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# Morphometrics of Caste System and Colony Structure of the Asian Weaver Ant, *Oecophylla smaragdina* Fabricius, 1775 (Hymenoptera Formicidae) from Cacao Farms in Luzon Island, Philippines

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**Abstract:- Morphometric measurements were applied to the caste system of the Asian weaver ant *Oecophylla smaragdina* Fab. 1775 collected from two cacao farms in Luzon Island, Philippines namely: gyne (deleate ant/reproductive female with shed wings); female alate (female reproductive with wings); and male alate (male reproductive). Length, width, and height dimensions for the brood (egg, larvae, and pupae) were also taken and recorded. The morphological measurements and inferential analysis for broods are made available with other caste systems as most studies of this nature delves into worker caste and not the reproductive and broods. A total of nine weaver ant nests were extracted from the two sites of study. Each nest was dissected and the specimens were separated according to caste. The colony structure of *O. smaragdina* consisted of a deleate queen, eggs, larvae of female alates, pupae of major and minor workers, pupae of female alates, major workers, minor workers, female alates, and male alates. The study shows that *O. smaragdina* had a distinct caste system and the frequency of individuals in each caste reflect their respective functions which show eusocial behavior that contributed to the success of their colony.**

***Keywords:-*** *Caste System, Cacao Farm, Colony Structure, Oecopphylla Smaragdina.*

## I. INTRODUCTION

Morphometrics or morphometry are used by biologists to determine the quantitative analysis of form, a concept that encompasses the size and shape of the organism (Marcus, 1990). Morphometric analyses are commonly performed on organisms and could be used to deduce developmental changes in form and infer factors that may affect the size and possibly shape (Chiappe et al., 2008).

General and Alpert's (2012) synoptic review of Philippine ant genera could be considered the most relevant systematic ant data available in the country, and like most endeavors of this nature, it has based its taxonomic key of Philippine ants also on the worker caste. Providing morphometry such as core measurements and indices coming from the Asian weaver ant caste proves to be valuable as such measurements may be included in pertinent studies and are often important, but the measurements extracted should be limited to those useful in distinguishing the species and in comparing it with relatives or similar species (Wilson, 1999). In addition, morphometry of core measurements was used by Hoffman et al., (2011) in unison with other identification protocols such as molecular (Filipova et al., 2011) data to help identify cryptic ants as proper identification can be limited by a lack of taxonomic resources (modern keys), distinctive morphological characters, or even a muddled taxonomic history. Traditional morphometrics by way of core measurements can analyze lengths and ratios (Marcus, 1990) and help readers picture the scale of the reproductive against the worker caste and could very well provide a reference for future statistical analysis.

Ants live in colonies and many instances, a colony can be allocated to one nest. Nonetheless, to assess ant colony structure, it is imperative to be precise: a colony is a society, a nest its vessel, and in many species, a colony has more than one nest (Steiner et al., 2010). All ants start as eggs, grow as larvae, and develop into adults as pupae; these immature stages are fed, groomed, groomed, and protected by workers (Kaspari, 2000).

Considering what happens within colonies, Wilson (1971) emphasized that ants are eusocial organisms, characterized by cooperative brood care, overlapping generations of workers, and a highly developed caste system. Kaspari (2000) reiterates that an important aspect of this structure is that castes are groups of specialized colony members that perform different functions with corresponding differences in form. The numbers and identities of female and male reproductive are key characteristics of colony structure (Steiner et al., 2010) as they are connected to mating, dispersal, colony foundation, and colony growth (Andre et al., 2006; Bourke and Franks, 1995; Crozier and Pamilo, 1996; and Holldobler and Wilson, 1990). (Kaspari, 2000) went on to say that an important aspect of the colony is the queen, once a winged female in another ant colony, will be the center of colony life – often the largest in the colony, the queen's central role is that of egg-laying, and is considered as the mother of all

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the other colony members. Leaf 'pavilions', where ants and trophobiont mutuals are sheltered, but no brood is raised, are constructed in the same way (Way, 1963). It could be noted that depending on the time of the year, one may encounter larger, winged ants, aptly called the male and female alates or sexuals (Kaspari, 2000).

In the Philippines, most small-scale producers process their cocoa beans into “tableya,” a native chocolate confection. A survey of the countries’ status on cacao farming was initiated by the Peace and Equity Foundation (PEF), a non-profit, non-government organization in March 2016. The report mentions that cacao (or cocoa for some) is a bean derived from the *Theobroma cacao* L. or cocoa tree, which grows in elevations of 1,000 meters above sea level. Originating from South American rainforests, cocoa thrives best in wet climates with rainfall evenly distributed across the year. The report also mentioned that cocoa is a raw material ingredient primarily for chocolate and cocoa powder and other products.

It is worth noting that 265 species were collected from the Luzon Islands (General and Alpert, 2012). The southern part of Luzon, specifically in the Batangas area has been reported by the PEF’s Philippine Industry Study report on cacao to be where cocoa was first introduced in the Philippines by the Spanish Colonizers four centuries ago, while the northern part, specifically the Cagayan Valley area is where a new genus of ant was reported by General in 2015.

Previous studies have focused on the different biological structures of *O. smaragdina* colonies with their community (Peng et al., 1998; Steiner et al., 2010; Way and Khoo, 1991; Pinkalski et al., 2015). However, little is still known about the morphometry of the caste system together with the colony composition of these weaver ants in cacao areas (Schlüns *et al*. 2009). Studies on weaver ant dynamics such as morphometry of caste composition may give additional insights such as inferences on its size and shape while colony structure may explain how the social structure inside the nest influences the behavior of individuals outside the nest. Therefore, the objective of this study is to: 1.) provide core and specialized morphometry measurements for the deleate queen, reproductive female, and male and give dimension measurements for the brood and 2.) demonstrate the colony structure of *O. smaragdina* inside the nests found in cacao

## II. MATERIALS AND METHODS

### A. Collection Sites

➢ *Quezon Agriculture Experiment Station (QAES)*

The Quezon Agriculture Experiment Station (QAES) (13.9541 °N; 121.3393 °E), an attached government agency of the Department of Agriculture in Tiaong, Quezon where farmers could train and study the latest agricultural advancements the Philippine government could provide. The local authorities in this satellite office plan to have more areas of land in the station planted with cacao trees to support the growing interest in the cacao tree and its products. Farmers, agriculturists, and students here could also loan both seedlings and seeds that could be used in their agricultural undertakings.

➢ *Options Farm, Sto. Tomas, Batangas*

This Batangas collection site (14.071110 °N; 121.198966 °E) is an established backyard farm with more than 100 fruiting pruned cacao trees 2.5 meters apart spawned upon 300 square meters of land area. Although research and development and eventually the sale of cacao seedlings are the main interest of this farm, an area for the manual processing of cacao products is also available within the premises for small-scale production and demonstration to those who are interested in cacao farming. A fungicide (Ridomil brand) that acts to control soil and leaf diseases in a variety of crops was used sparingly used in this area. Figure 1 shows the map of the collection site.

