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Status of Biological Control as a Management Tool for Leucaena psyllid, *Heteropsylla cubana,* Crawford (Homoptera: Psyllidae) in Eastern Tanzania

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ABSTRACT

Biological control offers economic and environmental solutions against insect pests. Two Biological control agents *Tamarixia leucaena* and *Psyllaephagus yaseeni* were introduced from Trinidad to Tanzania for the biological control of the Leucaena psyllid (*Heteropsylla cubana* Crawford) which attack agroforestry fodder called Leucaena. We investigated status of biocontrol agents of *H. cubana* and indigenous predators of *H. cubana* in Morogoro and Tanga regions. Terminals of infested growing shoots were collected and treated to remove indigenous predators associated with *H. cubana*. Mean abundance of mummies, indigenous predators and parasitism percentage of *H. cubana* were quantified. The mean number of *T. leucaenae* and *P. yaseeni* mummies were 2.33 and 1.68 in Tanga and 2.64 and 2.10 in Morogoro per terminal shoot. Parasitism rate of *P. yaseeni* and *T. leucaenae* were 0.16% and 0.11% in Tanga and 0.15% and 0.14% in Morogoro respectively. The dominant indigenous predators were spiders followed by ladybird beetles. Therefore, introduced biological control agents and indigenous predators play a vital role in controlling *H. cubana*. However, there is a need to understand the interactions between indigenous predators and *H. cubana* in order to advice farmer on appropriate biological control measures

Key words: biological control - *Heteropsylla cubana* – Tanzania - Parasitism – Mummies.

INTRODUCTION

Biological control is the use of living organisms to suppress pest populations, making them less damaging than they would otherwise be (Le Hesran *et al*. 2019). It can be used against all types of pests, including insects, vertebrates, weeds and plant (Le Hesran *et al*. 2019, Lyimo 2016). It is considered as one of the best possible solutions for the control of forest insect pests because of several advantages (Valenciaga *et al*. 2020). It is little or no collateral, rare cases of resistance, long-term control adverse effects, the benefit/cost ratio is very favorable and can be used as part of Integrated Pest Management (Rodriguez and Arredondo 2007, Valenciaga *et al*. 2020).

Heteropsylla cubana Crawford is a tiny yellow-green insect in the family Psyllidae of the order Homoptera. *Heteropsylla cubana* feeds on young growing shoots of several plant species related to the genera Mimosa, Piptadenia and Leucaena (Ahmed *et al.* 2014, Nair 2007, Valenciaga *et al*. 2020). It is native to Central and South America. The first spread from its natural habitat was recorded Hawaii in 1984 and later Asia in 1985 and East Africa in 1992 (Ahmed *et al.* 2014, Nair 2007, Madoffe and Petro 2011). *Heteropsylla cubana* damages plants when both the nymphs and adults suck from the shoots and young foliage. Heavy infestations result to defoliation of the plant and stop growth, although older leaves are not directly damaged by psyllid. However, *H. cubana* is sticky fluid exudates promotes growth of sooty mold on leaves and limits photosynthesis (Shelton 2008). Biological control efforts against *Heteropsylla cubana* were successfully by using specific natural enemies such as the predators, *Curinus coeruleus* and *Olla v-nigrum*, and parasitoids, *Psyllaephagus yaseeni* and *Tamarixia leucaenae* in Asia-Pacific Region and Africa (Madoffe et al. 2000, Shivankar *et al*. 2010, Madoffe and Petro 2011, Valenciaga *et al*. 2020). In additional, several arthropod natural enemies were associated with the *H. cubana*, the most dominant being spiders, lacewings, dragonflies, ladybird beetles and ants in Tanzania (Madoffe *et al*. 2000, Valenciaga *et al*. 2020).

