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Sex Ratio, Age Structure and Parasitism in *Unaspis mabilis* (Hemiptera: Diaspididae) in the Philippines

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ABSTRACT

Lanzones scale insect (LSI) has been an important insect pest of lanzones since its first record in 2004. It causes massive defoliation on trees which eventually results to underdeveloped and sour fruits. Different lanzones-growing areas in the Philippines were surveyed for LSI along with its associated parasitoids in commercial lanzones farms located in Laguna (Los Baños,Nagcarlan and Sta. Maria), Oriental Mindoro (Villa Cerveza, Villa Cerveza, San Gabriel-Alcate), Negros (Abante-Pamplona, Poblacion - Pamplona, Lunga, Valencia, Talisay - Negros Occidental, Jawa-Valencia, Lunga-Valencia, Bongbong), Misamis Occidental (Aloran - Misamis Occidental, Calamba, Oroquieta, Sapang Dalaga, Plaridel), Camiguin (Catarman, Poblacion, Sagay, Tagdo, Mahinog), North Cotabato (Makilala, Kidapawan, and Kabacan) and Sulu (Maimbung, Patikol,Talipao). From each collection site, a total of 10 infested trees were sampled at random with leaflets (N=10) collected in four cardinal directions around canopy. Leaflets were scanned, photographed, and transported to the laboratory. Population estimates of each local population was obtained along with demographic structure *viz.* age structure and male-female sex ratio. The sample per tree were kept individually in customized cages for parasitoid emergence and determination of parasitization rate. Parasitoids were identified as *Aphytis sp.*, *Encarsia sp.* and 2 other unidentified species. LSI population and percent parasitism in Laguna were quite high compared to North Cotabato. Results of this study will contribute to the basic knowledge needed to improve control strategy on LSI.

INTRODUCTION

A new species of armored scale insects has been found infesting lanzones trees, *Lansium domesticum* L. in the Philippines. It was recently identified as *Unaspis mabilis* by Lit & Barbecho (2014) and was formally made as a junior synonym of *Unaspis lansivora* by Watson (2015a). It was named after the “tagalog” adjective “mabilis” which refers to the rapid spread of its infestation to various lanzones growing areas in the country. Even if this species is currently known only from the Philippines, it was doubtful to be considered as a native species. The apparent aggressive behavior of this insect is generally interpreted as characteristics of invasive alien species (Lit & Barbecho, 2014).

Lanzones scale insect (LSI) has become widespread in many lanzones growing areas in the Philippines. Initial observation of its occurrence

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was reported in Tupi, North Cotabato followed by several attacks in nearby municipalities of South Cotabato, Davao and Sarangani Province (Watson, 2015b). The damage that the scale insect inflicts in lanzones trees includes massive defoliation of leaves which eventually cause underdeveloped and sour fruits. Prolonged attacks can also cause death of trees because of the unavailability of leaves to support them. In September 2007, the infestation of LSI resulted in losses of 5 million pesos to lanzones growers in the town of Magpet alone.

Various pest management strategies were employed in order to control the population of LSI in the field. A predatory beetle, *Chilocorus nigritus* was utilized as biological control agent thru the DA-BAR funded project implemented by the DA-RFO XI Southern Mindanao Integrated Agricultural Research Center. Field releases were done at a rate of 100 adults per tree. Additionally, chemical control was also used. An organophosphate and a neonicotinoid were applied in Lanzones trees in region 11 thru spraying and trunk injection. It is undeniable that these tactics can create control to the population of LSI but there are still additional data that needs to be generated in order to create IPM program.

Demographic parameters relevant for population size (age structure, sex ratio, longevity, and survival rate, among others) can be used to evaluate population dynamics and structure (Barretto et. al., 2019). Knowledge on the age structure is essential to the understand basic properties of insect populations (Carey et al., 2012). Specifically, details of age distributions in insect populations that consist of mixtures of young, middle, and old age classes aid demographic interpretation and inference. At the community level, age structure may affect dynamics along with life spans and dispersal (Price et al., 2011; Hoy et al., 2019). Based on field observations, age structure in insects may vary between seasons and years (Franceschini et al., 2013; Barretto et al., 2019; Tasnin et al., 2021).

Link between insect host age and parasitism and between parasitoid age and parasitism has been extensively studied (Pak, 1986; Calvin et al., 1997; Queiroz et al., 2019) and found to vary between different species (Pak, 1986; Queiroz et al., 2020). Parasitism in *Unaspis spp.* by hymenopteran parasitoids have been widely documented (Bayoumy et al., 2013; Suh & Evans, 2015). It is well-established that parasitoids have significant role in regulating insect pest populations and preventing pest outbreaks (Péré et al., 2013; Huang et al., 2020). Abiotic factors for example, temperature can cause reduction in the parasitoid population and in the levels of parasitism (Soares et al., 1997; Bayoumy et al., 2013).

Innately, in sexually reproducing animal species, sex ratio has a major influence on its biology and adheres with the Fisher's principle (i.e., 1:1) (Girondot & Pieau, 1993; Wei, 2008; Papach et al., 2019; Compton & Tu, 2022). For insects, male-biased or female-biased sex ratios can be observed including species in Hemiptera (Greeff, 2002; Santolamazza-Carbone & Rivera 2003; Henri & Van Veen, 2011). Variation in insect's sex ratio throughout its life span is indicative of its reproduction potential and is key to understanding its mating behavior (Smith et al. 2004; Henri & Van Veen, 2011). Sex ratio can also affect the ecology and genetics of an insect population (Henri and Van Veen, 2011). As such, it will be beneficial to investigate on sex ratio of species in order to forecast timing and magnitude of insect pest outbreaks (Wei, 2008).

