*, *E. robusta* and *E. camaldulensis*. It is widely recognized in many tropical, sub-tropical and Mediterranean regions of the world as a gall inducer attacking *Eucalyptus* species, particularly seedlings (Ananthakrishnan, 2009; Hesami *et al.*, 2005). It induces galls on leaf midribs, petioles and twigs or stems, particularly of new re-growth. Repeated pest attack leads to twisted and knobbed appearance of the leaves. In East Africa, the pest was first reported in western Kenya and eastern Uganda in 2002. By 2007 it had spread to southern parts of Africa, including South Africa (Mendel *et al.*, 2004; Gupta & Poorani, 2009).

Eucalyptus is the third widely grown plantation tree genus in Kenya, after *Pinus* (Pineaceae) and *Cupressus* (Cupressaceae). It is estimated that 15,000 ha of *Eucalyptus* are grown by Kenya Forest Service (KFS) and 35,000 ha by private sector while small-scale farmers, urban and county councils have also put substantial areas of land under *Eucalyptus* trees (Oballa & Wamalwa, 2007). A survey by Mutitu *et al.* (2007) covering five Districts in western Kenya (Bungoma, Busia, Nyando, Nandi and Vihiga) showed that *L. invasa* pest attack is one of the constraints to *Eucalyptus* growing in the region where 60,000 ha are under threat, other constraints being limited land, effect of drought and other insect pests like termites.

Several control methods have been prescribed for various insect pests in many agroecological systems, including gall-forming types (Thacker, 2002). With regard to *L. invasa* pest, classical biological control and cultural control are some of the options that could be recommended for use in *Eucalyptus* wood production sector but little effort, if any, has been put to explore such options due to scanty information on the pest's biology and ecology (Protasov *et al.*, 2007b). Chemical control strategy is generally hampered by the fact that *L. invasa* insect pest lives and completes much of its life cycle inside host tissue, well out of reach of contact insecticides. While systemic insecticides could be effective in controlling the blue-gum chalcid from economic point of view, increasing global concern on adverse

effects of chemical insecticides on the environment and application challenges in view of tree height and acreage limits their use in the control *L. invasa* pest. Cultural control methods like pruning and destruction of infested plant and plant parts could alleviate the pests' severity, but are labour-intensive (Buss, 2003) and can induce stress on the plants, thereby increasing their susceptibility to attack by secondary pests and diseases. Other cultural control methods, particularly those that do not involve tree mutilation, could be effective in controlling the pest but these need be empirically elucidated. This study was done to gather ecological information needed to make *L. invasa* amenable within eucalyptus agroecosystems by cultural control. Specific objectives were to determine: (1) cues for *L. invasa* oviposition in relation to olfaction and visual stimuli; (2) foraging and patch use by adult *L. invasa*; (3) plant host condition in relation to successful attack by *L. invasa*; and (4) variability of *L. invasa* attack between major Eucalyptus species.

Materials and Methods

Site Description

Pest infested Eucalyptus seedlings for these studies were collected from Kenya Forest Service Zonal tree nursery in Kisumu County (Kenya). The County lies between 1130 – 1835 metres above sea level (M.A.S.L.) with a mean annual rainfall ranging from less than 1000 mm to 1630 mm. It has mean annual maximum temperature of 25⁰ – 30⁰ C, and mean annual minimum temperature of 9⁰ – 18⁰ C (GOK, 1997a). Laboratory experiments were conducted at University of Eldoret, situated in Uasin Gishu County (Kenya). The County lies between 1200 – 2100 M.A.S.L. with a mean annual rainfall of 960 mm. It has mean annual maximum temperature of 24⁰ – 26⁰ C, and mean annual minimum temperature of 6⁰ – 10⁰ C (GOK, 1997b).

General Insect Rearing Procedure

Insect Colonization

Twenty potted and infested *E. saligna* seedlings measuring 10 – 25 cm in height were randomly collected from K.F.S. zonal tree nursery in Kisumu County and used as sources of insect larvae for colony establishment. In a well lit laboratory the seedlings were divided into two groups of ten and each group randomly arranged in a 1 m³ ventilated glass emergence cage. The cages were managed at room temperature till insect emergence occurred, which took four and a half (4 ½) months. Temperature measurements inside cages were taken using thermometers centrally suspended from the roof of each cage. Mean room temperature was determined from three thermometers held outside the cages by means of retort stands. Temperature measurements were taken thrice a day at 8:00 a.m., 12:00 noon and 4:00 p.m.