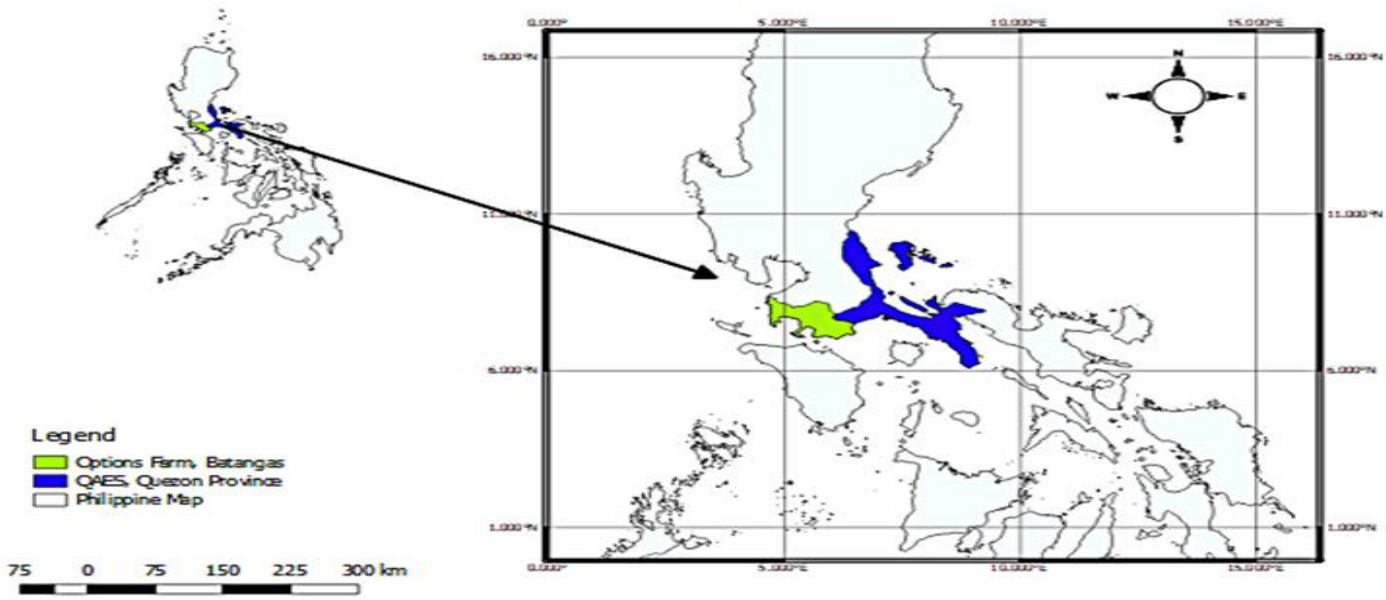


Fig 1 Map of the Collection Sites in Quezon and Batangas Province, Luzon Island

ISSN No:-2456-2165

*B. Oecophylla Smaragdina Nest Collection, Processing, and Handling*

The nests were removed from the trees by cutting them from the base using a cutter (Sharpex brand) and placed them into (60 cm x 80 cm) grade 3 transparent plastic containing cotton wads wetted with chloroform. All nests were collected between 10 a.m. to 12 p.m., corresponding to the time of day when the weaver ants were least active which was determined in a preliminary study. Each nest was kept separately in individual plastic buckets. These plastic buckets were brought back to the laboratory and kept inside a freezer for 24 hours to ensure that the weaver ants were all dead. After the time allotted, the nests of *O. smaragdina* ants were dissected and sorted according to the following castes: dealate queens, egg, larvae, pupae, female alates, male alates, major workers, and minor workers. The number of individuals of each caste for each nest was counted and recorded. The collected specimens were then preserved in 95 % ethanol. The images of each specimen of *O. smaragdina* were captured and measurements were determined using a stereomicroscope (Nikon SZX9) which was connected to Image analyzer Cell A (Nikon computer). The mean number and standard error of the mean (S.E.M) for each caste were determined using Statistical Packages for the Social Sciences (SPSS 20).

*C. Core and Specialized Measurements and Indices*

The terms used to appoint the external morphology follow Bolton (1994, 2000) and the terminology of surface sculpturing follows Harris (1979). The reproductive females are called gynes, as suggested by De Andrade and Baroni-Urbani (1999).

Core and specialized measurements followed Bolton (2000) and were obtained using a Nikon SZX9 stereomicroscope with a 100X ocular lens with a five-ring lamp; all measures are given in millimeters. Below are the abbreviations and explanations of the core and specialized measurements mostly based on the ZooKeys and ZooTaxa publications of Boudinot and Fisher, (2013) and Branstetter (2013) respectively.

➢ *Core Measurements*

- HL Head Length. Head length (full-face view): maximum length of the head, measured from the posterior margin of the head to the anterior-most extremity of the clypeus.
- HW Head Width. Head width (full-face view): maximum width of the head, eyes excluded.
- EL Eye Length. Eye length (most suitable view): the maximum diameter of the compound eye, including the outer ring of ommatidia, which are often black.
- EW Eye Width. Measured one of two ways: 1.) Maximum eye width; 2.) Maximum eye width measured in full face view.
- MandL. Mandible. The straight line length of the mandible at full closure, measured in the same plane for which the HL measurement is taken (i.e. full-face view), from the mandibular apex to the anterior clypeal margin.
- PronW Pronotum Width. (dorsal view): maximum width of the pronotum.
- SL Scape Length. The maximum straight-line length of the scape, excluding the basal constriction or neck occurs just distal of the condylar bulb. (In taxa with a hypertrophied subbasal lobe on the scape SL is measured from the tip of the sub-basal lobe to the scape apex.).

➢ *Core Indices*

Note that in about 70% of cases, indices are multiplied by 100 (giving a range of 0-100) rather than being expressed as simple ratios (with a range of 0-1).

- CI (cephalic index): HW/HL x 100.
- Eye size indices: EI (eye index): EL/HW x 100; REL (relative eye length) EL/HW x 100.
- MandI MandL/HL x 100.
- SI (scape index): SL/HW x 100.
- Specialized measurements
- CFW Clypeal Fork Width. Measured between the anterior-most points of the clypeal teeth.
- CW Clypeus Width. Distance between the apices of the frontal lobes across the clypeus.
- HFL Maximum Length of Hind Femur. Measures hind femur in anterior view.
- HLA Head Length, Anterior. Distance between the anterior edges of the eyes to the mandible bases in full-face view.
- HTL Maximum length of Hind Tibia. Excludes the proximal part of the articulation which is received into the distal end of the hind femur.
- MTL Maximum Length of Mid Tibia. Excludes the proximal part of the articulation which is received into the distal end of the femur.
- PetH Petiolar Height. In lateral profile, measured as the perpendicular distance from the ventral margin to the highest point of posterolateral tubercles
- PetW Maximum Width of the petiolar node in dorsal view.
- PTH Petiole Height. Measured from petiole sternum to apex in lateral view.
- PTLPetiole Length. Measured from anterior to posterior inflections of the petiole node.
- TL The total outstretched length of the ant from the mandibular apex to the gastral apex; when measured in profile the sum of Mandibular length + head length + mesosoma length + lengths of waist segments + length of gaster.