Data on age structure, sex ratio and parasitism in armoured scales insects attacking *Lansium* in the Philippines are scarce. More specifically, this study aimed to determine the current level of LSI infestation in major lanzones growing areas in the country and in the context of biological control, identify parasitoids attacking LSI and thereafter derive field parasitism rates among the areas surveyed. As of the moment, parasitoids are not explored as alternative in existing biological control of LSI in the Philippines which is focused on predators especially *Chilocorus spp.* and *Telsimia nitida*. When harnessed optimally, these parasitoids can be used as effective biological control against which can form part of the integrated pest management for LSI.

MATERIALS AND METHODS

Collection Sites

A countrywide survey for LSI populations together with its associated parasitoids was done in commercial lanzones farms from July 2019 to October 2022 on 8-40 years old *Lansium domesticum* Corr., lanzones trees located in various locations in the provinces of Laguna (Los Baños,Nagcarlan and Sta. Maria), Oriental Mindoro (Villa Cerveza, Villa Cerveza, San Gabriel-Alcate), Negros (Abante-Pamplona, Poblacion - Pamplona, Lunga, Valencia, Talisay - Negros Occidental, Jawa-Valencia, Lunga-Valencia, Bongbong), Misamis Occidental (Aloran - Misamis Occidental, Calamba, Oroquieta, Sapang Dalaga, Plaridel), Camiguin (Catarman, Poblacion, Sagay, Tagdo, Mahinog), North Cotabato (Makilala, Kidapawan, and Kabacan) and Sulu (Maimbung, Patikol,Talipao) (Table 1). Collection sites for each province was determined based on the severity of infestations observed, where moderate of high level of infestation was given priority.

Population Sampling for LSI

In each collection site, a total of 10 infested trees were sampled at random with leaflets (N=10) (Coranado-Blanco & Ruiz-Cancino, 1995; Pekas, 2010) collected in four cardinal directions around tree canopy. Each leaflet was placed in a resealable plastic bag and labelled accordingly and these were transported to the Insect Ecology Laboratory, Institute of Weed Science, Entomology and Plant Pathology, University of the Philippines Los Baños then scanned and photographed and each LSI stages were counted. From this, population estimates of each LSI local populations were obtained as well as demographic structure including sex and age of scale insects. Since field local populations were used, only alive individuals per each stage LSI stage was accounted for the demographic data.

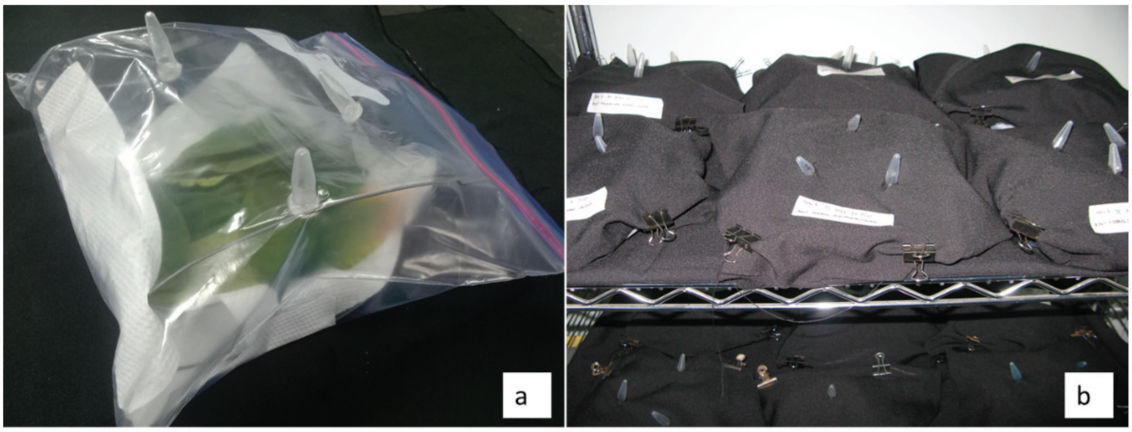


Fig. 1. Customized cage for emergence of lanzones scale insect parasitoids: a) individual and b) general set-up.

Table 1. Sites of collection for LMSI and its associated parasitoids in the Philippines

Sites	Date/s of Sampling	Development Stage of Trees
Sta. Maria, Laguna	Jul. 2, 2019	10 yrs. old
Nagcarlan, Laguna	Jul. 30, 2019	10 -15 yrs. old
Los, Banos Laguna	Mar.18, 2022	8-10 yrs. old
Negros	Nov.17-18, 2021	10 -20 yrs. old
Camiguin	Oct. 17-19, 2022	9-12 yrs. old
Misamis Occidental	Sept.15-17, 2022	10-20 yrs. old
North Cotabato	Aug. and Nov. 2020	11- 40 yrs. old
Mindoro	Oct. 27-28, 2021	10-20 yrs. old
Sulu	Oct. 1, 2019	10-15 yrs. old

Percent Parasitism

The sample leaflets per tree were kept individually for ten days in customized cages (Fig. 1) lined with tissue paper at both sides and lifted using a wire as support, for parasitoid emergence and emerging parasitoids were counted. Using authoritative taxonomic keys and dissecting microscope, each specimen was identified from family to genus level. The parasitization rate for each collection site was determined using the eqn. 1:

$$\%\ \text{Parasitism} = \frac{\text{No.of parasitoids}}{\text{No.of LSI per bag}} \quad \text{..........................} (1)$$

From each site, per tree, there were 15 leaves sampled, containing the base, mid and top canopy, in each cluster of the leaf, 1 leaflet was collected. Each was placed in re-sealable bag and labelled accordingly as TREE 1-10; SITE 1-3 (i.e. TREE 1, SITE 1 and so on). After counting emerged parasitoids from each bag, specimens were sorted and each individual was placed on 80% ethanol and kept as vouchered specimen.