Cage Management

Cage management included daily cleaning, watering, weeding and fertilizer application. Cage floor was cleaned thoroughly to remove abscised leaves, excess water that spill after watering the seedlings, and soil. Watering was done after every two days by adding 20 cm³ of water to each polythene tube containing the seedlings. Weeds were removed by hand daily, i.e. immediately they germinated. Fertilizer application involved putting five (5) pellets of urea 4 cm from the root collar of each seedling and was done once after four weeks.

Insect Rearing

Once the insects emerged from the caged *E. saligna* seedlings they were immediately transferred to 250-ml beakers where they were reared on artificial diet (15% sucrose solution). The beakers containing the insects were covered with cotton cloth and 15% sucrose was supplied on ball of cotton wool placed on the cloth cover. The insects, thus, fed from beneath the cloth cover. This was done to avoid accidental insect mortalities due to insects getting stuck on sucrose solution. An insecticide in powder formulation was sprinkled round a set of beakers containing *L. invasa* in order to prevent other crawling insects like ants from reaching the wools soaked in sucrose solution.

Cues for *L. invasa* Oviposition in Relation to Olfaction and Visual Stimuli

Twenty experimental trials were done using artificially fed insects in twelve (24) beakers (one insect per beaker) under room temperature (26⁰ C) and subjected to eight treatments with three replicates as follows:

Treatment A: An insect put together with a piece of host plant leaf (1 x 1 cm) in a vial.

- Treatment B: An insect put together in a vial with a piece of host plant leaf (1 x 1 cm) that had been smeared with clear varnish and left overnight for the varnish odour to diffuse away.
- Treatment C: An insect put together in a vial with a piece of host plant leaf (1 x 1 cm) and a piece of filter paper (1 x 1 cm) soaked in leaf extract.
- Treatment D: treatment B was repeated with a piece of filter paper soaked in leaf extract added into the vial.
- Treatment E: An insect put together in a vial with a piece of host plant leaf (1 x 1 cm) and a piece of filter paper (1 x 1 cm) not soaked in leaf extract.
- Treatment F: treatment B was repeated with a piece of filter paper not soaked in leaf extract added into the vial.
- Treatment G: An insect put together in a vial with a piece of filter paper (1 x 1 cm) soaked in leaf extract.
- Treatment H: An insect put together in a vial with a piece of filter paper (1 x 1 cm) not soaked in leaf extract.

Oviposition behaviours shown by the insects were noted. Pieces of leaves and filter papers were removed from the vials after four days of exposure and inspected for oviposition punctures under microscope (x 100). The leaf tissue was then dissected under a microscope (x100) and any eggs revealed were counted. The resulting set of data was summarized and subjected to one -way ANOVA using SPSS version 17 software, and differences determined using multiple comparisons of Tukey test (Zar, 1984).

Foraging and Patch Use by Adult *Leptocybe invasa*

An equal number of singly caged adult *L. invasa* were provided with two different types of habitat structures repeated twelve times (12 trials). The first set of habitat structure presented vertical structure comprising four (4) seedlings each of *Eucalyptus saligna*, *Cupressus lusitanica* and *Grevillea robusta* ranging from 10 cm to 15 cm. A total of twelve (12) seedlings were therefore kept in each cage and exposed to *L. invasa* insect. The second set of habitat structure presented horizontal structure comprising four sets of petri dishes and each petri dish containing randomly arranged five 1 cm by 1 cm pieces of filter papers. Each of the filter papers had one of the following treatments: dry, moist (soaked in water), soaked in *E. saligna* leaf extract, soaked in *G. robusta* leaf extract, and soaked in *C. lusitanica* leaf extract. Patch use was predicted from travel time and time taken at a patch (residence time) on the premise put forth by marginal value theorem (Brown, 1988). Each was closely monitored one at a time with each set up lasting 20 minutes for the following variables: patch type landed on, time taken at a patch and time taken from one patch to another.