➢ *Antennal Segment Measurements:*

- ASL1 – ASL12 Length of 1st to 12$^{th}$/A scape antennal segment.
- ASW1 – ASW12 Width of 1st to 12$^{th}$/A scape antennal segment.

➢ *Wing Measurements*

- FWL:- ForeWing Length. Measured from anterior to posterior apex of the forewing.

ISSN No:-2456-2165

- FWH:- ForeWing Height. Measured from the most superior to the superior part of the forewing.
- HWL:- HindWing Length. Measured from anterior to posterior apex of the hindwing.
- HWH:- HindWing Height. Measured from the most superior to the superior part of the hindwing.

➢ *Brood Measurements*

- Eminl:- Egg Minor Length. Measured from the anterior to the posterior part of the egg.
- Eminw:- Egg Minor Width. Maximum width of the egg in dorsal view.
- Eminh:- Egg Minor Height. Measured from the superior to the inferior part of the egg.
- Emajl:- Egg Major Length. Measured from the anterior to the posterior part of the egg.
- Emajw:- Egg Major Width. Maximum width of the egg in dorsal view.
- Emajh:- Egg Major Height. Measured from the superior to the inferior part of the egg.
- EmajHCapL:- Egg Major Head Capsule Length. Measurement of the visible inner head capsule's length
- EmajHCapW:- Egg Major Head Capsule Width. Measurement of the visible inner head capsule's visible width
- LarFemAL:- Larvae of Female Alate Length. Measured from the anterior to the posterior part of the larvae
- LarFemAW:- Larvae of Female Alate Width. Maximum width of the larvae in dorsal view.
- LarFemAH:- Larvae of Female Alate Height. Measured from the superior to the inferior part of the Larvae.
- PupMajWL:- Pupae of Major Worker Length. Measured from the anterior to the posterior part of the pupae.
- PupMajWW:- Pupae of Major Worker Width. Maximum width of the pupae in dorsal view.
- PupMajWH:- Pupae of Major Worker Height. Measured from the superior to the inferior part of the pupae.
- PupMainWL:- Pupae of Minor Worker Length. Measured from the anterior to the posterior part of the pupae.
- PupMinWW:- Pupae of Minor Worker Width. Maximum width of the pupae in dorsal view.
- PupMinWH:- Pupae of Minor Worker Height. Measured from the superior to the inferior part of the pupae.

➢ *Morphometry Measurements*

Gyne (deleate queen) and female alate (female reproductive)

All members of the caste system to be measured were initially placed in a petri dish with tissue paper to remove the 70% ethanol used as a preservative before actual measurements were taken.

As both the gyne and female alate were of similar size dimensions, they were accorded the same procedure. The dissecting microscope (Nikon SZX9) used was adjusted to M1or the lowest magnification of 100x as the specimens were too large to fit in its field of vision. The measurement tool was activated and used following how Boudinot and Fisher (2013) and Branstetter (2013) described the morphological characters. Placing a point-mounted specimen of this caste in a modified Eguchi ball for convenient maneuvering of the parts needed to be measured did not work as the non-acidic stage available was too small to hold the large specimen. Therefore, a customized petri dish with a lower surrounding vertical lid was used to raise the head of the gyne and female alate. A regular petri dish would raise and tilt the head too high and core measurements for the head would be compromised if they are not at a level with the dissecting microscopes overhead digital camera. Light forceps were then used to steer the specimen into specific positions for the needed core morphometry measurements. As the body of this specimen was longer than the diameter of the field of vision of the microscope used, the total length of the gyne and female alate was defined by taking two images, one from mandibular apex up to propodeal (mesosoma) apex, and from the tip of the propodeal apex to the gastral apex. These measurements were then added to determine the total length. The wings of the female alate were also longer than the field of vision thus, two images were also taken (one from the tip near the mesonotum where the wings originate up to the widest part in the middle, and one from the middle up to the most posterior tip near the gastral apex). These were again added to come up with wing lengths.

*D. Male alate (male reproductive)*

The male alate was significantly smaller than both the gyne and the female reproductive and was able to be held by the non-acidic paper stage when point (card) mounted. A non-toxic water-based glue was used to attach the specimen to the said paper stage. It was then placed in a modified Eguchi ball for better directional maneuvering for measurement and imaging. The Eguchi ball was named after its inventor, Japanese Katsuyuku Eguchi. A modified Eguchi ball was made from a simple table tennis ball cut open with a diameter of about three centimeters then two-thirds filled with cement. After the cement has cured, the remaining one-third volume was filled with non-toxic molding clay. The ball with cement and clay is then placed in a bottle cap that has a diameter well enough to hold and clasp the apparatus but still allow it to move and rotate. The point-mounted male alate is then secured in the clay part that holds it firmly even if the ball is rotated. The ability to rotate the ball with the point-mounted specimen in place allows for a convenient and efficient way to take images and measurements. Fine forceps and entomological pins attached to simple levers were used to properly arrange anatomical parts such as scape antennae and legs for proper imaging and measurements.

*E. Brood (Egg, Larvae, Pupae)*

The brood was carefully placed in the customized petri dish that had a darker color against each brood for contrast. Fine forceps and entomological pins were then used to arrange and manipulate the broods to properly measure their length, width, and height dimensions. The anterior and

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posterior apexes for the dimensions were used as measurement points.

## III. RESULTS

### A. *Caste Composition*

The caste composition of O. smaragdina from the nine nests collected in the study is shown in Table 1. Five deleate queens (gynes)were found in the QAES colony. These deleate queens found in the field had varying shades of color from yellow-green (Fig. 2) to a light brown shade in its mesosoma (Fig. 3). Another deleate queen had a strong dark-brown color (Fig.4). These deleate queens could be seen to have already shed its wings, signaling that it has already mated and may or had already produced eggs for the colony. As expected, all male alates (Fig. 5-7) were smaller in size relative to the deleate queen and had black coloring throughout its head, mesosoma, and gaster.

