DOI: 10.21608/alexja.2024.338578.1113

Assessment of Infested and Healthy Trees of Eucalyptus Planted on Treated Sewage Water: Reasons of Infestation, Symptoms and Control

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ARTICLE INFO

Article History

Received: 22/11/2024

Revised: 20/12/2024

Accepted: 21/12/2024

Key words: *Corymbia citriodora*, *Eucalyptus camaldulensis*, *Phoracantha semipunctata*, Insects infestation.

ABSTRACT

This research was carried out in Serapium plantation of *Corymbia citriodora*, and *Eucalyptus camaldulensis* where infestation symptoms caused by *Phoracantha semipunctata*on these sites had been detected. Results showed that *Eucalyptus camaldulensis* species was more resistant than *Corymbia citriodora* species, since the infestation percentage was 9.6% and 26.5%, respectively. Moreover, decreased moisture content of plants and soil (owing to drought period and increasing temperature) affected strongly infestation levels.

INTRODUCTION

Eucalyptus is one of the most widely planted timber species in the world. It is native to Australia, Indonesia, and New Guinea, it is a genus of more than 500 species of long and ever green hardwood tree belonging to family Myrtaceae, (Teketay, 2000 and Rassaeifar *et al*., 2013). Currently, *Eucalyptus* species are planted around the Mediterranean regions, in southern Africa, South America, and Asia as one of the most important sources of commercial cellulose fiber, paper pulp, timber, wood fuel, charcoal, pesticide and medicinal products. Furthermore, it planted widely for its fast growth rate and its adaptation to different soils, such as saline, sodic, waterlogged and poor soils. Also, it grows under a wide range of climatic conditions from warm to hot, sub humid to humid. In addition, it is useful as shelter belts and wind breaks on large scale farms, and as plantations. (Dereje *et al*., 2012 and Belal *et al*., 2017).Moreover, farmers and consumers now oriented to replace their farms with *Eucalyptus* species especially in Ethiopia for its economic, social and ecological benefits on the local community (Alemayehu and Melka, 2022).

It is a fact that *Eucalyptus* plantations are exposed to a serious pest attack by wood boring insect namely, *Phoracantha semipunctata* , which considered as the main enemy of the *Eucalyptus*, that caused considerable damage, since the 80's,which estimated more than 2,000,000 trees, that conjunction with spread of many eucalypt species around the world outside their endemic range and shifting of local herbivore populations onto new host trees. So, understanding the mechanisms underlying host specificity of Australian insects can provide insight into patterns of host range expansion of both native and exotic insects (Timothy *et al.*, 2011 and Belal *et al*., 2017). In addition, at the last 100 years, plantations of eucalypt species particularly (*Eucalyptus* and *Corymbia*) in the tropics and Southern Hemisphere, have expanded widely. There are many diseases and pests attacking and damaging early plantations, it is clear that trees separation from their natural enemies has resulted in exceptional performance. Its noticeable that, both the incidence and impact of diseases and pests in eucalypt plantations has increased with time, because of the accidental introduction of pests and pathogens from native areas of the trees to new environments (Hunter *et al.*, 2009). *Phoracantha semipunctata* (Coleoptera, Cerambycidae), was recorded in Tunisia since 1960s, while the other species, *Phoracantha recurva*, was detected in 1999. They were also introduced towards the other parts of the world, including the Mediterranean basin. In most cases, these insects attack mainly freshly dying or stressed trees. However, in Australia, they are not dangerous and attack only died trees. In Tunisia, both *P. semipunctata* and *P. recurva* are continue to cause serious damages mainly after drought period. The serious infestations noted in Tunisia between the 1960s and 1980s are the consequence of multiple factors such as, bad adaptation of the *Eucalyptus* species to the soil and climatic conditions, high biological multiplication and to the absence of natural enemies (Ben Jamâa *et al*., 2002 and 2009). In Egypt, *Corymbia citriodora* and *Eucalyptus camaldulensis* are fast growing trees, planted in large area at different plantations.