Data Analysis

Demographic data for each LSI stages (Fig. 2) and percent parasitism during the surveys in lanzones orchards were collated, expressed as means and analyzed in using R version 4.1.1 (R Core Team, 2021). Significant difference was also determined for between population means using Fisher's - LSD test ($\alpha = 0.05$). Subsequently, percent composition of LSI by age for each sampling site was also calculated. Correlational analyses were done for pooled parasitism rate and demographic data across surveyed areas. Moreover, different diversity indices which are Simpson's dominance index (I), Simpson's index of diversity (1-D), H' - Shannon Diversity Index and Evennes Index (E) were also computed for the parasitoids collected from each province (Table 2).

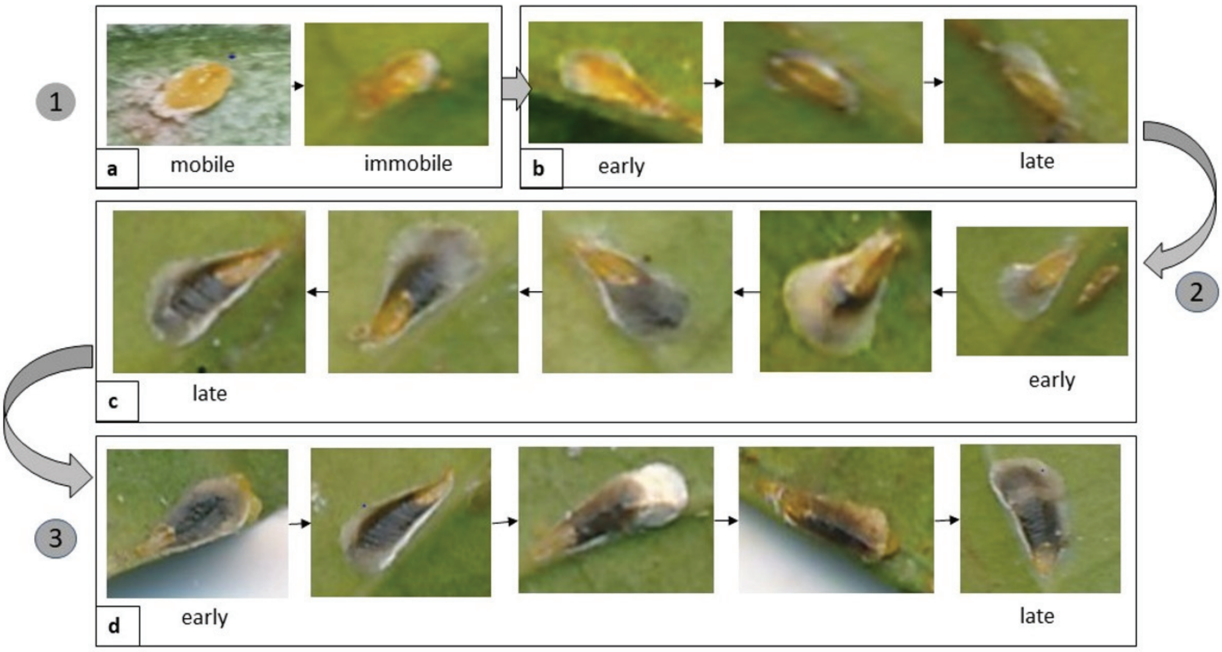


Fig. 2. Transition of phase of LMSI from first instar (a), second instar (b), third instar (c) to adult (d).

Table 2. Mean field parasitization rates of LMSI and diversity indices of parasitoids collected in different lanzones-growing provinces surveyed from 2019-2022 in the Philippines

Island	Province	MFP ± SD		N	S	I	1-D	H'	E
Luzon	Laguna	0.45 ± 0.37	b	37	4	0.34	0.66	1.16	0.84
	Oriental Mindoro	0.04 ± 0.03	b	33	7	0.25	0.75	1.49	0.77
Visayas	Negros Oriental	0.27 ± 0.29	b	12	4	0.36	0.64	1.08	0.78
Mindanao	North Cotabato	0.96 ± 1.17	ab	17	2	0.88	0.12	0.22	0.32
	Misamis Occidental	0.16 ± 0.04	b	36	4	0.39	0.61	0.97	0.70
	Camiguin	0.58 ± 0.15	ab	4	3	0.17	0.83	1.04	0.95
	Sulu	1.80 ± 1.73	a	36	3	0.39	0.61	0.99	0.90

Remarks: MFP ± SD = Mean field parasitism ± standard deviation, N = Total Number of Individuals, S = Species Richness, I = Simpson's Dominance Index, 1-D = Simpson's Index of Diversity, H' = Shannon Diversity Index, E = Evennes Index

