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RESEARCH ARTICLE

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Assessment of coconut bug, *Pseudotheraptus wayi* Brown (Hemiptera: Coreidae) damage on litchis in the Limpopo and Mpumalanga provinces of South Africa

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A survey of the coconut bug, *Pseudotheraptus wayi* damage on litchi fruits was conducted on eight farms in the Limpopo and Mpumalanga provinces to assess infestation levels. Ten Mauritius litchi trees per study site/farm were randomly selected and monitored in November and December 2023. Fallen/aborted immature fruits were collected from the mature litchi trees. A total of 11 083 fruits were collected and inspected for coconut bug damage. A total of 5 262 fruits were found to be damaged by coconut bugs. The results of the predicted percentage means from the GLMM modelling of the damage caused by the coconut bugs ranged from 19.71% to 62.41% on aborted fruit from farms, with 33.77% and 57.53% in Limpopo and Mpumalanga provinces, respectively. An indication that the coconut bug caused an average annual loss of 45.65% on immature fruit that were subsequently aborted in production from the two provinces. These findings point towards the fact that there is a considerable presence of coconut bug on the farms and also that litchi is a very good host of the coconut bug. The coconut bug damage increased when other host plants are cultivated in close proximity. Further research to evaluate economic impact of this pest is therefore needed.

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INTRODUCTION

South African litchi, *Litchi chinensis* Sonn, has relatively few insect pests of serious concern. Van den Berg et al. (2001) listed 28 phytophagous insect species on litchi in South Africa. The changing dynamics of insect pests and the emergence of new pests may become a hindrance to profitable litchi production. During the last few years, there has been an increase in the number of insect species damaging litchi fruits. The coconut bug, *Pseudotheraptus wayi* Brown (Hemiptera: Coreidae), is becoming one of the insect pests of concern to the litchi industry in South Africa (Begemann 2014). The coconut bug is a serious pest of a variety of crops grown in Eastern and Southern Africa (Egonyu et al. 2014). Host range studies show that it is also a significant pest of coconuts, cashews, macadamia, mango, guava, and avocado (Egonyu 2013; Mariau 1969; Van Der Meulen and Schoeman 1994; Nyambo 2009). In South Africa, this pest was reported for the first time in 1977 on mangoes (*Mangifera indica*: Anacardiaceae) and guavas (*Psidium guajava*: Myrtaceae) (De Villiers and Wolmarans 1980) and for the first time during 2007 on litchis (*Litchi chinensis* Sonn: Sapindaceae) (Schoeman 2019). It has also been reported to feed on other subtropical crops such as macadamia (*Macadamia integrifolia*: Proteaceae) and avocado (*Persea americana:* Lauraceae) (Schoeman 2014). In sub-Saharan Africa, the coconut bug feeds on commodities that are economically significant and destined for export markets of Europe and the United States of America (Obeng-Ofori 2013).

Feeding by both the nymphs and adults of the coconut bugs causes wilting and necrosis of shoots, leaves, inflorescences and fruits by its sap sucking feeding activity (Egonyu et al. 2014). The piercing mouthparts inject toxic saliva that have a lytic action on the cellular components on fruits causing scars leading to deformation and premature abortion of affected fruits (Schoeman and Morey 2016; Doh et al. 2014). The damage caused by the coconut bug is known to inflict 75–100% direct damage to shoots and flowers, which lead to an 80% or greater loss across a range of crop species (Maniania and Ekesi 2016). Coconut bugs are polyphagous and can easily shift from crop to crop if conditions become unsuitable on one crop (Schoeman and Morey 2016). Nymphs, being flightless, are essentially trapped on the branch or fruit, where they subsequently cause severe damage (Schoeman 2022).

The coconut bug can cause severe harm even at low pest densities, with only ten bugs per hectare causing significant economic loss of coconuts (Van Mele 2008). Damage from the coconut bug may affect only certain branches of a tree because of its patchy dispersal spreading (Schoeman et al. 2010). Although some fruit abort due to various abiotic factors such as lack of available nutrients, poor attachment and environmental factors such as wind, fruit load, temperature, water stress and human activities, the coconut bug may pose a threat for the tree crop industry in Africa (Ndlela et al. 2022), particularly where intensification in agriculture may lead to the establishment of orchards with susceptible hosts in close proximity to each other (Ndlela et al. 2022).