Serapium plantation is an example of promising plantation of fast growth rate (FAO, 2012).This research is aimed to the assessment of the potential of *Phoracantha semipunctata* infestation of *Corymbia citriodora* and *Eucalyptus camaldulens* in Serapium plantation and to investigate, causes and precisely the symptoms and to apply methods of the control.

Methodology:

Inspection of the location:

This research was carried out to assess an infestation level, since it appeared by the end of 2019 in Serapium plantation that located in north eastern Egypt 30°, 29', 15.55" N, and 32°,14',25.43" E, Governorate of Ismailia, about 16 km. south of Ismailia, Figure (1), shows the location of stand inspection and Table (1) presented the average of climate condition of Ismailia.

Symptoms and infestation.

Symptoms were checked and noticed in eight locations in *Corymbia citriodora*, and *Eucalyptus camaldulensis* at Serapium plantation, trees numbers, age, height and diameter were measured.

Infestation level:

Total number of planted trees *in situ* was counted as well as the number of infested trees, healthy trees and dead ones to determine the infestation level (%).

Sampling

Samples of infested and healthy trees and soils were collected and prepared for chemical analysis and moisture content. Also, numbers of insect bores, bores diameter, dead, infected and healthy trees were calculated.

Moisture content (M.C.%):

Wood moisture content was determined using oven dry method (EN,2002) according to the next equation:

$$M.C.\% = \frac{G.W - D.W.}{D.W.} X\ 100$$

Where:

M.C. % is wood moisture content percentage

G.W. is wood green weight

D.W. is wood oven dry weight

Soil and plant chemical analysis

Samples of leaves, wood and bark of healthy and infested trees were collected washed and dried at 70 C^0 and grinded, 0.5 g. of fine sample was wet digested for chemical analysis, according to (Cottenie, 1980).Soil samples were collected at 30, 60 and 90 cm depth, samples, then air dried for chemical analysis according to Attanandana *et al*., (1999).

Figure 1: Locations of inspection and sampling of *Crombya citriodora* (C) and *Eucalyptus camaldulensis* (E) plantations.

Table 1: Simultaneous climate data of Egypt-Ismailia-ksaseen (2015-2020)

Year	Temperature(T) and Relative Humidity (R.H) Average from 1/6 to 31/8		Max. daily temperature	Month
	T	RH		
2015	38.78	46.10	45.4	8
2016	39.57	45.20	45.6	6
2017	39.27	45.95	43.6	7
2018	38.92	46.39	43.2	6
2019	39.34	44.83	46.7	5
2020	38.95	46.73	43.5	8

Statistical analysis

For, Infestation Levels means (±SE) of data are shown to be as appropriate in this regard to reveal whether inner bark damage (%) is related to tissue moisture (%) and soil moisture (%) regression procedure was used in SAS, according to Snedecor and Cochran (1989).

RESULTS AND DISCUSSION

Insect description:

Fig (2A) showed the adult beetle which isolated from trunk of eucalypt trees in serapium plantation. The beetle has a dark brown color with two zig-zag yellow parts on its back, and two yellow oval dots on the wings. It's about (2.5 - 3.75 cm length). The horns are light brown colored and longer than the insect's body. The larvae attacked the lowest part of stem causing most of the damage (Fig. 2B), it occurs and digging gallery under the bark, this finding is matching with (Ali *et al*.,1986).

Infestation level and symptoms:

Table (2) and Figure (3) showed that the infested trees are aged 8-10 years old with mean height of 13.9 m and 42.4 cm dbh, at the same time means of holes numbers / 50 cm length was 5 holes (1.0 cm*0.48 cm) dimension and tunnels the mean of hole diameter is 1.5 cm. the infestation level was 7.5 holes per square meter.