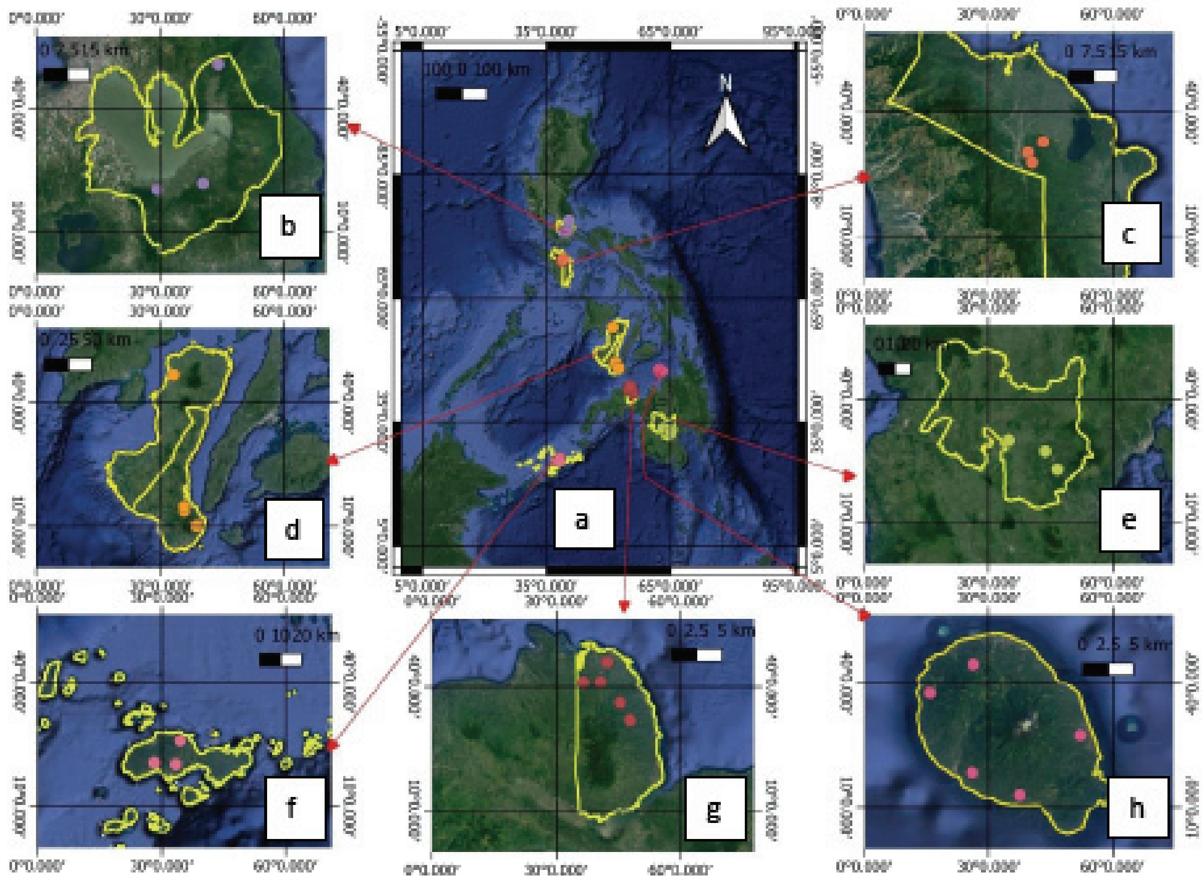


Fig. 3. Sites of collection (multi-color dots) per province for lanzones mussel scale insect population survey from 2019 – 2021 in the Philippines: a) country map, b) Laguna, c) Oriental Mindoro, d) Negros Island, e) North Cotabato, f) Camiguin Island, g) Misamis Occidental and h) Sulu.