Applications of broad spectrum pesticides like cypermethrin, and lambda-cyhalothrin are used to control infestations of coconut bug on litchis and other crops (Mitchell 2000; Egonyu et al. 2014; Doh et al. 2016). Additionally, the pest has also been effectively managed by the African weaver ant *Oecophylla longinoda* (Hymenoptera: Formicidae) which are hostile territorial ants, wherein they attack any approaching coconut bugs while foraging. Moderate pruning has also been found to have a significant regulating effect on coconut bug populations, since large dense trees gives the insects a place to hide (Gruber and McKenzie 2018). Therefore, environmentally sound integrated management options for this pest are urgently required. However, before a management strategy can be developed, the infestation levels and the degree of damage caused by the coconut bug on litchi fruit needs to be determined. Therefore, the aim of this study was to determine the infestation levels caused by the coconut bug on litchi fruits in the production areas of Limpopo and Mpumalanga provinces of South Africa.

MATERIALS AND METHODS

Litchi fruits (cv. Mauritius) were collected from mature trees (more than 30 years old) in the Limpopo and Mpumalanga provinces, at eight study sites (4 replicates per province) during November and December 2023. Descriptions of each study site per province are presented in Table 1. The sampling of litchi fruit was permitted by the respective provincial departments of agriculture and land-use owners.

Makhado, in the Limpopo province, has an average maximum temperature of 31 °C and an annual mean minimum of 18 °C. Average rainfall is 500 mm which occurs mostly in summer. The area's soils include deep, well-drained loamy soil with a pH that is mildly acidic (Madzivhandila 2015). Thulamela is classified as a sub-tropical type climate, with the majority of the rain falling within the summer months from October until March. The mean annual precipitation ranges between 400 mm (northern and north-eastern region) and more than a 1 000 mm (south-western region) with an average of approximately 800 mm (Materechera-Mitochi 2023). The mean maximum temperatures range from 34 °C in the northeast to 26 °C in southwest and the mean minimum temperature ranges from 5 °C in the west to 12 °C in the northeast. The area is mainly covered by general soil types ranging from sandy soils, silty sands, loamy soils and clayey soils.

Nkomazi, in the Mpumalanga province, is characterised by warm sub-tropical temperatures and heavy summer rainfall. Winter mean maximum temperatures range from 5 °C to 20 °C, while mean summer maximum temperatures range from 25 °C to 35 °C. About 550 mm of rain falls there on average each year. Mbombela is characterised by a humid subtropical climate with mild winters and warm summers (Ndoro et al. 2023). The average daily temperature fluctuates from 6 °C in winter to 29 °C in summer. The average rainfall is 10 mm during winter and 120 mm during summer.

An experimental unit consisted of ten randomly selected trees in each farm. These trees were regarded as independent replications and were individually monitored during the study. All the trees were healthy, with no mechanical damage, and within orchards trees were spaced at 10 m × 10 m (100 trees/ha). The coconut bug is most effectively monitored by means of physical visual inspections using established scouting methods (Radzilani et al. 2012). Fruits that dropped during the first two months (November and December) after fruit set were collected and examined for coconut bug damage. Dropped fruits of 5 mm in diameter or smaller were not collected because they had not yet matured enough for the assessment of bug damage. The collected fruits were placed into brown paper bags and placed inside a cooler bag for the retention of moisture before being taken to Tshwane University of Technology (TUT) laboratory for examination. The fruits were dissected a day after collection. Fruits were regarded as positively affected when feeding puncture marks on the inside of the skin, as well as discoloured sunken lesions on the developing seed, described by Waite (1990) and Schoeman and Mohlala (2013), were present. These fruits were dissected and examined to determine the incidence of coconut bug damage to litchi fruits.

Statistical analysis

Generalised Linear Mixed Model (GLMM) analysis was applied to the proportions of damaged fruit with the Binomial distribution and the logit link function, because the proportions were not usually normally distributed to test for differences between the eight farms or two provinces. The random effects of two collection dates and ten trees per date were accounted for in the analysis (Freund, Mohr and Wilson 2010). Fisher's protected least significant difference was used at the 5% level ($p < 0.05$) to compare mean proportions when significance was indicated. Back-transformed means (Predicated %) followed by the same lower-case letter did not differ significantly at the 5% level. Data were analysed using Genstat software (VSN International 2022).