Host Plant Condition in Relation to Successful Attack by *Leptocybe invasa*

Eucalyptus saligna seedlings of two age categories were used. One-week old *E. saligna* seedlings constituted one age category while six-weeks old *E. saligna* seedlings another age category. For each age category, a randomized complete block design (RCBD) was used to subject groups of nine caged seedlings to all possible combinations of the following treatments for two months : Factors: Age (A), watering regime (W) and N-fertilization (N). Each factor had the following levels: none, low and high based on the scale presented in Table 1. Treatments given to *E. saligna* seedling before being exposed to *L. invasa* attack are shown in Table 2. Thereafter, an equal number of ten *L. invasa* were introduced into the cages and monitored for gall formation. The numbers of galls per seedling were recorded at week 20 from exposure time. The resulting data were subjected to univariate ANOVA and means separated by Tukey HSD test using SPSS version 17.0 software.

Table 1. Factors under Consideration in Determining *E. saligna* Host Condition in Relation to Successful Attack by *Leptocybe invasa* (Hymenoptera: Eulophidae)

Factor	Level
Age*	One week old <i>E. saligna</i> seedlings (A1)
	Six weeks old <i>E. saligna</i> seedlings (A2)
Watering	No watering (W1)
	10 cm ³ of water added once a week (W2)
	10 cm ³ of water added thrice a week (W3)
Nitrogen fertilization	No fertilization (N1)
	1g CAN fertilizer added every after 6 weeks (N2)
	1g CAN fertilizer added every after 2 weeks (N3)

*Age after transplanting seedlings in polythene tubes

Table 2. Treatments Given to *E. saligna* Seedling before being Exposed to *L. invasa* Attack

S/NO.	CODE	TREATMENT
1.	A1W1N1	one week old seedling + no watering + no fertilizer
2.	A1W1N2	one week old seedling + no watering + 1g CAN* fertilizer applied after every 6 weeks
3.	A1W1N3	one week old seedling + no watering + 1g CAN fertilizer applied after every 2 weeks
4.	A1W2N1	one week old seedling + 10 cm ³ water added once a week + no fertilizer
5.	A1W2N2	one week old seedling + 10 cm ³ of water added once a week + 1g CAN fertilizer applied after every 6 weeks
6.	A1W2N3	one week old seedling + 10 cm ³ of water added once a week + 1g CAN fertilizer applied after every 2 weeks
7.	A1W3N1	one week old seedling + 10 cm ³ of water added thrice a week + no fertilizer
8.	A1W3N2	one week old seedling + 10 cm ³ of water added thrice a week + 1g CAN fertilizer applied after every 6 weeks
9.	A1W3N3	one week old seedling + 10 cm ³ of water added thrice a week + 1g CAN fertilizer applied after every 2 weeks
10.	A2W1N1	six weeks old seedling + no watering + no fertilizer
11.	A2W1N2	six weeks old seedling + no watering + 1g CAN fertilizer applied after every 6 weeks
12.	A2W1N3	six weeks old seedling + no watering + 1g CAN fertilizer applied after every 2 weeks
13.	A2W2N1	six weeks old seedling + 10 cm ³ of water added once a week + no fertilizer
14.	A2W2N2	six weeks old seedling + 10 cm ³ of water added once a week + 1g CAN fertilizer applied after every 6 weeks
15.	A2W2N3	six weeks old seedling + 10 cm ³ of water added once a week + 1g CAN fertilizer applied after every 2 weeks
16.	A2W3N1	six weeks old seedling + 10 cm ³ of water added thrice a week + no fertilizer
17.	A2W3N2	six weeks old seedling + 10 cm ³ of water added thrice a week + 1g CAN fertilizer applied after every 6 weeks

* CAN- Calcium ammonium nitrate

Variability in *Leptocybe invasa* Attack between Major *Eucalyptus* Species

A total of forty (40) caged three-weeks old seedlings of four *Eucalyptus* species (*E. saligna*, *E. camaldulensis*, *E. citriodora* and *E. globulus*) of 12.5 ± 2.5 cm height were divided into five groups of eight (8) as follows:

- (i) Eight (8) *E. saligna* seedlings caged alone;
- (ii) Eight (8) *E. camaldulensis* seedlings caged alone;
- (iii) Eight (8) *E. citriodora* seedlings caged alone;
- (iv) Eight (8) *E. globules* seedlings caged alone; and
- (v) Two (2) of each of the four seedlings caged as a mixture (i.e. eight seedlings of different species caged together).

Seedlings in each cage were then exposed to *L. invasa* by releasing ten (10) of the insects into the cages. The seedlings were managed till gall development occurred. The number of galls per seedling was recorded and the resulting data subjected to one-way ANOVA at 95 % confidence interval using SPSS version 17 software. Means were separated by Tukey HSD test (Zar, 1984).