The outbreak of the devastating Leucaena psyllid, *H. cubana* discouraged the spread of Leucaena based fodder production technology and many other uses in Tanzania (Lulandala and Hall 1987, Madoffe *et al.* 2000). *Leucaena leucocephala* (Lam.) de Wit is one amongst many multipurpose trees that has been promoted for fodder production in Tanzania (Lulandala and Hall 1987). The tree is found in many parts of Tanzania and usually planted along farm boundaries and in homesteads for fodder, soil fertility improvement and fuelwood (Msangi *et al.* 2002). Most Leucaena stands were lowered after invasion of *H. cubana* (Madoffe *et al.* 2000). The Asia-Pacific experience was considered the best option to adopt in Kenya and Tanzania as an effort to control *H. cubana* (Ciesla and Nshubemuki 1995, Madoffe and Petro 2011). Hymenopterous parasitoids *Tamarixia leucaena* Boucek (Hymenoptera: Eulophidae), and *Psyllaephagus yaseeni* Noyes (Hymenoptera: Encyrtidae) from Trinidad and Tobago were released in Tanzania (Madoffe *et al*. 2000. The biological control agents were well established and spread over large areas, and were appeared to be effective against *H. cubana* in Tanzania (Madoffe *et al.* 2000, Madoffe and Petro 2011). *Tamarixia leucaenae* is a solitary ectoparasitoid that lay eggs behind the hind coxae of third or fourth instar *H. cubana* nymphs (Patil *et al*. 1993) thereby inhibits further nymphal development. *P. yaseeni* is a solitary endoparasitoid which attacks *H. cubana* first and second instar, then after continue to develop until instar fifth when they mummify (Patil *et al.* 1993).

Reduced *H. cubana* population and Leucaena shoot damage in some areas were attributed due to the role rendered by parasitoids and indigenous predators in Tanzania (Madoffe *et al*. 2000). However, little is known on abundance of *H. cubana* mummies of *T. Leucaenae* and *P. yaseeni* and percentage of parasitization of *H. cubana* in Africa, including Tanzania (Geiger and Gutierrrez 2000). In addition, little has been done to identify the indigenous predators of the *H. cubana* in Tanzania and what already reported was not at species level (Kisaka 1994, Madoffe *et al*. 2000). Therefore, this study aimed at identifying and determining the abundance of indigenous predators associated with *H. cubana*, abundance of *H. cubana* mummies of *T. Leucaenae* and *P. yaseeni* and percentage of parasitization of *H. cubana* in Morogoro and Tanga regions. The findings result from this study is useful to farmers whom abandoned planting *L. leucocephala* in the country to have a clear picture on the status of the role played by biological control agents against *H. cubana* in Tanzania.

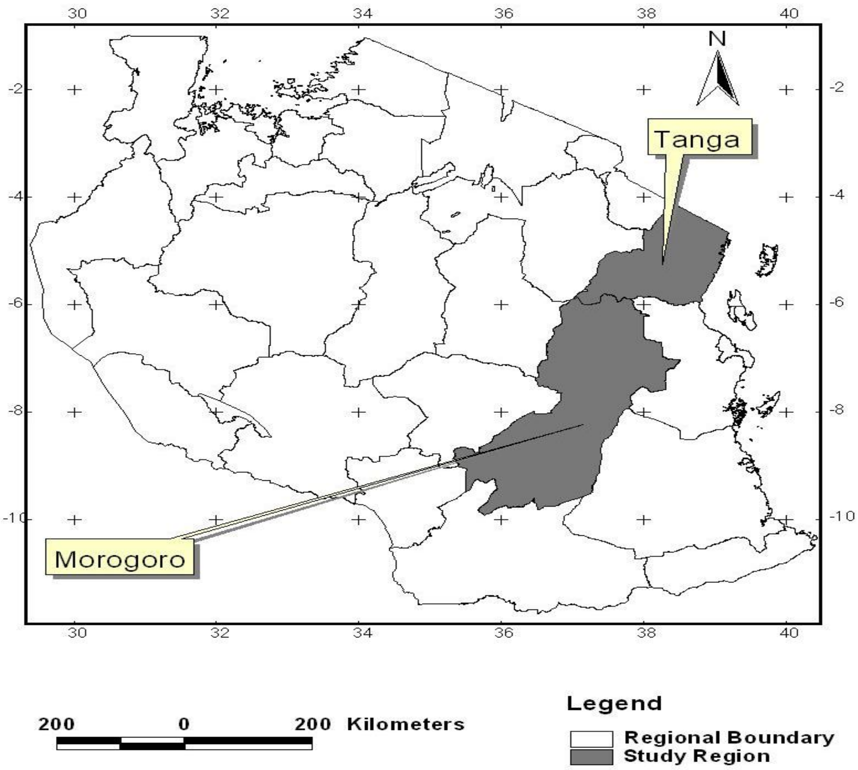
MATERIALS AND METHODS

Description of study area

Studies were conducted in selected sites of Morogoro and Tanga region, namely; Morogoro: SUA farm, Melela A and B; Tanga: Mlingano, Tanga dairy farm and

Ziwani (Table 1 and Figure 1). These sites were used in 1990s for the release of two *H. cubana* parasitoids and later assessed for their spread and establishment (Madoffe *et al*. 2000). Morogoro region lies between latitude 5° 58" and 10° 0" to the South of the Equator and longitude 35° 25" and 35° 30" the East Greenwich with an area of 72, 939 square kilometers of the total Tanzania mainland and population of 2,218,492 (MRSEP 2006, NBS Census 2012). Tanga Region is situated at the extreme northeast corner of Tanzania between 4° and 6° degrees below the Equator and 37° - 39° 10' degrees east of the Greenwich Meridian. The region occupies an area of 26677 km^2 with a population of 2.045.205 (NBS Census 2012).