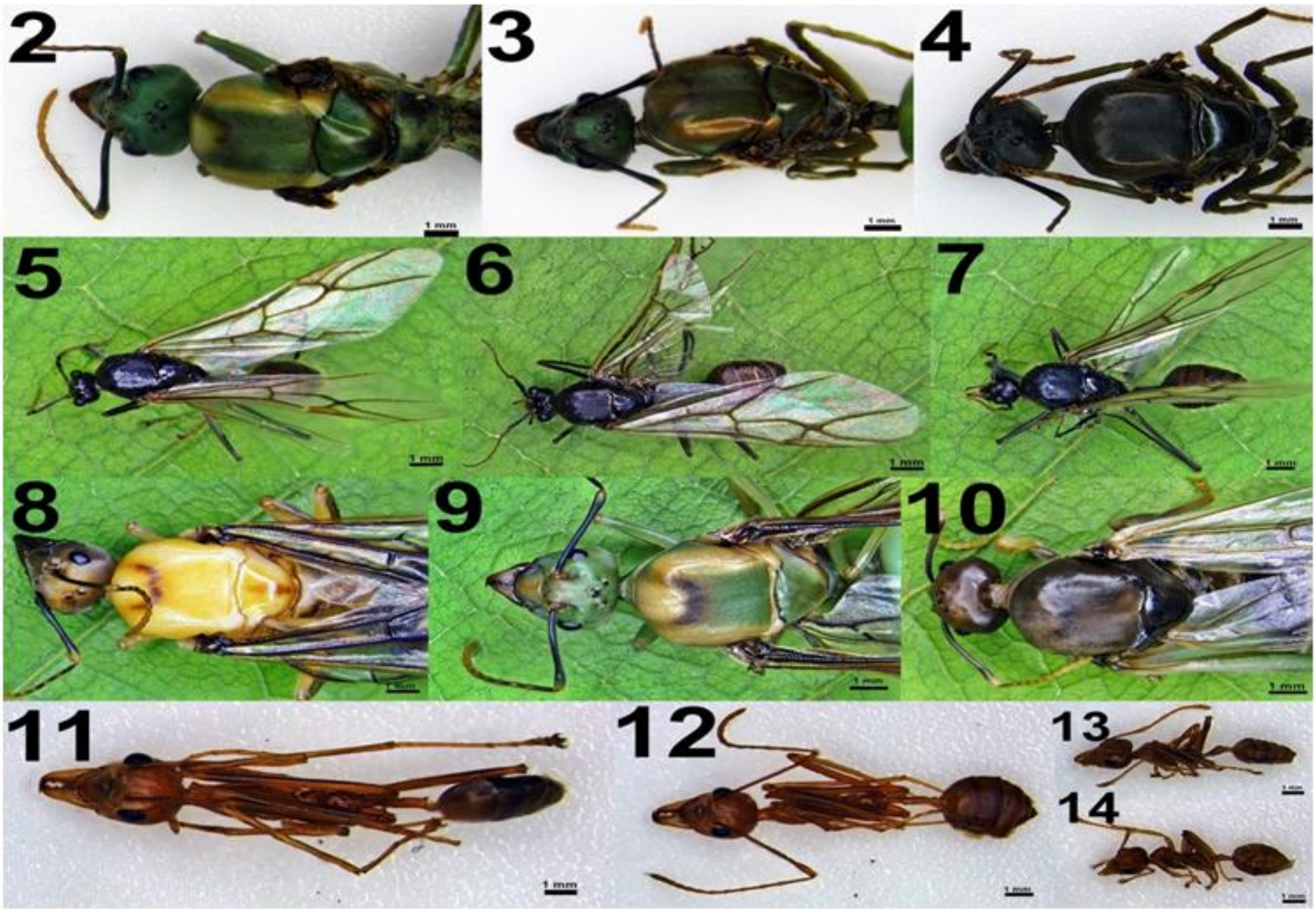


Fig 2-14: Figs. 2-4. Deleate queens of *O. smaragdina* from QAES colony showing varying shades of color; Figs. 5-7. Three male alate individuals of O. smaragdina from the QAES colony; Figs. 8-10. Female alate of *O. smaragdina* from the QAES colony showing varying degrees of color; Figs. 11-12. Major workers of *O. smaragdina* from QAES and Options farm respectively; Figs. 13-14. Minor workers of *O. smaragdina* from QAES and Options farm respectively.

No deleate queen and male alate were sampled in the Options farm colony during the time of collection. Only the QAES colony had female alates collected in this study and its colors varied from yellow (Fig. 8) to green (Fig. 9) to dark brown (Fig. 10). These female reproductive alates could be seen to still have their wings. The deleate queen and female reproductive had different color morphologies conspicuously seen at the dorsal part of its mesosoma up to the gaster part. This color polymorphism may have been due to the community relationship pressures available at different areas of the cacao farm and cacao tree. The major workers (Figs. 11-12) were bigger in size compared to the minor workers (Figs. 13-14) of both colonies. Table 1 also demonstrates that the highest number in any individual caste was major workers in the QAES farm site (999.57 ± 84.7).

ISSN No:-2456-2165


Fig 15-29: Figs. 15-16. Eggs of major workers of *O. smaragdina* from both colonies; Figs. 17-18. Eggs of minor workers of *O. smaragdina* from both colonies; Figs. 19-21. Larvae of female alate of *O. smaragdina* from both colonies; Figs. 22-24 Pupae of major workers of *O. smaragdina* from both colonies; Figs. 25-27. Pupae of minor workers of *O. smaragdina* from both colonies. Figs. 28-29. Pupae of female alate of *O. smaragdina* from QAES colony.

Table 1 Caste Composition of O. Smaragdina for Each Qaes and Options Colony (Mean ± S.E.M./Nest)

| **Colony** | **Caste system** | **Delete queen** | **Eggs** | **Larva of female alates** | **Pupae of workers** | **Pupae of female alates** | **Major workers** | **Minor workers** | **Female alates** | **Male alates** |
|---|---|---|---|---|---|---|---|---|---|---|
| QAES | Mean ± | | | | | | | | | |
| | S.E.M./ nest | 0.71 | 29.71 | 20.14 | 42 | 0.33 | 999.57 | 431.43 | 10 | 241.71 |
| | n=8 nests | ± .421 | ± .14.792 | ± 9.743 | ± 19.887 | ± .211 | ± 84.679 | ± 134.127 | ± 5.196 | ± 126.069 |
| Options | Mean ± | | | | | | | | | |
| farm | S.E.M./ nest | 0 | 38 | 16.5 | 417.5 | 0 | 1349.5 | 378 | 0 | 0 |
| | n=8 nests | 0 | ± 7.00 | ± 4.5 | ± 72.50 | 0 | ± 140.500 | ± 54.00 | 0 | 0 |

It should also be noted that the number of major workers was higher than the minor workers for both colonies (QAES = 999.57 ± 84.679; 431.43 ± 134.13) (Options farm = 855.5 ± 53.5; 378 ± 54.00). Both eggs (Figs. 15-18) and larvae (Figs. 19-21) were white and had similarities in shape but the larvae were bigger. Pupas of major and minor workers presented here coming from both colonies could be seen as different developing stages as seen from their coloration wherein earlier pupa stages have bodies entirely white (Figs. 22 and 25); middle pupa stages starting have the distinct red-orange coloration on some body parts (Figs. 23 and 26); and later pupa stages, which now has more parts colored red-orange than white (Fig. 24 and 27). Two female alate pupas were collected from QAES colony, one was white, which seems to be at an earlier stage (Fig. 28) and the other was seem to be at a later stage and colored brown (Fig. 29). These female alate pupas were almost the size of the adult alate and already had developed eyes, mouth, legs, and wings. Figure 30 and 31 show the mean distribution and percentage of the colony structure for both collection sites respectively.