Results

Cues for *L. invasa* Oviposition in Relation to Olfaction and Visual Stimuli

Mean *L. invasa* egg counts ($\pm$ SE and $\pm$ SD) in response to cues for oviposition in relation to visual and olfaction stimuli are presented in Table 3.

Table 3. Mean *Leptocybe invasa* Egg Coont Following Four Days of Exposure to Different Visual and Olfaction Treatments

S/N. Treatment	N	Mean	SD	SE
1 Unvanished <i>E. saligna</i> leaf	60	5.30	1.14	0.15
2 Vanished <i>E. saligna</i> leaf	60	1.72	1.15	0.15
3 Unvanished <i>E. saligna</i> leaf with soaked filter paper	60	4.85	2.33	0.30
4 Soaked filter paper with unvanished <i>E. saligna</i> leaf	60	3.25	0.65	0.08
5 Vanished <i>E. saligna</i> with soaked filter paper	60	1.28	0.76	0.09
6 Soaked filter paper with vanished <i>E. saligna</i> leaf	60	5.20	0.68	0.08
7 Unvanished <i>E. saligna</i> leaf with unsoaked filter paper	60	6.33	2.23	0.29
8 Unsoaked filter paper with unvanished <i>E. saligna</i> leaf	60	1.40	0.64	0.08
9 Vanished <i>E. saligna</i> leaf with unsoaked filter paper	60	2.92	1.14	0.15
10 Unsoaked filter paper with vanished <i>E. saligna</i> leaf	60	0.47	0.50	0.06
11 Soaked filter paper	60	4.58	1.68	0.22
12 Unsoaked filter paper	60	1.12	0.78	0.10
Total	720	3.20	2.30	0.08

The highest mean ($\pm$ SE) *L. invasa* egg count (6.33 ± 0.29) was recorded on unvarnished piece of *Eucalyptus saligna* leaf presented together with a piece of filter paper not soaked in *E. saligna* leaf extract. The lowest egg count (0.47 ± 0.06) was recorded on piece of filter paper not soaked in *E. saligna* leaf extract and presented together with vanished piece of *E. saligna* leaf. Vanished pieces of *E. saligna* leaf presented together with unsoaked pieces of filter paper had higher *L. invasa* egg counts (2.92 ± 0.15) as compared to unsoaked pieces of filter paper presented alone (1.12 ± 0.10). There were significant differences between effects of the twelve treatments on mean *L. invasa* egg count ($p < 0.05$) and *L. invasa* had a preference for vanished *E. saligna* leaf over unsoaked filter paper as surface for oviposition (Table 4).

Table 4. Tukey HSD * Homogenous Subsets of Mean *Leptocybe invasa* Egg Count Following Four Days of Exposure to Different Visual and Olfaction Treatments

S/ NO. Treatment	N	Subset for alpha = 0.05				
		1	2	3	4	5
1 Unsoaked filter paper with vanished <i>E. saligna</i> leaf	60	0.47a				
2 Unsoaked filter paper	60	1.12a	1.12b			
3 Vanished <i>E. saligna</i> with soaked filter paper	60		1.28b			
4 Unsoaked filter paper with unvanished <i>E. saligna</i> leaf	60		1.40b			
5 Vanished <i>E. saligna</i> leaf	60		1.72b			
6 Vanished <i>E. saligna</i> leaf with unsoaked filter paper	60			2.92c		
7 Soaked filter paper with unvanished <i>E. saligna</i> leaf	60			3.25c		
8 Soaked filter paper	60				4.58c	
9 Unvanished <i>E. saligna</i> leaf with soaked filter paper	60				4.85c	
10 Soaked filter paper with vanished <i>E. saligna</i> leaf	60				5.20c	
11 Unvanished <i>E. saligna</i> leaf	60				5.30c	
12 Unvanished <i>E. saligna</i> leaf with unsoaked filter paper	60					6.33d
P		0.195	0.307	0.960	0.095	1.000

Means for groups in homogeneous subsets are displayed. Those with same letters are not significantly different.

* Uses Harmonic Mean Sample Size = 60.000.