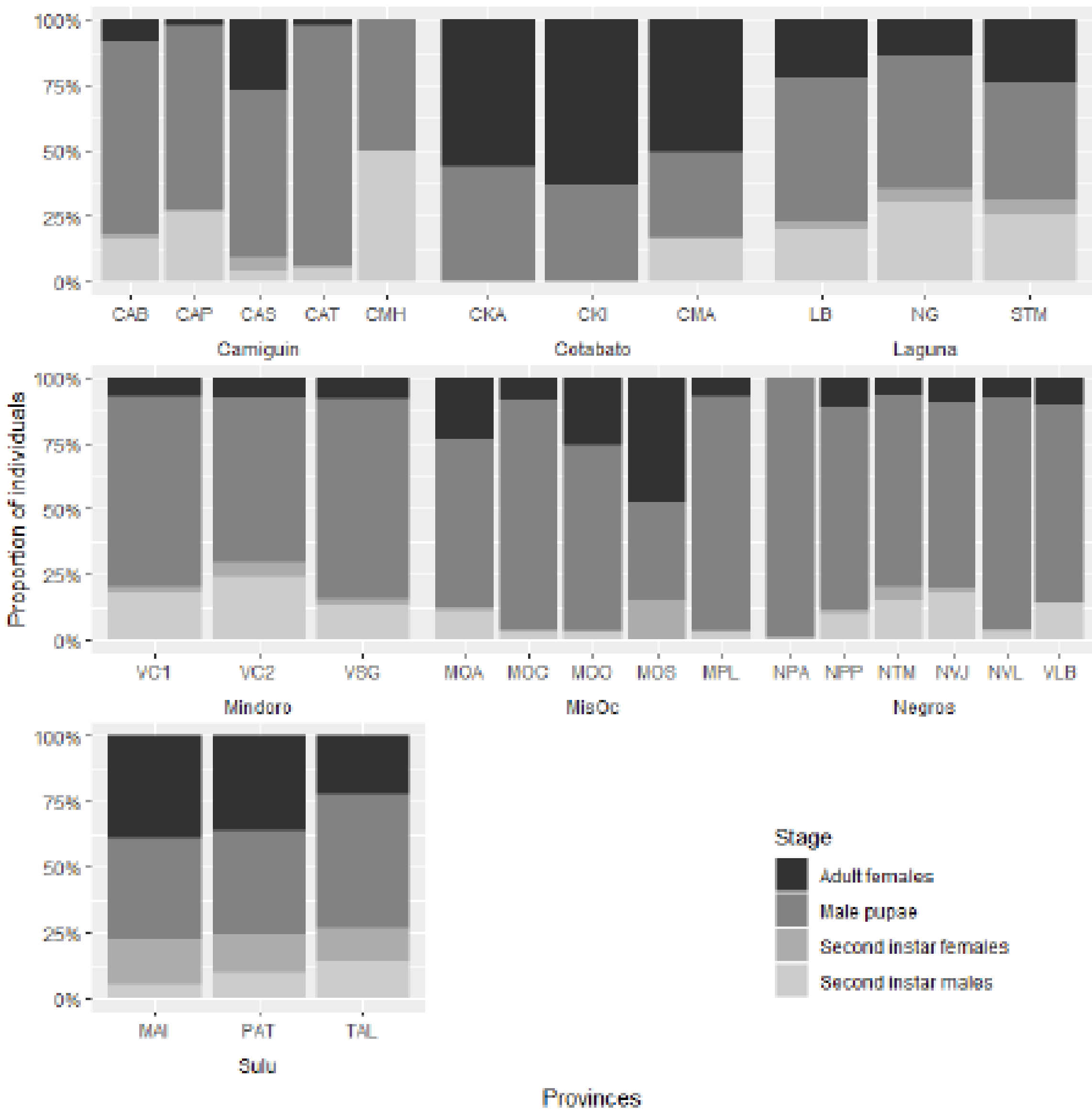
RESULTS AND DISCUSSION

Populations of the lanzones scale insect which include different stages were collected in the lanzones orchards from the provinces of North Cotabato, Laguna, Oriental Mindoro, Misamis Occidental, Camiguin, Negros Oriental and Sulu (Fig. 3). There were a total of three (3) families of parasitic wasps found to be associated among the local scale populations collected from various orchards that were visited. In general, moderate to high LSI infestation levels were observed among these plantations. In those farms, the existing control measures done during LSI outbreak or infestation include pruning or sanitation, spraying of insecticides and release of predatory beetles.

As shown in Fig. 4, age structure of LSI in a total 19 collection sites from seven (7) provinces in three main island groups namely Luzon, Visayas and Mindanao, may differ as reflected in the proportions of individuals found by sex and insect stage. In Luzon Island, scale insects were collected from provinces of Laguna and Mindoro. In the former, across three sites *viz.* LB, NG and STM, most of the population consists of male pupae at 49.47 and 38%, respectively. While adult females and second instar males were at par with proportion values ranging from 15-28%, whereas second instar females were 11% at most. Similarly, majority of the LSI individuals recorded for three collection sites in Mindoro were male pupae where the highest percentage was recorded in VSG at 76% and the least was in VC2 at 60%. For Negros provinces in Visayas, LSI individuals collected from six (6) sites were relatively old and male. Among these sites, the trend for the proportion for male pupae was highest for NPA at 98% followed by NPP at 78%. For adult female population, the greatest percentage was at most at 11% which was found in NPP while the lowest was from NPA at nil. The proportion of younger individuals, i.e., second instar males and females were quite low ranging from nil to 17 %.

In Mindanao, male pupae constitute most of LSI populations collected from sites in Camiguin, Misamis Occidental and Sulu except for Cotabato. The highest proportion of male pupae in Camiguin was computed for CAT at 95% and least for CAS at 68%. In terms of adult females, CAS also recorded the greatest proportion of individuals at 25% and while CMH at nil. For younger female population, only CAB and CAS had at two and four percent, respectively. On the other hand, for second instar males, CMH had the highest proportion at 50% while CAB and CAP had none. In Cotabato, adult females' proportion were consistently highest (at a range of 45 – 59 %) in all sampling sites but least for both younger male and female populations except in CMA at 15%. In Misamis Occidental, the highest proportion of adult females and younger individuals regardless of sex was found in MOS at 45% and 15%, respectively. On the other hand, in Sulu, TAL had the highest proportion of male pupae while for MAI had the highest for adult female. In terms of immatures, TAL had the least for females at 5% and MAI for males at 5%. In general, it is speculated that LSI is widespread in Mindanao Island wherever lanzones are found given its aggressiveness, provided it has already established on it host plant. Although, similar with other known invasive scale insect species, the long-distance dispersal is mainly through trade and transport of seedling or planting stocks from an area with infestation to uninfested one.

Overall, male pupae had the highest recorded number of individuals in all sampling sites except in Cotabato where greater proportions of adult females were observed (Fig. 5). In all local populations, higher proportions of male individuals were observed compared with its female counterparts ranging from 3-26% excluding Sulu populations, wherein second instar females (16%) were twice higher than second instar males (8%). Across all sites surveyed, young female individuals was consistently fewer than adult female LSI and this trend was also observed for male scale insects. Between sampling areas, the mean proportion was highest for male pupae at 81% collected from Misamis Occidental followed by Camiguin at 79%. Lastly, it can be noted that in each local populations collected, the trend for proportions at each life stage and sex was distributed unevenly. In natural populations, it is expected that a 1:1 male to female ratio is attained at some point. In a survey conducted by Nora & Djamila (2017), a balanced distribution between scale populations and with considerably high diversity was found in two of the eight citrus orchards studied in Algeria. The phenological phase of the host crop, might be also a factor on LSI abundance observed from each site. As for *Aclerda takahashii* Kuwana, 1932 (Hemiptera: Aclerdidae), scale insect pest of sugar cane, seasonality of the species in the municipality of Jaboticabal, São Paulo, Brazil, showed an appearance pattern at the phenological phases of the plants (Monteiro et al., 2023).



Remarks: LB = Los Baños, NG = Nagcarlan, STM = Sta. Maria; CKA = Kabacan, CKI = Kidapawan, CMA = Makilala; MAI = Maimbung, PAT = Patikol, TAL = Talipao; VC1 = Villa Cerveza 1, VC2 = Villa Cerveza 2, VSG = San Gabriel; CAP = Poblacion, CMH = Mahinog, CAT = Tagdo, CAS = Sagay, CAB = Catarman; NPA = Abante, Pamplona, NPP = Poblacion, Pamplona, NVL = Lunga, Valencia, NTM = Talisay, Negros Occidental, NVJ = Jawa, Valencia, NVL = Lunga, Valencia, VLB = Bongbong, Valencia; MOA = Aloran, Misamis Occidental, MOC = Calamba, MOO = Oroquieta, MOS = Sapang Dalaga, MPL = Plaridel

Fig. 4. Age structure of lanzones mussel scale insect, *Unaspis mabilis* per locality surveyed in seven lanzones growing provinces of the Philippines in 2020-2022