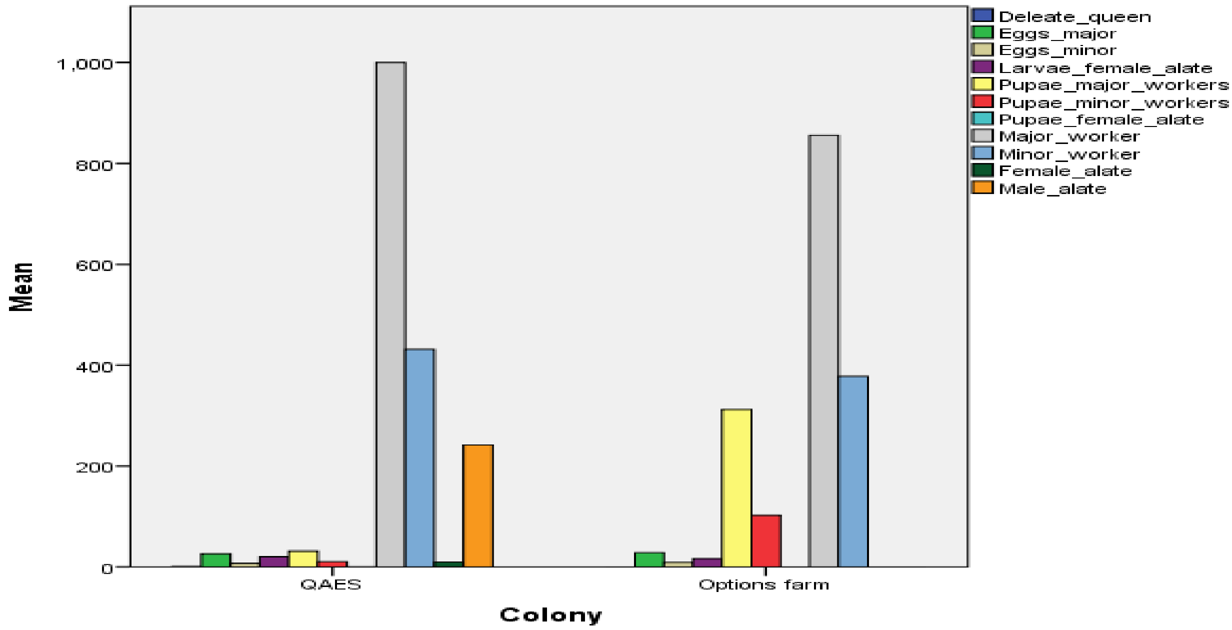


Fig 30 Mean Distribution of the Colony Structure from the QAES and Options Farm Study Sites on June 2018

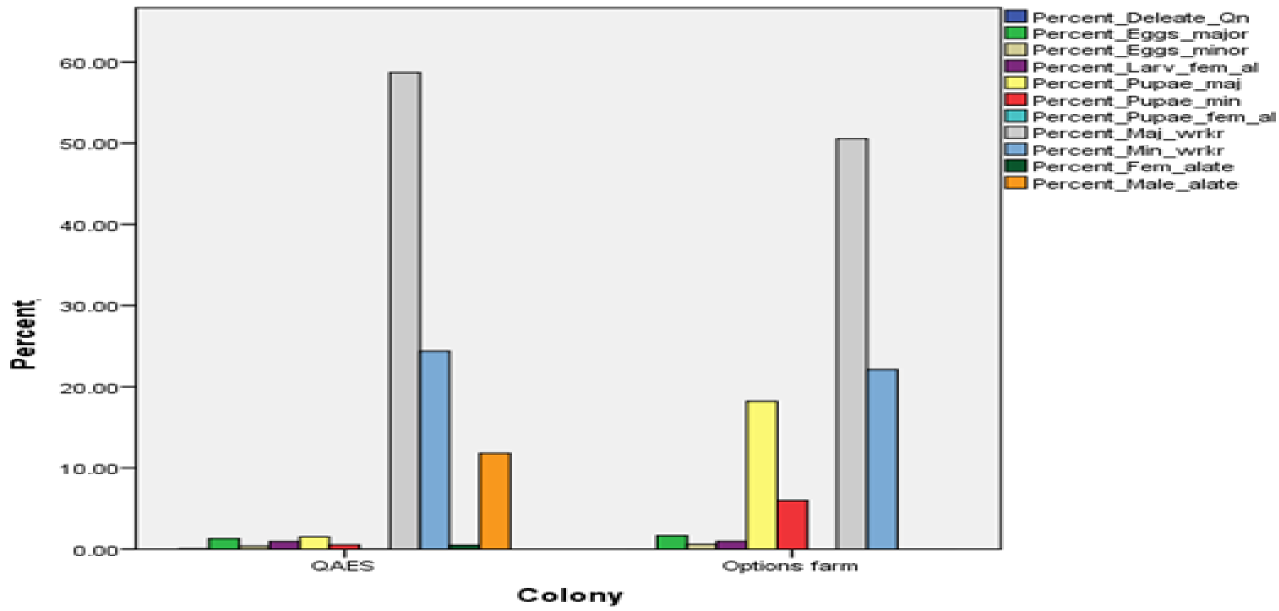


Fig 31 Mean Distribution of the Percentage of the Colony Structure from the QAES and Options Farm Study Sites on June 2018

*B. Core and Specialized Morphometry*

*O. smaragdina* gyne or deleate queen's core and specialized average morphometric measurements coming from 5 individuals from the Luzon Island collection site are presented in Table 2. The standard error is given to have a reference regarding the approximate standard deviation of the sample population, while the range depicts the minimum and maximum values for each character. The mean shows the average measurement of the specific caste for the particular character.