Table 1: Description of study areas.



Region	Location name	Latitude	Longitude	Altitude (m)
Morogoro	SUA farm	6°.822097	37°.661160	500.7
	Melela A	6°54'53.6"	37°26'0.61"	488.19
	Melele B	6°55'84.6"	37°19'.61"	486.9
Tanga	Mlingano	5°.06667	38°.91667	87.12
	Tanga dairy farm	5°15'S	39°15	65.34
	Ziwani	5°.3354	38°.5494	236.43

Figure 1: Map of the study regions

Sampling Design

The Point Centre Quarter method (PCQ) was employed to assess population of *H. cubana* and parasitoids, damage rate and shoot health (Figure 2) (Marisa 2015). Five sampling points were established in each site, where one at center and other four at the corners of site (Figure 2). In each sampling point, four quadrants were established. The adults and regenerants *L. leucocephala* near sampling point at each quadrant were sampled and recorded. *L. leucocephala* were grouped into two cluster of regenerants (dbh< 1 cm) and adult species (dbh≥ 1 cm).

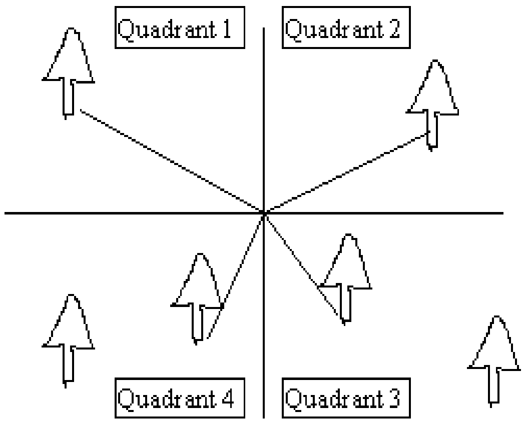


Figure 2: The layout of sampling point on the study area.

Adult Leucaena trees were categorized into three dbh classes i.e., (1-5 cm), (6-15 cm) and (>15 cm) and then into three crown levels (upper, middle and lower level). In each quadrant, two adults *L. leucocephala* for each dbh classes and two regenerants were sampled.

Data collection

Data were collected during early morning (05:30-9:00am). One 15cm growing shoot was randomly selected and sampled from each crown level for adult species and two 15cm terminal growing shoot of two regenerants in each quadrant. The shoots were carefully cut into a polythene bag (destructive sampling) and put in a refrigerator to ensure its flesh for observation. The collected shoots were washed carefully with the help of a brush and ethanol (70%) into a petri-dish to remove mummies of *P. yaseeni* and *T. leucaenae*. In the Laboratory mummies of *P. yaseeni* and *T. leucaenae* were counted under a dissecting microscope.

The collected growing shoots were washed carefully with the help of a brush and ethanol (70%) into a petri-dish to remove indigenous predators associated with *H. cubana*. The laboratory indigenous predators were counted under magnifying hand lens for identification of indigenous predators to species level.

Data analysis

R version 3.2.3 software programs were used in data analysis. Descriptive statistics were used to determine mean abundance of *H. cubana* mummies of *P. yaseeni* and *T. leucaenae* and indigenous predators associated with *H. cubana*. Analysis of Variance (ANOVA) at 5% level of significance was used to determine whether the means abundance in *H. cubana* mummies of *P. yaseeni* and *T. leucaenae* between dbh classes and growing sites are different. The percentages of parasitization were calculated from mummy and 5th-instar counts using the method of Luck *et al*. (1988).

$$Percentage\ parasitism = \frac{Number\ of\ mummies/shoots}{(Correction\ factor) * (Number\ of\ 5th\ instar/shoot}$$

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with

$$Correlation\ factor = \frac{Development\ time\ of\ mummy}{Development\ time\ of\ 5th\ instar/shoot}$$

RESULTS

Abundance of Mummies of *Tamarixia leucaenae* and *Psyllaephagus yaseeni* in Morogoro and Tanga region