Foraging and Patch Use by Adult *Leptocybe invasa*

Results on foraging and patch use by adults of *L. invasa* are presented in Figures 1 and 2. Travel time from patch to patch was longer (4 - 6 min) when *L. invasa* landed on plants other than *E. saligna* than when the insect landed on *E. saligna* (1-2 min) (Figure 1). For both vertical and horizontal habitat structures, time taken by *L. invasa* on the patch of *E. saligna* (i.e. residence time) was longer and marked by shorter travel time from patch to patch compared with corresponding duration when the insect was on other patch types (i.e. *G. robusta* and *C. lusitanica*) (Figures 1 and 2).

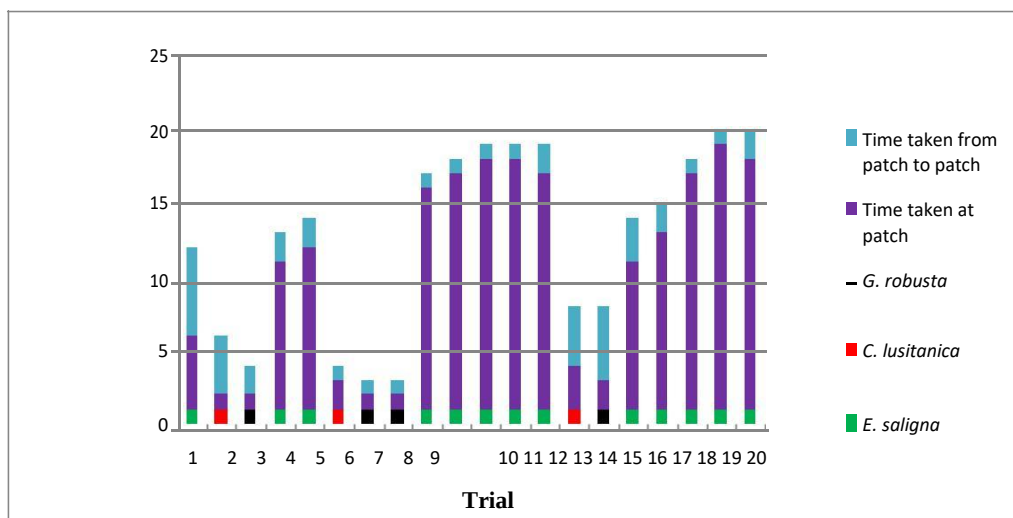


Figure 1. Travel and Residence Time Taken by *L. invasa* in Relation to Different Vertical Patch Types

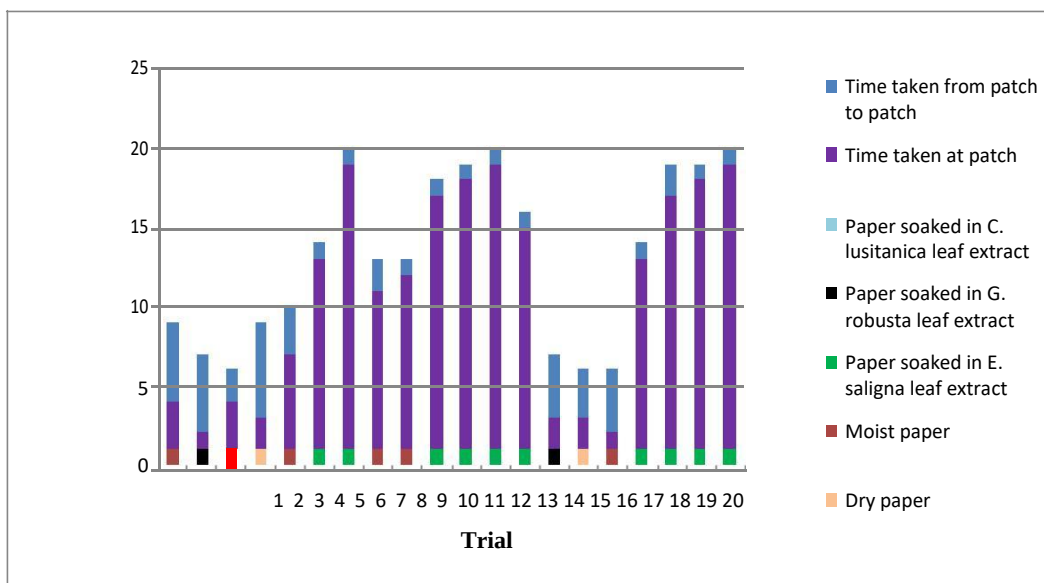


Figure 2. Travel and Residence Time Taken by *L. invasa* in Relation to Different Horizontal Patch Types