RESULTS

Total number of fruits collected, i.e., aborted fruits and the number of coconut bug damaged fruits are provided in Table 2. Percentages of damage due to coconut bugs are provided as mean damage and predicted means from the GLMM modelling of the incidence of damaged fruit per farm. In Mpumalanga province, coconut bug damage was highest (62.41%) on the Agricultural Research Council-Tropical and Subtropical Crops (ARC-TSC)

Table 1: Description of study sites farms, crops planted and their geographical locations

Province	Local municipality	Area	Farm name	Planted crops	GPS Coordinates
Limpopo	Makhado	Levubu	Pristentia	Litchi, macadamia	23°05'37.1" S, 30°17'19.0" E
	Makhado	Tsianda	Khuba	Litchi, macadamia, avocado, soft citrus	23°02'30.4" S, 30°21'47.3" E
	Thulamela	Duthuni	Tshivhase	Litchi	22°57'41.9" S, 30°22'37.0" E
	Thulamela	Phiphidi	Madima	Litchi, avocado, banana	22°58'00.4" S, 30°22'42.1" E
Mpumalanga	Nkomazi	Malelane	Neos Estate	Litchi, mango, orange, grapefruit, sugarcane	25°39'19.7" S, 31°35'04.0" E
	Nkomazi	Malelane	Letubi Valley	Litchi, grapefruit, banana, sugarcane	25°34'58.0" S, 31°35'41.7" E
	Mbombela	Nelspruit	ARC-TSC Nelspruit	Litchi, macadamia, mango, avocado, pecan, guava, banana	25°27'06.2" S, 30°58'11.1" E
	Mbombela	Kiepersol	ARC Burgershall	Litchi, macadamia, avocado, banana	25°04'07.5" S, 31°03'08.7" E

Nelspruit farm (Table 2). Damage assessed in the ARC-TSC Nelspruit differed significantly from the other Mpumalanga farms. Letubi Valley (54.87%) and ARC Burgershall (53.64%) farms did not differ significantly from each other. Neos Estate (58.50%) on the other hand was not significantly different from ARC-TSC Nelspruit nor Letubi Valley and ARC Burgershall. In Limpopo province, the farm Pristentia had the highest coconut bug damage (56.84%) (Table 2). Pristentia significantly differed from Khuba (33.75%), Tshivhase (19.71%) and Madima (23.46%) farms. Khuba farm was also significantly different from Tshivhase, Madima and Pristentia. While Tshivhase and Madima were not significantly different from each other.

From all the farms in both provinces, ARC-TSC Nelspruit farm had the highest incidence of coconut bug damage, while Tshivhase farm had the least damage. The incidence of damage recorded in the Limpopo province (33.77%) was significantly ($p < 0.001$) lower compared to that in the Mpumalanga province (57.53%) (Table 2). Figure 1 represents the mean incidence of damaged fruits given as a percentage of the total fruits collected from the two collections (November and December) on each farm in the Limpopo and Mpumalanga provinces. The statistical analysis (Table 3) indicates that there was no significant difference in infestation damage by the coconut bug between the two collection periods (months).

Table 2: Total counts of dropped and damaged fruits and incidence of damaged on different farms, followed by the predicted means from the GLMM modelling of the incidence of damage.

Province	Farm	Sample sizes (number of trees)	Number of fruits		Mean damage (% ± SD)	Predicted (%)
			Collected	Damaged		
Limpopo	Pristentia	20	1 130	642	57.00 ± 9.20	56.84^{ab}
	Khuba	20	1 422	479	35.10 ± 6.20	33.75^{c}
	Tshivhase	20	1 029	203	21.15 ± 5.06	19.71^{d}
	Madima	20	1 107	259	24.09 ± 6.36	23.46^{d}
	Total	80	4 688	1 583	34.33 ± 15.69	33.77^{B}
Mpumalanga	ARC-TSC Nelspruit	20	2 015	1 256	61.27 ± 9.04	62.41^{a}
	ARC Burgershall	20	1 911	1 020	53.31 ± 8.17	53.64^{b}
	Neos Estate	20	1 294	758	57.74 ± 10.49	58.50^{ab}
	Letubi valley	20	1 175	645	55.18 ± 7.92	54.87^{b}
	Total	80	6 395	3 679	56.87 ± 9.29	57.53^{A}

Predicated % followed by different lower or upper-case letters differed significantly at the 5% level. The *p*-value in both the test for farm and province differs significantly at the 5% level, i.e. $p < 0.001$, higher in Mpumalanga (57.53%) than Limpopo (33.77%)

Table 3: Damage occurrence of the two collection dates (November and December) in both the two provinces.