ISSN No:-2456-2165

Table 2 O. Smaragdina Gyne (Deleate Queen) Core and Specialized Measurements Collected from the Cacao Farms in Luzon Island, Philippines On June 2018 (N=5)

| Caste | Char. | Mean | Range | Std. Error | Caste | Character | Mean | Range | Std. Error |
|---|---|---|---|---|---|---|---|---|---|
| Gyne | HL | 2.35 | 1.91 – 2.66 | 0.183 | Gyne | ASL7 | 0.29 | 0.23 - 0.33 | 0.023 |
| | HW | 2.61 | 2.58 - 2.66 | 0.013 | | ASL8 | 0.36 | 0.30 - 0.42 | 0.025 |
| | EL | 0.65 | 0.57 - 0.71 | 0.028 | | ASL9 | 0.39 | 0.33 - 0.44 | 0.026 |
| | EW | 0.5 | 0.49 - 0.52 | 0.01 | | ASL10 | 0.41 | 0.39 - 0.49 | 0.02 |
| | MandL | 1.16 | 1.16 - 1.21 | 0.028 | | ASL11 | 0.8 | 0.77 - 0.85 | 0.015 |
| | PronW | 3.22 | 3.17 - 3.3 | 0.053 | | ASL12 | 2.84 | 2.55 - 2.99 | 0.08 |
| | SL | 2.83 | 2.8 - 2.99 | 0.74 | | ASW1 | 0.2 | 0.18 - 0.22 | 0.007 |
| | CFW | 0.58 | 0.38 - 0.78 | 0.088 | | ASW2 | 0.2 | 0.19 - 0.20 | 0.002 |
| | CW | 1.49 | 1.41 - 1.55 | 0.034 | | ASW3 | 0.21 | 0.18 - 0.22 | 0.007 |
| | HFL | 2.96 | 2.66 -3.47 | 0.164 | | ASW4 | 0.2 | 0.18 - 0.22 | 0.007 |
| | HLA | 2.29 | 1.91 - 2.45 | 0.163 | | ASW5 | 0.19 | 0.19 - 0.20 | 0.002 |
| | MTL | 2.13 | 1.97 - 2.52 | 0.101 | | ASW6 | 0.18 | 0.18 - 0.19 | 0.002 |
| | PetH | 0.76 | 0.70 - 0.9 | 0.229 | | ASW7 | 0.18 | 0.18 - 0.19 | 0.002 |
| | PetW | 1.01 | 0.89 - 1.24 | 0.26 | | ASW8 | 0.16 | 0.15 - 0.17 | 0.002 |
| | PTH | 0.86 | 0.78 - 0.9 | 0.022 | | ASW9 | 0.14 | 0.13 - 0.15 | 0.003 |
| | PTL | 0.56 | 0.36 - 0.76 | 0.083 | | ASW10 | 0.15 | 0.13 - 0.17 | 0.009 |
| | TL | 17.09 | 15.62 - 18.3 | 0.525 | | ASW11 | 0.15 | | 0 |
| | ASL1 | 0.31 | 0.29 - 0.32 | 0.007 | | ASW12 | 0.14 | 0.13 - 0.14 | 0.002 |
| | ASL2 | 0.21 | 0.20 - 0.22 | 0.005 | | FWL | 18.36 | 18.0 - 18.57 | 0.043 |
| | ASL3 | 0.21 | 0.20 - 0.24 | 0.006 | | FWH | 5.24 | 4.9 - 5.7 | 0.033 |
| | ASL4 | 0.21 | 0.20 - 0.24 | 0.007 | | HWL | 12.04 | 11.8 - 12.3 | 0.112 |
| | ASL5 | 0.23 | 0.18 - 0.28 | 0.023 | | HWH | 3.2 | 2.9 - 3.7 | 0.121 |
| | ASL6 | 0.24 | 0.19 - 0.31 | 0.023 | | HTL | 3.34 | 2.8 - 3.47 | 0.323 |

Table 3 O. Smaragdina Female Alate (Virgin Queen) Core and Specialized Measurements Collected from the Cacao Farms in Luzon Island, Philippines On June 2018 (N = 15)

| Caste | Char. | Mean | Range | Std. Error | Caste | Char. | Mean | Range | Std. Error |
|---|---|---|---|---|---|---|---|---|---|
| Fem. Alate | HL | 2.52 | 2.41 - 2.61 | 0.044 | Fem Alate | ASL7 | 0.31 | 0.24 - 0.33 | 0.018 |
| | HW | 2.51 | 2.48 - 2.56 | 0.014 | | ASL8 | 0.39 | 0.31 - 0.42 | 0.02 |
| | EL | 0.61 | 0.58 - 0.63 | 0.009 | | ASL9 | 0.41 | 0.43 - 0.44 | 0.021 |
| | EW | 0.49 | 0.42 - 0.48 | 0.012 | | ASL10 | 0.43 | 0.39 - 0.49 | 0.024 |
| | MandL | 1.12 | 1.05 - 1.18 | 0.029 | | ASL11 | 0.82 | 0.76 - 0.85 | 0.017 |
| | PronW | 3.12 | 3.06 - 3.17 | 0.024 | | ASL12 | 2.74 | 2.55 - 2.9 | 0.078 |
| | SL | 2.73 | 2.54 - 2.87 | 0.076 | | ASW1 | 0.2 | 0.18 - 0.21 | 0.007 |
| | CFW | 0.53 | 0.37 - 0.76 | 0.073 | | ASW2 | 0.19 | 0.19 - 0.20 | 0.002 |
| | CW | 1.52 | 1.41 - 1.55 | 0.032 | | ASW3 | 0.2 | 0.18 - 0.19 | 0.009 |
| | HFL | 3.2 | 2.60 - 3.47 | 0.159 | | ASW4 | 0.2 | 0.18 - 0.22 | 0.009 |
| | HLA | 2.33 | 1.91 - 2.73 | 0.184 | | ASW5 | 0.19 | 0.18 - 0.20 | 0.008 |
| | MTL | 2.22 | 1.9 - 2.52 | 0.126 | | ASW6 | 0.18 | 0.17 - 0.22 | 0.002 |
| | PetH | 0.74 | .70 - .80 | 0.024 | | ASW7 | 0.18 | 0.18 - 0.19 | 0.002 |
| | PetW | 1.48 | 0.89 - 2.24 | 0.312 | | ASW8 | 0.16 | 0.15 - 0.17 | 0.004 |
| | PTH | 0.84 | 0.78 - 0.90 | 0.025 | | ASW9 | 0.14 | 0.12 - 0.14 | 0.004 |
| | PTL | 0.68 | 0.55 - 0.76 | 0.039 | | ASW10 | 0.15 | 0.13 - 0.17 | 0.008 |
| | TL | 16.54 | 15.62 - 18.28 | 0.486 | | ASW11 | 0.16 | 0.15 - 0.18 | 0.002 |
| | ASL1 | 0.29 | 0.27 - 0.31 | 0.007 | | ASW12 | 0.14 | 0.12 - 0.16 | 0.005 |
| | ASL2 | 0.22 | 0.20 - 0.22 | 0.004 | | FWL | 18.23 | 18.0 - 18.54 | 0.023 |
| | ASL3 | 0.22 | 0.20 - 0.23 | 0.005 | | FWH | 5.3 | 5.2 - 5.5 | 0.01 |
| | ASL4 | 0.22 | 0.20 - 0.24 | 0.0089 | | HWL | 11.97 | 11.8 - 12.14 | 0.009 |
| | ASL5 | 0.25 | 0.18 - 0.25 | 0.018 | | HWH | 2.7 | 2.4 - 3.59 | 0.909 |
| | ASL6 | 0.27 | 0.19 - 0.31 | 0.022 | | HTL | 3.2 | 2.8 - 3.47 | 0.162 |