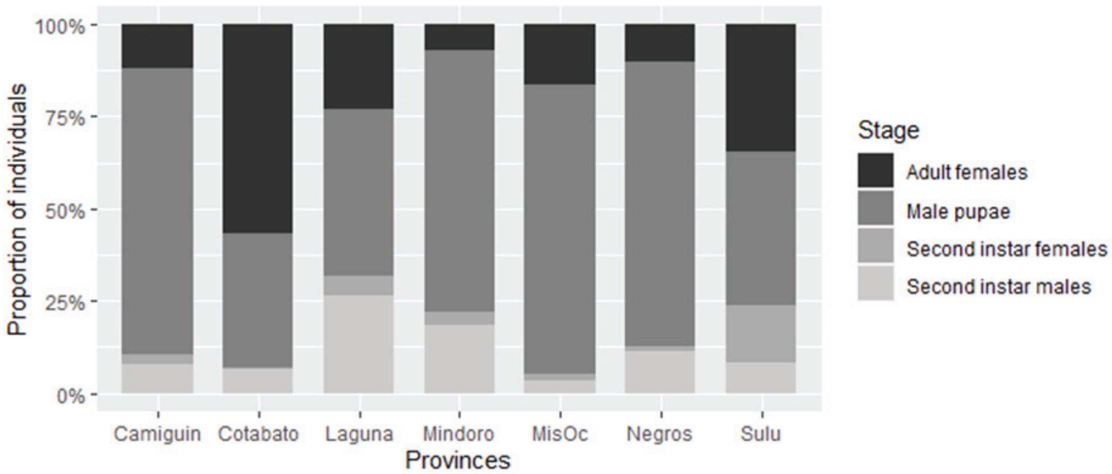


Fig. 5. Age-specific proportions of scales collected from seven major lanzones growing provinces in the Philippines.

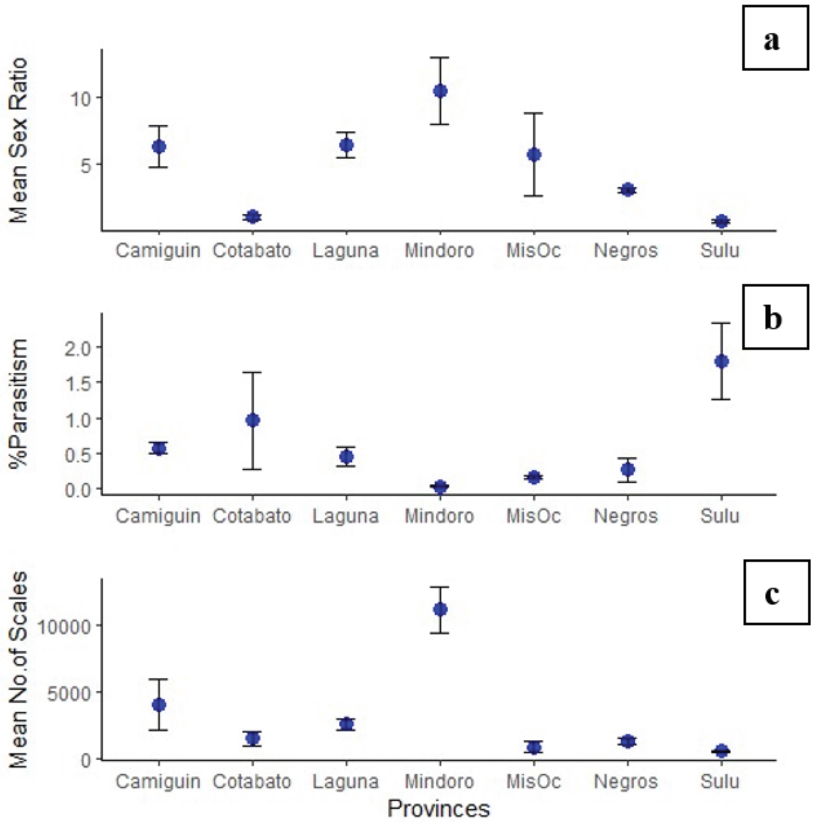


Fig. 6. Mean sex ratio (a), parasitism rates (b) and number of scales (c) of seven *U.mabilis* local populations collected in lanzones-growing areas in the Philippines

Mean field parasitism rate of LSI was highest in the province of Sulu in Mindanao at 1.80 (Table 2 and Fig. 6a). In Luzon, particularly in Laguna, the mean parasitism rate was recorded at 0.45 but lowest in Oriental Mindoro at 0.03. In Visayas, the mean field parasitism in Negros' provinces (i.e., Negros Occidental and Oriental) was computed at 0.27. While for Mindanao, the mean parasitism rate was highest in Sulu as stated followed by North Cotabato at 0.96. On the other hand, the mean parasitism rate in Camiguin was three-fold of that in Misamis Occidental at 0.58 and 0.16, respectively. The most species-rich province in terms of LSI parasitoids was Oriental Mindoro (S=7), whereas species dominance was apparent in (I = 0.88) North Cotabato which could be attributed to highly abundant *Aphytis spp*. In addition Table 2 showed that the most diverse in terms of parasitoids was in Luzon particularly, Oriental Mindoro followed by Laguna as reflected with higher H' values. Aphelinidae displayed the greatest diversity, with nine species in the subfamily Aphelininae, including six identified to species level in diaspidid scale insects in Chile (Amoroux et al., 2019).

As shown also in Table 1, there were a total of nine (9) species of parasitic wasps belonging to three (3) families found to parasitize LSI in the field from the various lanzones orchards that were visited. In Laguna, these are *Aphytis spp.* and *Encarsia spp.* belonging to Aphelinidae and two unidentified encyrtid parasitoids. Similar set of parasitoids was found in Mindoro provinces, except for one mymarid wasp. In Negros, similar parasitoids were collected except for *Encarsia sp*. and with an additional mymarid parasitoid documented. In this survey, unique encyrtid parasitoids were collected from Misamis Occidental and Camiguin (*Encyrtidae sp*. 5), similarly for a mymarid species found in Negros. Based on computed diversity indices from each site where infestation was noted and presence of parasitoids was confirmed, the level of diversity of parasitoids in one area might differ from the other. This level of diversity of parasitoids in each lanzones-growing area might possibly influence LSI population dynamics and structure, in turn affecting the level of damage on lanzones trees.