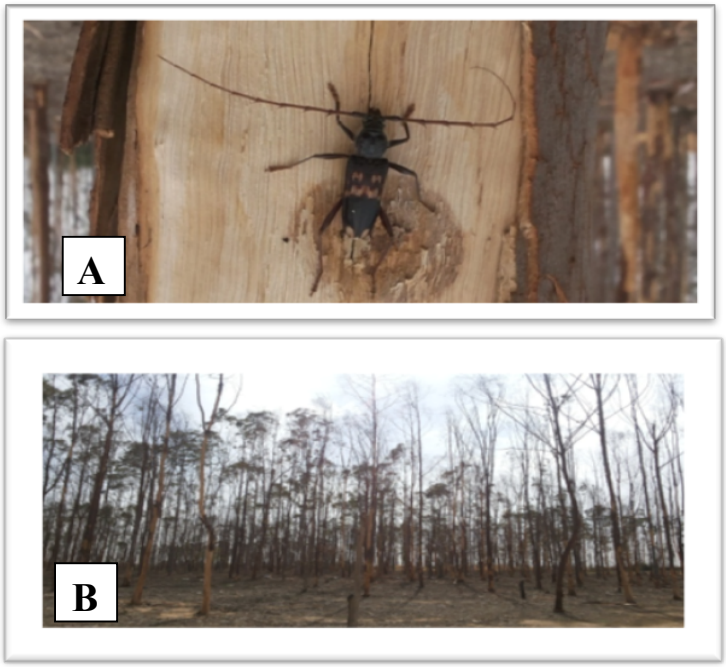

Figure 2: A: Adult beetle of *Phoracantha semipunctata*. B: dieback symptoms of damaged trees by the insects.

Figure 3: Infested stem of *Crombiya citriodora* displayed the gallery of infested wood by *Phoracantha semipunctata* (cm)

Table 2: Means of tree height, dbh, holes diameter, tunnels width cm and holes number of infested trees

species	Mean of Height (m)	Mean of dbh (cm)	No. of Holes / m^2	Mean of hole diameter (cm)	Mean of Tunnel width (cm)
Crombya citriodora	13.9	42.4	7.5	0.74	1.5

Health Status of eucalypt stands:

Figure (1) illustrates the plan implies eight locations of *Crombya citriodora* and *Eucalyptus camaldulensis*. All locations were subjected to severe drought periods several times in addition to hot weather that caused tree weakness and susceptibility to attacking by insects specially by *Phoracantha semipunctata*. Healthy status of both species were studied and recorded as it presented in Table(3). Data showed that *Eucalyptus camaldulensis* was more resistant than *Crombya citriodora*, since infested, healthy and mortality percentage were (26.5, 51, 28.3 and 9.6, 66.7, 23.7) for *C. citriodora* and *E. camaldulensis,* respectively.

Chemical analysis:

Table (4) and (5) showed the chemical analysis of soil and plant parts for both infested and healthy sites. Results showed nonsignificant differences of chemical content between the soils of healthy and infected plants, while bark of infected plants had the highest content of chemical content. Upon the chemical analysis of healthy soil obtained, the highest values of chemical contents compared to soil of infected sites except for K and organic carbon (O.C%). The soil of healthy site had C/N ratio (138.56) higher than that of infected one (82.25).

Relationship between soil and wood moisture content (M.C.%) and damage:

Data presented in Table (6 and 7) showed the moisture content of soil at different depth and plant parts for both healthy and infected sites. Distinctly, the percentage of tree damage and infestation *in situ* was indirectly proportional with moisture content for plant parts (leaves, bark and wood). Moreover, result of regression analysis of moisture content for both wood and soil and infestation level was significant as showed and presented in figure (4).

Table 3: Number and percentage of healthy and infested trees in inspected locations

location	species	Infested	healthy	dead	total	% infested	% healthy	% Mortality	Mortality &Infested%
1	*Crombya citriodora*	74	143	79	279	26.5%	51%	28.3%	55 %
2	*Eucalyptus camaldulensis*	19	132	47	198	9.6%	66.7%	23.7%	33.3%