Host Plant Condition in Relation to Successful Attack by *Leptocybe invasa*

Mean gall numbers per seedling due to attack by *L. invasa* in relation to host condition are presented in Table 5. High nitrogen fertilization and high watering regime for newly pricked out (transplanted) *E. saligna* seedlings rendered the plants more susceptible to attack by *L. invasa* as indicated by higher counts of galls per seedling (13.1 ± 0.9 galls per seedling) (Table 5). Old (six weeks old) subjected to low regimes of nitrogen fertilization and watering were less susceptible to attack by the pest

(2.6 ± 0.9 galls per seedlings) (Table 5). The differences in mean gall numbers per seedling as a response to host condition in relation to attack by *L. invasa* were significant ($p < 0.05$).

Table 5: Mean Gall Numbers per seedling in relation to *E. saligna* host condition for Successful Attack by *L. invasa*

Treatment	Mean $\pm$ SE
A1W1N1	6.3 ± 0.9 abcde
A1W1N2	7.8 ± 0.9 bcdef
A1W1N3	7.3 ± 0.9 bcdef
A1W2N1	9.5 ± 0.9 cdefg
A1W2N2	11.0 ± 0.9 fg
A1W2N3	11.2 ± 0.9 fg
A1W3N1	10.1 ± 0.9 defg
A1W3N2	10.6 ± 0.9 efg
A1W3N3	13.1 ± 0.9 g
A2W1N1	7.1 ± 0.9 bcdef
A2W1N2	6.8 ± 0.9 abcdef
A2W1N3	4.9 ± 0.9 ab
A2W2N1	2.6 ± 0.9 a
A2W2N2	3.4 ± 0.9 ab
A2W2N3	4.1 ± 0.9 abc
A2W3N1	5.1 ± 0.9 abc
A2W3N2	5.9 ± 0.9 abcd
A2W3N3	5.3 ± 0.9 b

Means with same letters are not significantly different at 95% CI

Variability in *Leptocybe invasa* Attack between Major *Eucalyptus* Species

Results on variability of *Leptocybe invasa* attack between major *Eucalyptus* species indicated that *E. saligna* was the most susceptible species to *L. invasa* attack (15.43 ± 0.29 galls per seedling) while *E. globulus* and *E. citriodora* seemed to tolerate *L. invasa* attack by $> 150\%$, having only 0.86 ± 0.07 and 0.94 ± 0.07 galls per seedling respectively (Figure 3 and Table 6). Whereas *E. camaldulensis* seemed resistant in the presence of *E. saligna*, the species also appeared slightly susceptible to *L. invasa* attack when exposed to the insect alone. In the presence of *E. saligna*, gall count per seedling on *E. camaldulensis* was 3.21 ± 0.33 while 7.11 ± 0.24 galls per seedling was recorded when the species was alone. The variability in *L. invasa* attack between the major *Eucalyptus* species was significant ($p < 0.05$).

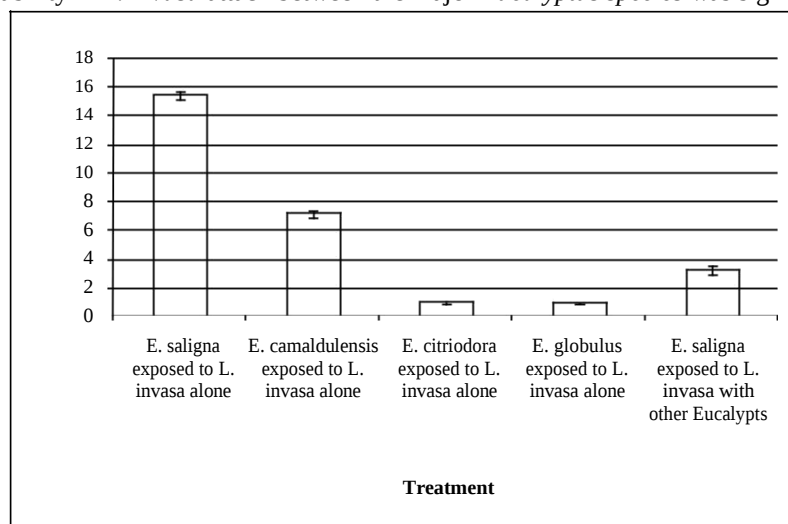


Figure 3. Mean Gall Count on Different Species of *Eucalyptus* Seedlings Following Exposure to *L. invasa* Attack Alone or together with other *Eucalyptus* Species