On the average, male-female sex ratio for each local populations of LSI derived from the population or demographic survey was 4.34 (df = 6, F = 8.61, p < 0.001) (Fig. 6b). The highest mean male-female sex ratio was recorded in Mindoro at 10.40, whereas the least was found in Sulu at 0.91. The second highest mean sex ratio was for the Laguna populations at 6.47 followed by Camiguin populations at 6.33 and with that of LSI populations from Misamis Occidental at 5.78. For Negros and North Cotabato, the average field male-female sex ratio was 3.14 and 1.16, respectively. Mean scale density per infested tree across provinces was determined to 2,497.15 (df = 6, F = 22.26, p < 0.001) (Fig. 6c). Highest mean number of scales was recorded in Mindoro population at 11,175. 67 followed by Camiguin population at 4,074.67. The least mean number of scales was recorded for Sulu populations at 533.10. Lastly, the mean number of scales between Negros, Misamis Occidental and Cotabato did not differ significantly. A positive association between pooled mean LSI density and mean field sex ratio was observed (Fig. 7a). On the other hand, pooled mean number of LSI was found to be negatively correlated to mean percent parasitism due to parasitoid attack (Fig. 7b).

Across all surveyed sites, LSI was found to be abundant, which was indicative of favourable microenvironment and the low populations of natural enemies associated with LSI which include predators and parasitoids. The observed abundance might be also due to the fact that this scale insect species has specialized to its host. There is an evidence that due to pervasive diet specialization, and phylogenetically conservative host use in tropical scale insects, specialized species are more abundant where they occur (Peterson et al., 2020). During the sampling, natural enemies of *U. mabilis* were observed such as predatory beetles, *Chilocorus spp*., the populations seemed to spread aggressively among neighboring lanzones trees. Similarly, Campolo et al. (2013) reported that despite presence of two species of coccinellids (Coleoptera: Coccinellidae) feeding on *Unaspis yanonensis*, namely *Chilocorus bipustulatus* L. and *Chilocorus kuwanae (*Silvestri) during their survey in citrus orchards in Italy, their impact on the mortality of the arrow head scale was negligible; with a maximum of 1% of scales were consumed during summer months only. Since in this study, both predators and parasitoids were found coexisting in each site with LSI, this indicated that combination of these natural enemies can have a density - altering effects on natural LSI populations. Similarly, recent study of Amoroux et al. (2019), documented in their survey of natural enemies of soft scales in Chile, numerous predators along with parasitoids. Moreover, it will be noteworthy to examine, biotic interactions such as host-parasitoid and predator-prey relationship which can serve as evidence that natural biological control agents or antagonists of LSI are effective and also to elucidate potential mechanisms working behind the population regulation of this insect pest.

Aside from predatory beetles, several parasitoids were found parasitizing local populations of LSI surveyed. The parasitoids that were identified parasitizing LSI in those areas were dominantly aphelinid and encyrtid wasps, which was suggestive that these species potentially have locally adapted on LSI as its host. Parasitoids are the most important group of natural enemies that can be used in biological control of insect pests (Pekas, 2010). Similarly, several parasitoid – diaspidid associations in the field were documented and each had been recommended as potential natural control in case of high scale insect infestation levels. In Egypt, the euonymus scale, *Unaspis euonymi* (Comstock) (Hemiptera: Diaspididae), a serious pest of several ornamental shrubs is known to be attacked by an aphelinid parasitoid *Encarsia citrina* (Bayoumy et al., 2013). Four species of aphelinids from were collected and identified as *Ablerus perspeciosus* Girault, *Encarsia citrina* (Craw), *Marietta carnesi* (Howard) and *Pteroptrix machiaveli* (Girault) were found parasitizing *Unaspis euonymi* (Comstock) infesting Japanese spindle (*Euonymus japonicus* Thunb. (Celastraceae)) leaves and twigs in Korea (Suh & Evans, 2015). In the Philippines, two hymenopteran parasitoids *viz.* the encyrtid wasp *Comperiella calauanica* (Almarinez et al., 2020) and aphelinid wasp, *Aphytis lingnanensis* Compere (Watson et al., 2015) have been successfully used as biological control against the invasive coconut scale insect, *Aspidiotus rigidus* Reyne.

Generally, it was confirmed from the results of the survey that numerous parasitoid species are associated with LSI across the country. In addition to common parasitoids of armoured scale *Encarsia spp.* and *Aphytis spp*., and a mymarid wasp was also collected. Hemipteran parasitoid wasps from the Mymaridae family are attracted with volatile organic compounds (VOCs) which are produced via Jasmonic Acid JA-mediated pathway (Parrilli et al., 2019). Jasmonic acid concentrations were found in *Lansium domesticum* leaves infested with *Unaspis mabilis* (Silva et al., 2019). This would mean that for more options which be explored as biological control agents against the lanzones scale insect. The parasitism rates ranged from 0.036 to 1.8 only were recorded whether during dry or wet months. This seemed to adhere to recorded average parasitism rates on euonymus scale, *Unaspis euonymi* (Comstock) by aphelinid wasp - *Encarsia citrina* (Craw.) which ranged from 0.55 to 0.8 during a summer field experiment (Rebek et al., 2005).