Table 4: Chemical contents (mg) of soil under healthy and infested locations

Soil depth	N	P	K	Organic Carbone (O.C) %	Ca	Mg	C/N
Soil depth of healthy *E .camaldulensis*							
30cm	47.88	5	63.93	0.076	55	21	35.87
60 cm	20.72	6	60.21	0.124	80	13.2	59.84
90 cm	22.4	5	52.35	0.096	35	9	42.85
Total	91	16	176.49	0.296	170	43.2	138.56
Soil depth of infested trees *C. citriodora*							
30 cm	24.92	2	119.9	0.116	31	15.6	27.03
60 cm	21	1	66.69	0.76	36	11.4	36.19
90 cm	12	0.76	63.39	0.104	24	6.3	19.03
Total	57.92	3.76	249.98	0.98	91	33.3	82.25

Table 5: Chemical content (mg) of healthy and infested plants

Plant sample	N	P	K	Organic Carbone (O.C) %	Ca	Mg
Healthy Leaves	0.59	0.32	0.25	20	0.254	0.05
Healthy wood	0.5	0.66	0.09	21	0.09	0.04
Healthy bark	0.95	0.48	0.11	*	1.18	0.12
Total	2.04	1.46	0.45	41	1.524	0.21
Leaves of Infected trees	0.58	0.2	0.29	21.2	0.103	0.143
Infected wood	0.58	0.3	0.34	21	0.27	0.097
Infected bark	1.08	0.72	0.64	*	1.137	0.38
Total	2.24	1.22	1.27	42.2	1.51	0.62

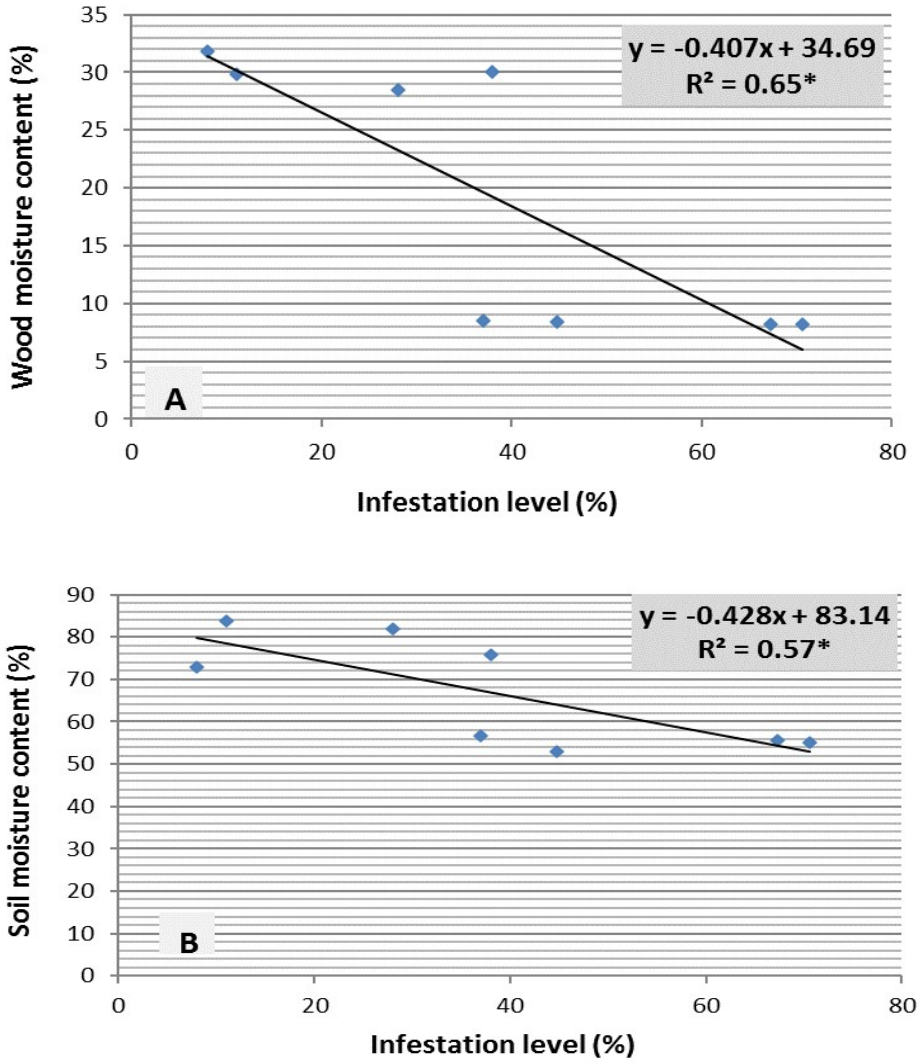

Figure 4: Regression analysis between (A) infestation level and wood M.C.(%)(B) infestation level and soil M.C.(%)