Table 6. Tukey's (HSD) Homogenous Subsets of Mean Gall Count per Seedling of *Eucalyptus* Species Following Attack by *L. invasa*

Treatment	N	Subset for alpha = .05			
		1	2	3	4
<i>E. globulus</i> exposed to <i>L. invasa</i> alone	160	0.86a			
<i>E. citriodora</i> exposed to <i>L. invasa</i> alone	160	0.94a			
<i>E. saligna</i> exposed to <i>L. invasa</i> with other Eucalypts	160		3.21b		
<i>E. camaldulensis</i> exposed to <i>L. invasa</i> alone	160			7.11c	
<i>E. saligna</i> exposed to <i>L. invasa</i> alone	160				15.43d
<i>P</i>		0.999	1.000	1.000	1.000

Means for groups in homogeneous subsets (with similar letters) are displayed.

* Uses Harmonic Mean Sample Size = 160.000.

Discussion

Animals usually require information about the state of their environment to take adaptive decisions (Tentelier & Fauvergue, 2007). A forager may assess current habitat profitability, based on cues it has perceived in the past, through a learning process (Ollasson, 1980; McNamara *et al.*, 2006). In these studies, a greater number of eggs was laid by *L. invasa* in response to olfaction than visual stimuli. Thus, based on the premise that host plant semiochemicals can influence infestation by *L. invasa*, the planting of susceptible Eucalypts in polycultures together with strongly aromatic and resistant species like *Eucalyptus citriodora* may alleviate the pest problem.

Shorter travel time from patch to patch by *L. invasa* on *E. saligna* than on other plant species (this study) suggests that the insect has perfected its host finding and recognition, probably through co-evolution with *E. saligna*. These results suggest that polycultures of *E. saligna* and other non-host plant species can increase travel time from plant to plant for *L. invasa* and lower residence time taken on a given plant. In effect, this would lower chances for host finding and oviposition by the pest. Other than finding and recognizing a suitable host, the host condition in relation to successful attack is an important factor in severity of attack by a phytophagous insect. In this study, low nitrogen fertilization and moderate watering regime seem to lower the severity of attack by the gall wasp, *L. invasa* (Hymenoptera: Eulophidae). This has implications on tree nursery practices where *L. invasa* infestation is common. High nitrogen levels in plant tissues promote succulence and luxuriant growth of plant tissues, providing suitable oviposition sites for *L. invasa*.

Eucalyptus citriodora and *E. camaldulensis* seemed resistant to *L. invasa* attack while *E. saligna* appeared highly susceptible to *Leptocybe* attack. In a separate work by Kulkarni *et al.* (2010), *Eucalyptus tereticornis*, *E. camaldulensis*, *E. grandis* and their hybrids were severely affected by the gall wasp, *Leptocybe invasa* (Hymenoptera: Eulophidae) while *E. alba*, *E. urophylla*, *E. citriodora* and *E. torelliana* were gall free. From these studies, however, *E. camaldulensis* appear resistant only in the presence of *E. saligna*, but is equally susceptible to *L. invasa* attack when it is grown in monocultures.

Conclusion

The following conclusions were made: (1) Olfaction stimuli elicits more cues for oviposition in *L. invasa* than visual stimuli, hence egg-laying by the insect pest can be disrupted by growing *Eucalyptus saligna* in polycultures stand. (2) Host plant finding by *L. invasa* is not a chance occurrence as patch residence time by the insect is greater than time spent in foraging from patch to patch. (3) Host plant condition influences chances of attack by the pest and *E. saligna* seedlings subjected to low nitrogen fertilization and watering regimes become relatively less susceptible to attack by *L. invasa*, and (4) *E. camaldulensis* in polycultures with *E. saligna* is less susceptible to *L. invasa* attack but is equally susceptible to the pest attack when in monoculture. *E. saligna* is the most susceptible Eucalyptus species to *L. invasa* attack.

This study recommends use of resistant *Eucalyptus* species like, *E. camaldulensis*; growing *E. saligna* in polycultures with resistant and aromatic species like *E. citriodora*; application of nitrogen fertilizers to six-weeks old (or older) seedling at low rates (0-1g CAN fertilizer per seedling); and optimal watering of seedlings (10 cm³ of water per caged seedling per week or equivalent volume) as cultural control strategies against the gall wasp, *Leptocybe invasa*.

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