The mean numbers of *H. cubana* mummies of *P. yaseeni* and *T. leucaenae* per 15cm terminal shoot were 2.33 and 1.68 in Tanga and 2.64 and 2.1 in Morogoro respectively (Figure 3 and 4). Results showed that the abundance of mummies of *Psyllaephagus yaseeni* in Morogoro was not statistically different among crown levels (F=1.21, df=2, P=0.298) and among dbh classes (F=1.29, df=2, P=0.27) in Morogoro. In Tanga mean numbers of *H. cubana* mummies of *P. yaseeni* were not significantly among crown levels (F=0.448, df=2, P=0.639) and among dbh classes (F=1.41, df=2, P=0.246). The interaction between dbh and crown level was not significantly different in both Morogoro (F=1.21, df= 4, P=0.302) and Tanga (F=0.827, df= 4, P=0.51).

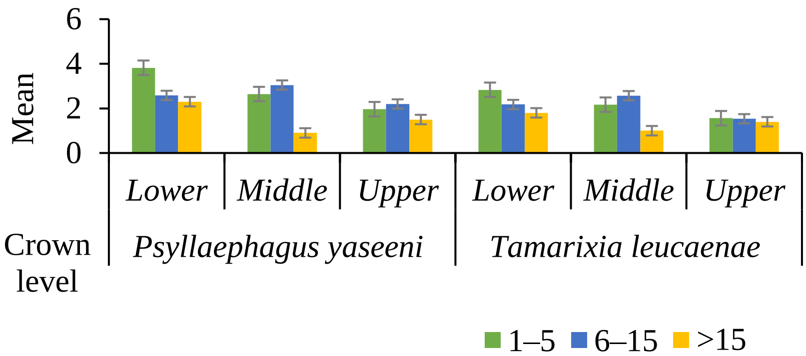

Figure 3: Mean numbers of *H. cubana* mummies of *P. yaseeni* and *T. leucaenae* for adult *L. leucocephala* in Morogoro region

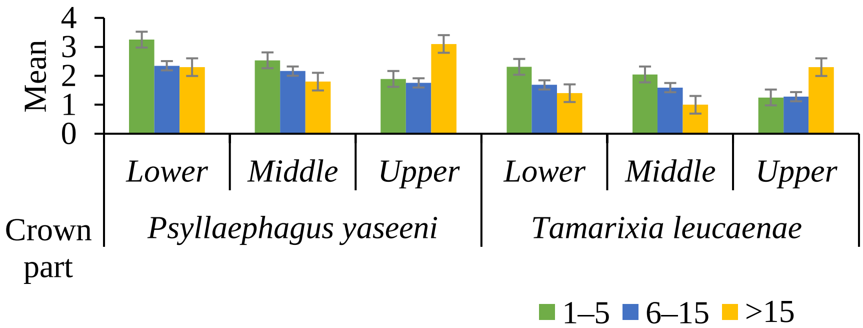

Figure 4: Mean number of *H. cubana* mummies of *P. yaseeni* and *T. leucaenae* for adult *L. leucocephala* in Tanga region.

The abundance of *H. cubana* mummies of *T. leucaenae* were not statistically different among crown levels (*F*=1.28, df=2, P=0.278) and among dbh classes (*F*=0.98, df=2, P=0.37) in Morogoro. In Tanga *H. cubana* mummies of *T. leucaenae* were not significantly among crown levels (*F*=0.19, df=2, P=0.82) and among dbh classes (*F*=1.227, df=2, P=0.294). The interaction between dbh and crown level was not significantly different in both Morogoro (*F*=0.928, df= 4, P=0.447) and Tanga (*F*=1.101, df= 4, P=0.355). There was high mean numbers of mummies in regenerants *L. leucocephala* than in adult *L. leucocephala* for both *P. yaseeni* and *T. leucaenae* in Morogoro and Tanga (Figure 5).