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Table 4 O. Smaragdina Male Alate (Male Reproductive) Core and Specialized Measurements Collected from the Cacao Farms in Luzon Island, Philippines on July 2018 (N = 15)

| Caste | Char. | Mean | Range | Std. Error | Caste | Char. | Mean | Range | Std. Error |
|---|---|---|---|---|---|---|---|---|---|
| Male alate | HL | 0.87 | 0.66 - 1 | 0.057 | Male alate | ASL7 | 0.11 | 0.10 - 0.12 | 0.005 |
| | HW | 0.95 | 0.81 - 1.02 | 0.037 | | ASL8 | 0.12 | 0.07 - 0.15 | 0.013 |
| | EL | 0.37 | 0.35 - 0.38 | 0.006 | | ASL9 | 0.14 | 0.13 - 0.16 | 0.002 |
| | EW | 0.26 | 0.23 - 0.27 | 0.007 | | ASL10 | 0.15 | 0.13 - 0.16 | 0.002 |
| | MandL | 0.39 | 0.29 - 0.47 | 0.3 | | ASL11 | 0.14 | 0.11 - 0.16 | 0.009 |
| | PronW | 1.4 | 1.36 - 1.45 | 0.015 | | ASL12 | 0.22 | 0.19 - 0.23 | 0.007 |
| | SL | 0.89 | 0.84 - 0.98 | 0.026 | | ASW1 | 0.09 | 0.07 - 0.15 | 0.009 |
| | CFW | 0.28 | 0.27 - 0.3 | 0.006 | | ASW2 | 0.07 | 0.06 - 0.08 | 0.004 |
| | CW | 0.48 | 0.41 - 0.54 | 0.027 | | ASW3 | 0.08 | 0.06 - 0.10 | 0.007 |
| | HFL | 2.42 | 1.84 - 2.94 | 0.244 | | ASW4 | 0.08 | 0.07 - 0.10 | 0.005 |
| | HLA | 0.89 | 0.66 - 1 | 0.066 | | ASW5 | 0.08 | 0.06 - 0.10 | 0.008 |
| | MTL | 1.69 | 1.19 - 1.88 | 0.134 | | ASW6 | 0.07 | 0.06 - 0.08 | 0.002 |
| | PetH | 0.28 | 0.22 - 0.32 | 0.019 | | ASW7 | 0.07 | 0.05 - 0.08 | 0.002 |
| | PetW | 0.3 | 0.27 - 0.36 | 0.016 | | ASW8 | 0.06 | 0.05 - 0.07 | 0.004 |
| | PTH | 0.28 | 0.22 - 0.32 | 0.019 | | ASW9 | 0.05 | 0.04 - 0.07 | 0.004 |
| | PTL | 0.53 | 0.5 - 0.55 | 0.01 | | ASW10 | 0.05 | 0.04 - 0.07 | 0.005 |
| | TL | 7.06 | 6.59 - 7.4 | 0.168 | | ASW11 | 0.07 | 0.05 - 0.08 | 0.005 |
| | ASL1 | 0.22 | 0.19 - 0.23 | 0.007 | | ASW12 | 0.1 | 0.07 - 0.14 | 0.014 |
| | ASL2 | 0.1 | 0.09 - 0.11 | 0.004 | | FWL | 7.81 | 7.42 - 8.23 | 0.987 |
| | ASL3 | 0.1 | 0.08 - .10 | 0.006 | | FWH | 2.39 | 1.82 - 2.74 | 1.009 |
| | ASL4 | 0.12 | 0.10 - 0.13 | 0.003 | | HWL | 4.88 | 4.32 - 6.26 | 1.987 |
| | ASL5 | 0.11 | 0.10 - 0.12 | 0.004 | | HWH | 1.9 | 1.68 - 2.00 | 0.789 |
| | ASL6 | 0.11 | 0.09 - 0.12 | 0.005 | | HTL | 1.69 | 1.73 - 2.64 | 0.909 |

The core and specialized measurements of the female alate (with wings) are almost in the same range as that of the deleate queen (Table 3). This is mainly because this particular caste would eventually become a founding queen. Upon mating with a male alate, it would then start to shed its wings and hence become a deleate queen. The male alate's core and specialized measurements (Table 4) has a discernibly smaller range than the deleate and winged female reproductive. This is seen to be the standard in the animal world as the female needs to carry and have inside its body the eggs and its needed nourishment.

### *C. Core Indices*

Table 5 Core and Specialized Indices of Colony Reproductive Collected from the Cacao Arms in Luzon Island, Philippines on July 2018

| Reproductive | CI | EI (REL) | MandI | SI |
|---|---|---|---|---|
| Gyne (N = 5) | 111.06 | 24.9 | 49.23 | 108.43 |
| Fem. al. (N = 15) | 99.6 | 24.3 | 44.44 | 108.76 |
| Male al. (N = 15) | 109.2 | 38.95 | 44.83 | 93.68 |

The cephalic, eye, mandible, and scape indices are presented in table 5. These measurements are based on composite measures of variables. *O. smaragdina* brood dimension measurement is seen in table 6. The length, width, and height measurements of eggs, larvae, and pupae average, range, and standard error for reference are presented.

Table 6 O. Smaragdina Brood Dimension Measurement Collected from Cacao Farms in Luzon Island, Philippines on June 2018

| Brood | Dim. | Mean | Range | Std. Error |
|---|---|---|---|---|
| Egg major (N=15) | Length | 0.93 | 0.83 - 1.14 | 0.033 |
| | Width | 0.79 | 0.72 - 0.9 | 0.02 |
| | Height | 2.01 | 1.83 - 2.1 | 0.052 |
| Egg minor (N=15) | Length | 0.65 | 0.50 - 0.74 | 0.027 |
| | Width | 0.61 | 0.55 - 0.68 | 0.016 |
| | Height | 1.2 | 1.02 - 1.28 | 0.025 |
| Egg Maj. Headcap | Length | 0.524 | 0.49 - 0.6 | 0.02 |
| (N=15) | Width | 0.46 | 0.37 - 0.48 | 0.024 |
| Larva female alate | Length | 1.564 | 0.9 - 1.94 | 0.123 |
| (N=15) | Width | 1.367 | 0.89 - 1.77 | 0.092 |
| | Height | 4.629 | 4.08 - 4.86 | 0.104 |
| Larvae of fem. alaHCap | Length | 1.213 | 0.9 - 1.37 | 0.052 |

| | | | | |
|---|---|---|---|---|
| (N=15) | Width | 1.152 | 0.89 - 1.44 | 0.057 |
| Pupae major worker | Length | 2.145 | 1.88 - 2.37 | 0.078 |
| (N=15) | Width | 1.582 | 1.33 - 1.78 | 0.07 |
| | Height | 7.2 | 7.02 - 7.29 | 0.042 |
| Pupae minor worker | Length | 1.47 | 1.27 - 1.77 | 0.0732 |
| (N=15) | Width | 1.08 | 0.98 - 1.18 | 0.03 |
| | Height | 4.29 | 4.07 - 4.79 | 0.175 |

## IV. DISCUSSIONS

Morphometry for the size and shape of the Aisan weaver ant, O. smaragdina were determined and recorded. Measurements are normally recorded in thousandths of a millimeter but reported to the nearest hundredth as a range from minimum to maximum across all measured specimens.