Table 6: Soil Moisture content (M.C.%)

Depth (cm)	Soil of healthy trees	Soil of infested trees
30	76.9 ±4.56	54.9 ±1.95
60	87.9 ±3.10	62.23 ±2.56
90	98.7 ±0.49	66.4 ±3.1
total	87.83 ±10.9	61.18 ±5.82

Table 7: Plant Moisture content % (M.C.%) of healthy *Eucalyptus camaldulensis* and infested *Crombiya citriodora*

Plant sample	Healthy E.	Infected C
Leave	26.67 % ± 2.52	8.43 % ± 0.5
wood	34.67% ± 2.08	9.63% ± 0.68
bark	25.57% ± 1.4	7.10% ± 0.66
Total	86.9% ± 4.97	25.17% ± 1.27

DISCUSSION

From previous results, the most impacting factors on *Phoracantha semipunctata* outbreak in eucalypt stand in Serapium plantation were drought and hot weather. Moreover, *E. camaldulensis* was more resistant than *C. citriodora* for attacking by *Phoracantha semipunctata.* Although, chemical content in plant parts and soil had nonsignificant effect on trees infestation. On the contrary of moisture content of plant tissue and soil which consider a significant factor with inverse relationship at infested trees. According to (Ali *et al*., 1986) larva are grows at tunnels, width of tunnels may reach three times the length of larva's head. Larva feeding disrupts water and nutrients flow through the plant and eventually dead. Moreover, healthy and vigor trees produce amounts of specific dark sticky gum that kills penetrating larvae. The effect of hot climate is decreasing the period of completing insect life cycle from egg to adult to two months instead of nine months at the cooler climates. The fact of outbreak potential of *P. semipunctata*is native in Mediterranean-climate *Eucalyptus* forest under severe water stress, was confirmed by Seaton *et al*., (2015) on their work at the Northern Jarrah Forest of Southwestern Australia after the most severe droughts period. They found that severe drought encourages outbreak of *P. semipunctata*, 80 times higher than that in the healthy sites. Recently died trees by drought had lower moisture on tissue, higher feeding damage and infestation levels than healthy forests. Moreover, the probability of increasing the intensity and frequency of drought duration attendant to extreme climate events in the future the beetle outbreak well be prevalent, that by creating a new conducive habitat and compromising host defenses (Seaton *et al*.,2015).

One of the reasons may explain that the Eucalyptus infestation is the host range of the Eucalyptus woodborer, *Phoracantha semipunctata*, is restricted mainly to species of *Eucalyptus* (Myrtaceae). Volatile semi chemicals possibly involved in host selection and non host rejection (Barata *et al.,* 2000).

Our results are matched with the findings of Poynton (1960) and Hanks *et al.,*(1995) where, the most resistance species of *eucalyptus* to *Phoracantha* spp. attack is the most drought tolerant species in Australia such as *E. camaldulensis* & *E. cladocalyx.* Moreover, the moisture content of bark is considered a critical factor of *Eucalyptus* resistance against *Phoracantha* larvae colonization (Hanks *et al.,*1991).Water stressed trees has lower mortality of *Phoracantha semipunctata* larvae than irrigated trees where, larvae mortality is related to the moisture content of bark, because of larvae boring through the bark can't survive in an environment saturated with water (Chararas 1969, Powell 1982, Tirado 1984, Hanks *et al*., 1991 and Hanks *et al*., 1999). Moreover, the highest larvae survival rate was found in logs that of the lowest bark moisture content. In this type of feeding guild, the close contact of larvae with the tree tissues makes bark moisture content a critical factor for larvae survival. Also, in eucalyptus species and several Mediterranean species the deficits of water affected carbon metabolism, increasing the concentration of soluble sugars in the bark tissues and reduced tree growth (Diamantoglou and Kull 1984, Myers and Neales1986, Rhizopoulou, 1990 and Meletiou-Christou *et al*., 1994), Moreover, a fast growth of larvae was obtained by (Chararas, 1969) in an artificial environment rich in soluble sugar.