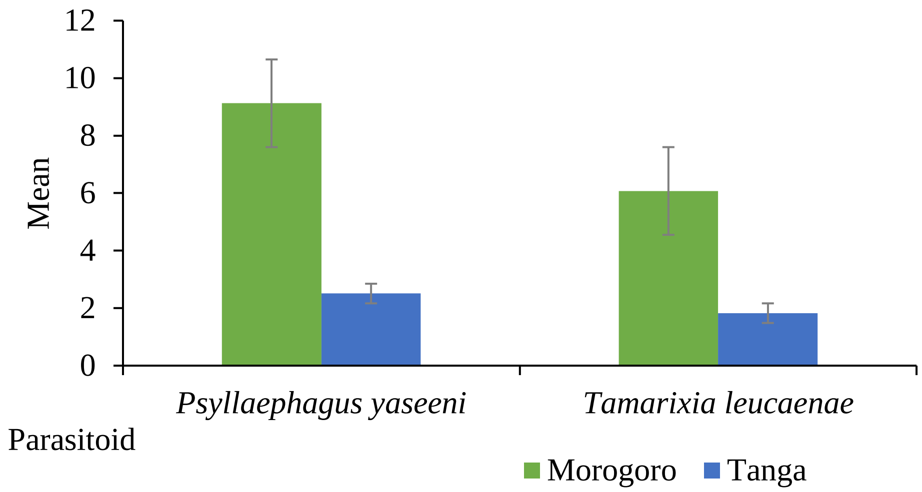

Figure 5: Mean number of *H. cubana* mummies of *Psyllaephagus yaseeni* and *Tamarixia leucaenae* for regenerants *Leucaena leucocephala* in Morogoro and Tanga regions.

Abundance of indigenous predators associated with *H. cubana* in Morogoro and Tanga region

The dominant indigenous predators found were spider (*Neoscona theisi* and *Araneus inustus*) (71.11%) of which about 60.44% observed in Tanga and 10.67% in Morogoro followed by ladybird beetles (*Coccinella transversalis*, *Chilocorus circumdatus*, *Coelophora inequalis*, *Menochilus sexmaculatus*, *Synonycha grandis* and *Harmonia* species) (22.67%) of which 14% in Morogoro and 8.67% in Tanga, unidentified dragonfly (5.11) of which 3.67 in Morogoro and 1.33% in Tanga and lacewing (*Chrysoperla sp.*) (1.11%) which was only observed in Morogoro for adult *L. leucocephala* (Figure 10 and 11). The almost the same was observed for regenerants as the predator was spider 37.02% and 22.98%, followed by ladybird beetles 15.74% and 15.74%, dragonfly 2.12% and 5.11% in Tanga and Morogoro respectively while Lacewing 1.28% was observed in Morogoro only for regenerants *L. leucocephala*.

Parasitism Percentage of *H. cubana* in Morogoro and Tanga regions

The result found rate of parasitism of small nymph and medium nymph for adults *L. leucocephala* were 0.15% and 0.14% in Morogoro and 0.16% and 0.11% in Tanga for *P. yaseeni* and *T. leucaenae* respectively (Table 2). The rate of parasitism of small nymph and medium nymph for regenerants *L. leucocephala* were 0.47% and 0.41% in Morogoro and 0.47% and 0.31% in Tanga of *P. yaseeni* and *T. leucaenae* respectively.

Results showed that rate of parasitism of small nymph by *P. yaseeni* was not statistically significant different among dbh classes in Morogoro (*F*= 0.478, df=2, P=0.621) and in Tanga (*F*= 2.95, df=2, P=0.055). The rate of parasitism of medium nymphs was significantly different among dbh classes in Tanga (*F*=3.07, df=2, P=0.049) but not in Morogoro (F=0.495, df=2, P=0.610). The rate of parasitism of small nymph and medium nymph for regenerants were high compared to adult *L. leucocephala* (Table 2).

Table 2: Percentage of parasitization of *H. cubana* for adult *L. leucocephala* in Morogoro and Tanga regions

Region	dbh classes	% Parasitism	
		Psyllaephagus yaseeni	*Tamarixia leucaenae*
Morogoro	1–5	0.16	0.14
	6–15	0.16	0.13
	>15	0.13	0.16
	Mean total	0.15	0.14
Tanga	1–5	0.18	0.12
	6–15	0.14	0.09
	>15	0.12	0.08
	Mean total	0.16	0.11

DISCUSSION

The study found low mean mummies compared to that reported by Madoffe *et al.* (2000), which was 10 and 11 mummies per growing shoot in Tanga and Morogogro respectively. The decline in mummies were due to the decline of *H. cubana* population as a result of role played by *P. yaseeni* and *T. leucaenae*, indigenous predators and environmental factors. The trend of mummies for both *P. yaseeni* and *T. leucaenae* in the three dbh classes and localities were not different from that of *H. cubana* population for both regenerants and adults *L. leucocephala*. The low abundance of both *H. cubana* and mummies in Tanga were due to unfavourable climatic condition which does not support *H. cubana* production. This concur with other studies which shows that *H. cubana* population is affected by temperature, moisture, humidity and exposure to wind (Ahmed *et al*. 2014, Geiger and Andrew 2000, McAuliffe 2008) and the ups and downs of the psyllid populations which in turn affect mummies production are related to an optimum cooler temperature range and the availability of tender shoots in Hawaii (Ahmed *et al*. 2014).