Both deleate and winged female reproductive have almost the same range as these castes only differ mainly because the former has already mated and is ready to produce eggs while the latter may still be a virgin or already mated but is still to shed its wings. These differences in color morphologies could be attributed to some mico-environmental factors that are likely to be different from one place to another. The yellow-green deleate queen may have been nesting in cacao areas with newly formed leaves and nearly ripened cacao pods that are also yellow-green in shade. The light-brown deleate queen could be deduced to have its nest in areas where the leaves are mature and cacao pods are in their intermediate development stage. The queen that had a strong dark-brown color may have been nesting very proximal in large branches and had weaved nests that are already mature. This nest may also have cacao pods that are still in the immature stages. This semblance of the deleate queens to its corresponding habitat gives additional camouflage to the weaver ant and therefore allows it to escape or evade its predators. The male alates measurements have a smaller range than the female two reproductives as males in the insect world tend to be smaller. This could be explained as the queen needing to carry more volume for the eggs and nourishment.

The available quantitative measurements for the *O. smaragdina* caste may now be used as a further reference to other studies of interest that may deal with regression analysis and correlation or any other significant statistical inference with another caste of different ant genera.

*O. smaragdina's* basic colony structure is mainly composed of deleate queens, male alates, female alates, major workers, minor workers, eggs, larvae, and pupae. This result adhered to the findings of Lokkers (1990) and Lee et al. (2003) where *O. smaragdina* ants are known to have a complete ontogenetic development that consists of immature stages: eggs, larvae, and pupae; and adults with reproductive phase: deleate queen; and non-reproductive period: workers. These workers of *O. smaragdina* are all females and have a dimorphic morphology known as major and minor workers (Wilson, 1953; Greenslade, 1972; Hölldobler and Wilson, 1990). The result also corresponded with what Wilson (1953) stated that this weaver ant genus has a unique feature wherein the major workers outnumber minor workers. Results of Bhattacharya (1943); Gibbs and Leston (1970); Greenslade (1971); and Way (1954) that winged male and female sexuals are produced mainly during the specific geographical area's wet season were also reflected in this study as a collection in the site happened in June which is the start of the rainy season in the Philippines. The results of this present study are in coherence with the findings of Peng et al. (1998a; 1998b) wherein they reported that a large number of major workers, eggs, larvae, and some minor workers, but no pupae or medium-sized or large-sized larvae are found in other nests within the given standard time of collection. Way (1963) had an output that is related to this study wherein broods of *O. Smaragdina* were detected to be raised and were collected in "pavilions" or smaller volume nests but were observed to be without a reproductive caste in the site.

No deleate queen was found in the Options farms collection site whereas five deleate queens were found in the QAES site. This may be because the latter site has a larger area with a 4:1 proportion against the former site and has more fruiting cacao trees that are less disturbed by human intrusions. The more disturbances, the higher the ants will form their nests, thus giving a higher chance of miscollection of the intended deleate queen. Another thing that may be considered is that the QAES site was established much earlier than the Options farm site. The nests which are taken from the Options farm site were also fewer in number compared to the nests of the QAES colony. This may also be the reason why no female and male alate was collected in the Options farm site.

The number of collected male alates in the QAES colony was higher than the collected female alates (241.71 ± 126.069; 10 ± 5.196) might be due to the behavior of female alates that mates with more than one male during swarming (Marcelo et al., 2012). This result was the same as (Marcelo, et al., 2012) and is further supported by Schlüns et al., (2009) who reported that half of the queen in their study mated up to five times, which suggested that more males needed to be available and involved during mating than females.

As major workers are tasked to do more work such as foraging, defending the colony, care for the queen and its brood, it had a higher number of individuals than minor workers which essentially remain in the leaf nests and cares for most of the brood (Holldobler and Wilson, 1990).

The ellipse-shaped eggs had sized that ranged from 0.5 mm to 1.5mm. Marcelo (2012) used a manual magnifying glass to see the eyes and the mouth of the larvae within eggs, this study, however, used a stacking application to vividly see the same manifestation.

This current study was able to observe that *O. smaragdina* ants can produce a new nest for their brood in less than 24 hours. This study provided a 2 x 2 square foot acrylic terrarium with four holes on 2 sides for ventilation for one of the ant nests. Upon settling, the workers immediately checked its surroundings, and within minutes started weaving approximately 4 -6 leaves of the cacao seedling placed in the terrarium and directly placed the broods coming from the plastic bags where they were kept in the newly weaved pavilion-type of the nest. It could be surmised from the ants' behavior that the safety of the brood is of utmost importance. A hallmark of a eusocial organism.

The two study sites had the major and minor workers ranked first and second for colony structure mean distribution (Figure 30) (QAES 999.57; 431, Options farm 855.5; 378) and percentage (Figure 31) (QAES 58.69%; 24.37%, Options farm 50.54%; 22.10%) of distribution respectively and adheres to the previous ideas mentioned that a colony needs a sufficient number of major workers cooperating to sustain the colony. Five deleate queens have been collected from the QAES site but no collections for this caste were recorded for the Options farm. This could be because the former is four times bigger in the area and had fewer human intrusions than the latter. Frequent human interferences may have forced weaver ants from the Options farm to build nests in higher canopy areas which were not noticed during standard collection time. This could also be the explanation for why there were also no collections for the female alate pupae, and male and female alate in the smaller study site. The eggs for the major and minor workers for the QAES farm had a proportion of 4:1 ratio in mean and percentage distribution (26.28:7.29; 1.3%:0.36%), while the Option farm had a 3:1 ratio (28.5:9.5; 1.66%:0.56%) and is in contrast with the data for the Pupa for both major and minor workers, wherein the Options (312:102.5; 18.22%:6%) farm site had a higher mean and percentage distribution than the QAES (31.43:10.6; 1.51%:0.51%) site. this could be attributed to the fact that the collector may have chanced upon what Way (1963) considers to be “pavilion” type nests wherein mostly developing pupa are found instead of reproductive.

*O. smaragdina* colony structure displays cooperation within the colony that fits its billing as a superorganism, a single organism with so many functional and integrated organs (Holldobler and Wilson, 1990). Cooperation within the colony is the undisputed foundation of the ecological success of eusocial insects (Bourke and Franks, 1995; Crozier and Pamilo 1996; Holldobler and Wilson, 1990). This manifestation of cooperation of the different castes of *O. smaragdina* observed and collected in this present study enabled them to perform a different but specific task to maintain their colony well. It could be concluded that QAES site has the more mature colony and more major workers based on the statement of Holldebler and Wilson (1990) who stated that a colony that is large enough to produce new, virgin queens and has enough major workers to maintain the colony may be called a “mature” colony.

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