Province	Collection month	Sample sizes	Mean incidence of damaged fruit (SD ± predicted %)
Limpopo	November	40	17.36 ± 33.07^{a}
	December	40	13.92 ± 35.21^{a}
Mpumalanga	November	40	11.18 ± 58.14^{a}
	December	40	7.05 ± 56.35^{a}

Predicted percentages followed by the same lower-case letter did not differ significantly at the 5% level.

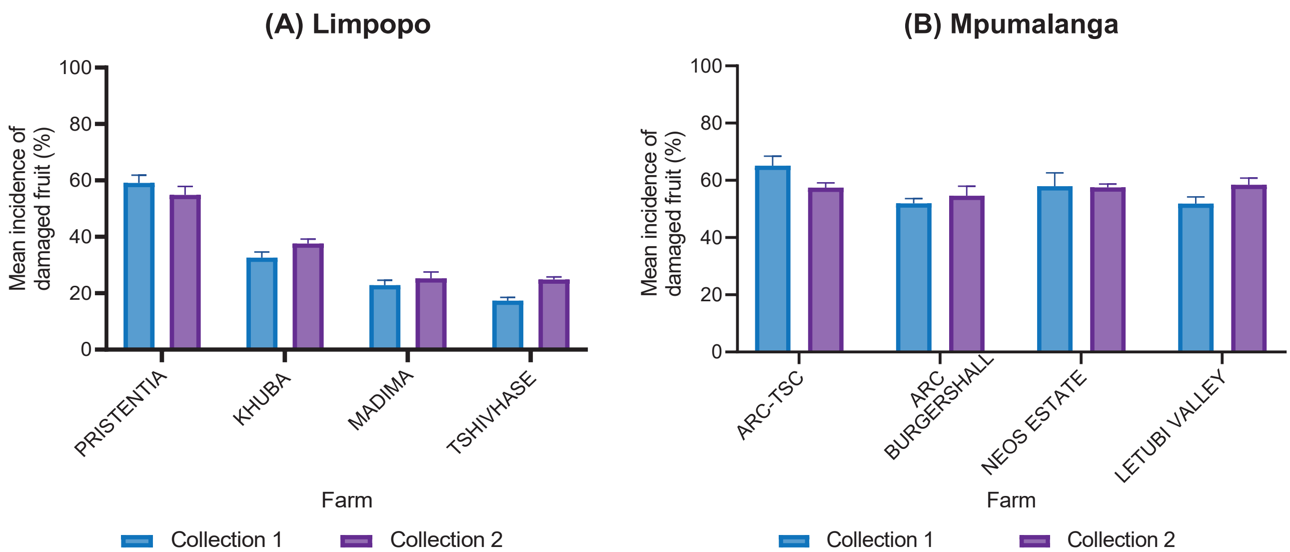

Figure 1: The incidence of damaged fruits collected on each farm in the Limpopo and Mpumalanga provinces of South Africa.

DISCUSSION

In this study, we found that coconut bug, *P. wayi,* induces early damage leading to aborted litchi fruit in the Limpopo and Mpumalanga provinces of South Africa. A total number of 11 083 fruits were aborted and subsequently collected during this study. Of these, 5 262 exhibited coconut bug damage. Damage symptoms observed in this study after dissecting the aborted fruits included dark feeding marks on the inside of the pericarp and dark brown necrotic lesions (discoloured sunken lesions) on the developing seed of aborted litchis. These coconut bug damage symptoms are similar to those observed by Schoeman et al. (2009) and Schoeman and Mohlala (2013). In this study, the damage lesions on aborted litchis were 4–5 mm in diameter, the size and severity of lesions resulted from bugs feeding activity.

More than 50% damage was observed on all four farms in Mpumalanga Province. This could be due to the farms having several hosts plants/habitats suitable for the bug throughout the season. Damage assessed in the ARC-TSC Nelspruit differed significantly from the other Mpumalanga farms (Letubi Valley and ARC Burgershall) while the incidence of damage at the other two Mpumalanga farms did not differ significantly from each other. Neos Estate on the other hand was not significantly different from ARC-TSC Nelspruit nor Letubi Valley and ARC Burgershall. The reason for the high incidence of damaged fruit at ARC-TSC research farm Nelspruit is most likely the high biodiversity of host plants such as litchis, macadamia, mango, avocado, pecans, and guava for they are all cultivated in a relative confined area. The results from this study correspond with the report from Schoeman (2014a) which indicated that the damage on various host plants caused by the coconut bug amounted to 70% was recorded from Nelspruit, where many alternate hosts are available. Our results also support the findings of Schoeman et al. (2009) which reported, that the incidence of the coconut bug in the Onderberg area (Malelane) was lower than in the Nelspruit region. It is probable that Neos Estate, Letubi Valley and ARC Burgershall farms have lower damage percentages when compared to ARC-TSC Nelspruit farm due to the lower diversity of host plants being cultivated. The area is an important production region for sugarcane, banana and grapefruit which are not listed as host plants for the coconut bug. The findings from this study links/correspond with the report from Schoeman (2022) indicating that the presence of a variety of nearby planted host plants may account for the higher population levels of coconut bug.