Also, nitrogen can be also an important factor in survival of larvae (White, 1974 and 1978), but according to (Bernays *et al*., 1981 and Scriber and Slansky, 1981) the bark total nitrogen was not affected by water stress, so, it is not a good indicator for nitrogen availability to insects because soluble nitrogen is more used by insects and increased according to water stress (Stewart and Larher 1980, Bultman and Faeth 1987 and Bernays and Chapman 1994). Moreover, bark of stressed trees has higher soluble sugar concentration than well-watered trees so, it affect positively on larvae growth. Also, (Koricheva *et al*., 1998 and Guérard *et al*., 2000)found that water stress could play an important role in the susceptibility of mature *E. globulus* trees to *P. semipunctata* attack. Inner bark tissue moisture has been found to be an important defense against the successful development of *P. semipunctata* in eucalypts (Skene 1965 and Hanks *et al*., 1999).

CONCLUSIONS

Understanding the relationship between water stress and susceptibility of trees to insect attack is one of most important components for sustainable forest management and decision makers. Inner bark tissue moisture has been found to be an important defense against the successful development of *P. semipunctata* in eucalypts. There are hundreds of species to choose from, but only a small percentage of these species was examined for susceptibility to *Phoracantha*s. It is important to know that even a resistant tree species should be kept in vigorous condition. Not surprisingly that susceptible tree species that is well cared for may be at less risk of infestation than a neglected tree of a resistant species.

Recommendation and control:

We can summarize the procedures to be considered as follows:

Protection and control procedures:

First, to avoid trees infestation:

- It's important to keep planted sites away from drought, because of larvae caused the main damage at weak and dead trees so, sufficient watering and fertilization keep trees vigor and healthy.
- Use resistance species of eucalypt.
- Considering biodiversity on planting new sites.

Second: controlling infestation sites:

Upon our findings, it is worth recommending here to apply salvage cutting as a silvicultural practice once appearing the pre infestation by the borers. It is recommended also to apply prescribed appropriate insecticide spraying upon the drought, if any. When, moderate and minor infestation larvae are collected by human or by natural enemies of predaceous and parasitic insects like in native area.

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الملخص العربى

تقدير الحالة المرضية والصحية لأشجار الكافور النامية على مياه الصرف الصحى المعالج (أسباب الإصابة- الأعراض- المكافحة)

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قسم الغابات وتكنولوجيا الاخشاب – كلية الزراعة- جامعة الاسكندرية

قسم الغابات وتكنولوجيا الاخشاب – مركز البحوث الزراعية- وزارة الزراعة

تم إجراء هذا البحث فى المزرعة الخشبية بسيرابيوم على أشجار الكافور البلدى والليمونى والتى ظهرت عليها أعراض الإصابة بحفار ساق الكافور ذو القرون الطويلة، وقد أظهرت النتائج ان الكافور البلدى أكثر مقاومة للإصابة من الكافور الليمونى حيث كانت نسبة الإصابة به ٩,٦% مقابل ٢٦,٥% فى الكافور الليمونى بالترتيب. كما أظهرت النتائج ان إنخفاض المحتوى الرطوبى فى النبات والتربة والذى يرجع الى تعرض الأشجار لفترات جفاف طويلة بالإضافة للإرتفاع فى درجات الحرارة والذى كان عامل معنويا فى الإصابة كما تبين من علاقة الإرتداد بين المحتوى الرطوبى ومستوى الإصابة كما تم تقديم بعض الإجراءات التى تقلل من الإصابة.