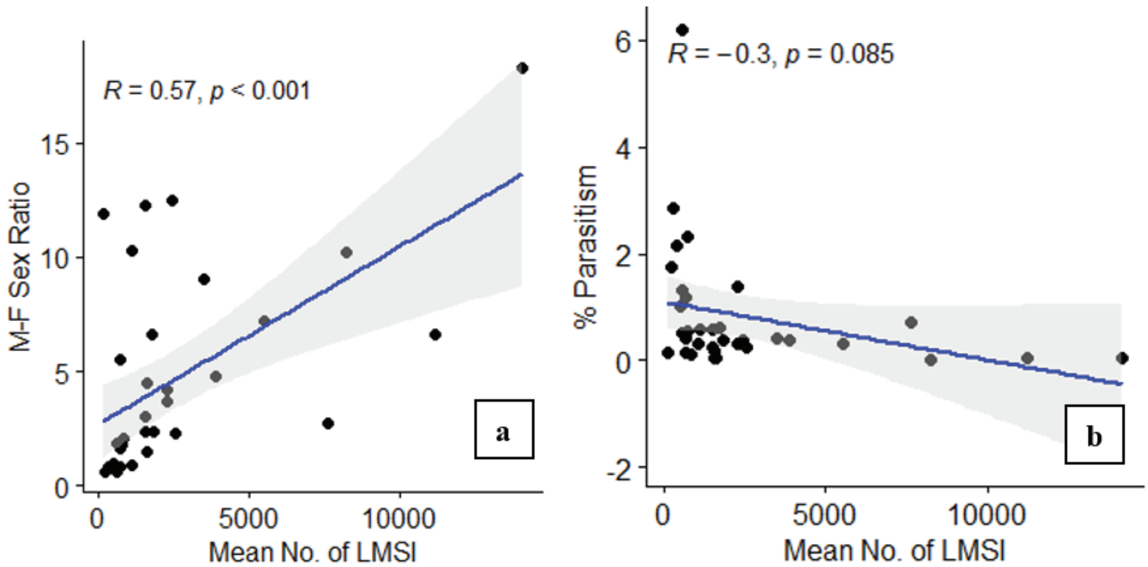


Fig. 7. Correlation plots of pooled mean LSI population to: a) field male-female sex ratio, b) field parasitism rates across provinces surveyed with 95% C.I. (gray band)

It was observed that field parasitism rates on local LSI populations varied markedly across the three main island groups in the Philippines, with provinces surveyed in Mindanao registering higher rates including Sulu and North Cotabato where the first outbreak of this scale insect was recorded. It is possible that the documented parasitoids in these areas have developed better adaptation strategies on LSI and its microenvironment say for instance those that are directly affecting fitness and offspring viability. It was observed that oftentimes, LSI were most abundant in areas that are fully shaded, humid and with abundant under canopy vegetation cover. The observed variability in parasitism rates can be an important parameter in selecting parasitoid species for effective biological control against LSI. Trait variation among parasitoids is a major consideration in almost all aspects of biological control programs (van den Bosch et al. 1979; Jarrett & Szűcs, 2022). One aspect is that seasonal synchrony with their insect hosts is critical for the establishment and long-term effectiveness of parasitoids (Touger et al., 2020). Optimization of traits is important for biological control via selective breeding requires presence of heritable genetic variation (Kruitwagen et al., 2018). By convention, highly host specific agents are potentially promising, per releases individual, than generalist agents (Van Driesche & Bellows, 1996).

From this, the mechanisms underlying the interaction of parasitoids to LSI must be uncovered to understand better deployment strategies, if these species will be utilized later on as biological control against LSI. Also, the nature of the parasitoid that will be selected must be considered, to wit, whether an idiobiont or koinobiont parasitoid is suitable for LSI. Other basic information on candidate parasitoids must be determined especially its life history, sensitivity to abiotic factors especially temperature, reproductive strategy, aggressiveness in parasitizing LSI and susceptibility to several exogenous factors including insecticides commonly applied in lanzones trees. Moreso, further studies in the laboratory to evaluate is important to determine which among these candidate parasitoid species is most suited and effective in managing LSI local populations if to be released in the field.

In addition, interspecific and intraspecific interactions between parasitoids, particularly occurrence of hyperparasitism or superparasitism may be also examined since this would also affect biological control for LSI (Basheer et al., 2014). Mutual interference between searching parasitoids, being suggested as a form of parasitoid density dependence can contribute to the stabilization of a parasitoid-host population dynamics (Hassekll & May, 1988; Bayoumy et al., 2013, Yousef et al., 2023). Each of the parasitoids, may differ on its density depending on host abundance, host quality, host age, food sources available, presence of alternative hosts (i.e. host preference) and other interactions especially competition with other species.

For the male-female sex ratio, two local populations namely Sulu and North Cotabato populations were found to approximately follow Fisher's principle while the rest manifested a male-biased sex ratio. Males of adult LSI have shorter lifespan than females, possibly because greater number of adult males would increase chances of mating, fertilization, and ultimately reproduction. Observations done in the laboratory using emergent individuals and as supported by existing literatures (Bayoumy et al., 2013), early second instar females of *Unaspis spp*. scales are normally preferred by parasitoids due to softer cover. As shown in the results, highest proportion of second instar LSI females was found in Sulu populations which coincides with highest field parasitism rates. Meanwhile, average parasitization levels were found on Camiguin and Laguna, where moderate proportions of second instar scales were collected. With these, it means that field release of these parasitoids should possibly coincide with conditions where younger LSI populations are present and abundant. Aside from second instar females, male *Unaspis* scale particularly prepupae or newly pupated can be also parasitized but to a lesser extent (Coranado-Blanco & Ruiz-Cancino, 1995, Pekas, 2010; Bayoumy et al., 2013) and in all provinces surveyed, significant percentage of LSI collected were male prepupae and as such it will be also important to identify effective pupal parasitoid for LSI.

CONCLUSION AND SUGGESTION

It can be concluded, that the density of early second instar females is associated with parasitism. Generally low parasitism rates on scales were observed in all local populations during the survey. Oriental Mindoro was the most diverse in terms of parasitoids, and *Aphytis spp.* was the most dominant species. A suite of parasitoids can be explored as a biological control against LSI. Finally, the bio-ecological information would serve as basis to formulate improved management strategy for this scale insect pest.

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