In Limpopo, the incidence of damaged fruits from Pristentia differed significantly from that of Khuba, Tshivhase and Madima farms. Khuba farm also had incidence of damage that was significantly different from Tshivhase, Madima and Pristentia. Regardless of Pristentia and Khuba farms being significantly different from each other, these two farms were found to have more coconut bug damage than the other two farms (Tshivhase and Madima) in the Limpopo Province. This may be due to the more uniform layout of trees where litchi is produced in a commercial scale (large scale) making it easier for the coconut bug to spread and establish. The two farms also contain other host plants such as macadamia and avocados that are planted at a higher density than at the other two farms. Bearing in mind that the coconut bug is present on various host plants, it can be concluded that having a high density and diversity of host plants provides a habitat for the coconut bug to reside while litchi fruits develop. These results are supported by Waite et al. (2000) who mention that a higher density of habitat plants may result in an increase in pest attack. The results are also supported by Schoeman (2014b) who found that pest-induced fruit damage is more common in orchards where trees are planted at high densities. Varanda and Pais (2006) found that pests move deeper into orchards planted at high densities because they are less disturbed, and food and shelter are abundant. Schoeman (2014b) also recorded that the sedentary nature of the female pest once a host is located results in multiple oviposition events on the same tree. Nortje and Schoeman (2021) found that the majority of Hemiptera damage occurred in the dense inner part of orchards, they also proved that insect pests prefer dense, overgrown dark orchards, possibly as a predator avoidance strategy.

The coconut bug damage at Tshivhase and Madima farms was minimal. These two communal farms fall under the Thulamela Local Municipality. They are surrounded by remote areas of less vegetation (located between households) and both farms have a more diverse layout which can limit the distribution of the coconut bugs. Due to the more diverse layout, trees are grown at lower densities resulting in less shelter for pests, making it easier for parasitoids or predators to locate and attack the coconut bug, potentially leading to reduced bug population. This also allows more sunlight penetration which may not be favourable for the coconut bug. These results support the finding of Vander Plank (1960) that open trees where sunlight penetrates through to the orchard floor, results in reduced numbers of coconut bugs compared to densely planted orchards. Furthermore, these two farms and the surrounding areas had only one or two host plants species and the distance to the nearest abundant vegetation containing host plants of coconut bug is at least 30 km. Thus, there is no nearby vegetation for the coconut bug to seek shelter in, which is important for the continued presence of heteropteran pests (Mizell et al. 2008).

The coconut bugs exhibited gregarious behaviour in all the farms of high and low density of trees, often resulting in a single highly infested tree surrounded by a group of uninfested trees or trees with low levels of infestation. This also corresponds with the findings of Schoeman et al. (2010) that coconut bug damage may be limited to a single limb of a tree.

There was no significant difference in the incidence of coconut bug damage between the two sampling dates. This supports the claim by Schoeman et al. (2009) that fruits appeared to be more susceptible to damage during their early developmental stages. Our results also suggest that litchis are susceptible to damage by the coconut bugs at all stages of fruiting.

CONCLUSION

The coconut bug is emerging as a significant pest that poses a threat to litchi production in South Africa. The findings in this study point towards the fact that there is a considerable presence of coconut bug in the farms where its host plants are cultivated in close proximity to each other. Therefore, it can be concluded that host plants planted/grown in high density and near the farm influences the severity of coconut bug infection. Furthermore, from the damage results observed on litchis it shows that litchi is a good host of the coconut bug, and it poses a threat for the litchi industry. Future research is required to estimate production losses by evaluating the economic and yield impacts on mature and harvested fruit.

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AUTHORS' CONTRIBUTION

M Netshipise, SR Netshifhefhe and PS Schoeman conceived and planned the original idea and experiments. M Netshipise carried out the experiments. R Gouws-Meyer contributed to the interpretation of the results. M Netshipise took the lead in writing the manuscript. All authors provided critical feedback and helped shape the research, analysis and manuscript. SR Netshifhefhe, PS Schoeman and R Gouws-Meyer helped supervise the project.

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