This study found a low rate of parasitism compared to 0.23% using mummy count reported by Geiger and Andrew (2000). The low rate of parasitism was due to few hosts available for parasitism. At both localities, parasitism rates showed increased with nymph density which was different from that of Geiger and Andrew (2000), that parasitism increased with no density. The low parasitism rates 0.18%-0.08% (Table 3) of the *H. cubana* population in this study were similar to those observed in Hawaii (Uchida *et al*. 1992), and appear insufficient to suppress psyllid populations. After exposing *T. leucaenae* to psyllid nymphs in quarantine, only one parasitized nymph was obtained and the entire culture eventually perished. As a result, there was no further attempt to utilize this species in Thailand (Napompeth 1994). *Tamarixia radiata* Waterson was introduced from Reunion to Taiwan between 1984 and 1988 for control of *Diaphorina citri* Kuwayama and has caused a substantial reduction in populations of the psyllid, with up to 100% parasitism recorded (Chien *et al*. 1989).

The current study revealed that the found indigenous predators associated with *H. cubana* are similar with previous studies reported. Indeed, the study did not prove that these indigenous natural enemies were feeding on the psyllid, consequently contributing to the declining psyllid population. Madoffe *et al.* (2000) found several arthropod natural enemies living in association with the *H. cubana* being spiders, ladybird beetles, ants, dragonflies and lacewings. In contrast to this study, ants were not found in association with *H. cubana*. The found indigenous predators were reported as important predators in South East Asia Pacific Region and Central America and (Ahmed *et al*. 2014, Nakahara *et al*. 1987, McClay 1990, Napompeth 1994) although there is still no quantitative evidence on the role of indigenous predators against *H. cubana* (Shivankar *et al*. 2010).

This study concurs Valenciaga *et al*. 2020 who reported *Chrysoperla cubana* fed on nymphs and adults of *H. cubana* in Cuba. The study by Geiger and Andrew (2000) were reported predominant coccinellid predators at all study sites were *Menochilus sexmaculatus* (F.), followed by *Oenopia sauzeti* Mulsant and *O. kirbyi* Mulsant (highland site only), and *Micraspis discolor* (F.). *Coccinella transversalis* F. and *Micraspis lineata* (Thunberg) were occasionally observed at the valley site. Numerous spider and dragonfly species, 4 species of ants, vespid wasps, syrphids, reduviids, mirids, 1 *Geocoris* species, and lacewings were also observed preying on *H. cubana*, but they were not abundant. This concurs with current study found in Morogoro and Tanga. Barrion *et al* (1987) in Philippines reported functional groups similar, in this case predators (species of ants and spiders) as natural control of *H. cubana* population in agroecosystems with *L. leucocephala*.

CONCLUSION AND RECOMMENDATION

Conclusion

This study found the introduced biological control agents (*T. leucaenae* and *P. yaseeni*) and other natural enemies are playing a vital role to control *H. cubana*. The biological control agents have been established successfully in Eastern Tanzania, despite the fact that *P. yaseeni* were neither released in Tanga nor Morogoro. Mummies population found lower significantly compared to what was reported soon after the release of the *T. leucaenae* and *P. yaseeni* in 1995/1996. The findings from the present study revealed that dominant indigenous predators of *H. cubana* in Tanzania are *Neoscona theisi*, *Araneus inustus*, *Coccinella transversalis*, *Chilocorus circumdatus*, *Coelophora inequalis*, *Menochilus sexmaculatus*, *Synonycha grandis*, *Harmonia* species, *Chrysoperla* species and several unidentified dragonflies and mantispid.

Recommendation

There is a need to understand in depth the interaction of natural enemies and *H. cubana* in order to advice farmer accordingly. So far, farmers are advised to plant *L. leucocephala* for various use without any fear about *H. cubana* as *T. leucaenae* and *P. yaseeni* has significantly manipulate psyllid's population. Due to time constraint this study has not manage to assess the temporal nature of both mummies of *T. leucaenae* and *P. yaseeni*, further investigation is recommended. Also, other investigation should look on the effect of abiotic factors such as rainfall, temperature, wind velocity and others on mummies of *T. leucaenae* and *P. yaseeni*.

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