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Morphology, Life Stages, and Longevity of a New Report of *Stenocranus* near *pseudopacificus* (Kirkaldy) in Kalinga, Philippines

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A new report of *Stenocranus* near *pseudopacificus* Kirkaldy is documented as an insect pest of corn in Kalinga, Luzon, Philippines. As the identification of this insect species was done only again in the first quarter of 2021, work understanding its biology and life history is in its infancy compared to other planthoppers with corn as the primary plant host, which may share similar genome organization and vectorial capacity to transmit phytopathogens. Very little knowledge is known regarding its biological and ecological characteristics. Here, the number of nymphal stages of *S.* nr. *pseudopacificus* – as well as its longevity on corn – were determined. Morphological identification of *S.* nr. *pseudopacificus* indicated that these planthoppers have whitish vertex slightly broader in the apex, reddish-brown band between median and lateral carinae running down to the frons, and similar built and yellow-orange coloration to *S. pacificus* Kirkaldy except in genitalia. To check for the longevity and life stages of *S.* nr. *pseudopacificus* Kirkaldy a total of 150 macropterous adults were collected from a local corn field in Tabuk City, Kalinga. Results showed that *S.* nr. *pseudopacificus* has four nymphal stages. Moreover, the incubation period of eggs was 11–12 d, first nymphal (N1) stage lasted for 4–-5 d, 3–6 d for the second nymphal stage (N2), 6–7 d for the third nymphal stage (N3), 2–6 d for fourth nymphal stage (N4), and 9–13 d for the adult stage. Based on these results, it was found that *S.* nr. *pseudopacificus* completes its life cycle, excluding its egg incubation period, from 24–37 d. The results of this study provided relevant new information about this species' life-history traits. Its presence in the key corn planting region of the country merits further data and survey collection for its impact on corn production.

Keywords: corn pest, life stage, longevity, morphology, *Stenocranus* nr. *pseudopacificus*

INTRODUCTION

Corn or maize (*Zea mays* L.) is a commodity as equally significant as rice in the Philippines. The crop is of great importance and it ranked as the second most important crop next to rice in the Philippines and third based on the harvested area at the global level (Ramirez-Cabral *et al.* 2017; Gerpacio *et al.* 2004). According to Dukhnytskyi (2019), the global agricultural production report of the Philippines has a 2020–2021 projected area of 2.60 million hectares (ha) attributed to corn. The country yield 2.15 metric tons (MT)/ha and a production of 8.20 million MT contributing to the worldwide area of 196.39 million ha. Additionally, based on the 2021 Philippine Statistics Authority report on rice and corn stocks inventory for December 2020, it is estimated that the total corn stocks inventory was estimated at 960.95 thousand metric T, which was higher than the previous year's inventory of 794.87 thousand metric T by 20.9%.

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The production of corn contributes greatly to the agro-economical aspect of the country. The corn production industries in the Philippines have an annual contribution of 100 billion pesos to the economy, whereas there are about 1.8 million farmers whose livelihood relies on farming white and yellow maize, which are grown mainly as a substitute staple and as the primary source of animal feed, respectively (Gerpacio *et al.* 2004; Naval and Dolojan 2020). More so, the annual report of Corpuz (2020) for the Philippines' grain and feed production showed that 70–75% of the total corn output is attributed to yellow corn, mainly from the country's top corn-producing regions such as Cagayan Valley plus Northern and Central Mindanao, while locally produced white maize accounts for a yield of 1.9 T/ha.

Stenocranus near *pseudopacificus* Kirkaldy is a relatively new paurometabolous insect pest of corn; thus, there is limited information regarding its bio-ecological processes such as its life span. *S.* nr. *pseudopacificus* Kirkaldy is a hemipteran insect pest classified under the superfamily Fulgoroidea, family Delphacidae, subfamily Stenocraninae, and tribe Stenocranini (Integrated Taxonomic Information System). According to Song and Liang (2013), the superfamily Fulgoroidea is one of the most dominant groups of phytophagous insects comprised of 20 families, which includes a total of 9,000 species worldwide. Muir (1923) classified 15 families initially under this superfamily – namely, Tettigometridae, Cixiidae, Delphacidae, Tropiduchidae, Derbidae, Achilixiidae, Dictyopharidae, Fulgoridae, Eurybrachidae, Achilidae, Acanaloniidae, Issidae, Lophopidae, Ricaniidae, and Flatidae. Furthermore, Fulgoroidea is distinct from other superfamilies for some distinguishing characteristics such as bearing a large second segment of the antenna where complex sense organs are situated – as well as the presence of well-developed tegulae, immobile posterior coxae, and the spiracles on the lateral areas of the abdomen (Muir 1923).

The family Delphacidae is a cluster of insects feeding on the phloem of economically important crops such as rice, corn, wheat, barley, and sugarcane and is comprised of 2,100 described species (Urban *et al.* 2010). Generally, species from the family Delphacidae have body lengths ranging from 1.8–8 mm and exhibit piercing-sucking mouthparts. Furthermore, the most distinct feature of delphacid species is the presence of calcar on their hind legs, which is a large and movable spur used to assist the insects in jumping (Bartlett *et al.* 2020). Moreover, most delphacid planthopper species can develop into different wing forms, which could either be long-winged or macropterous if they have fully developed flying wings. They can also develop into brachypterous or short-winged form, which exhibit non-functional membranous and somewhat thickened wings. The development of certain wing polymorphism is brought about by the population density during the nymphal stage, whereas high population density will result in the emergence of macropterous adults for dispersal (Bartlett *et al.* 2020). The subfamily Stenocraninae consists of the single tribe Stenocranini where five genera – *Frameus*, *Kelisicranus*, *Obtusicranus*, *Stenocranus*, and *Tanycranus* – belong to. The distribution of this subfamily is mainly of Holarctic. However, a few taxa are found in Neotropical, Indo-Malayan, and Afrotropical regions and are associated with plants from Poaceae and Cyperaceae families.

S. near *pseudopacificus* was initially regarded as an insect pest of economically low importance, recorded as a pest of rice with a reported incidence in Luzon, Philippines (Dupo and Barrion 2009). According to Dupo and Barrion (2009), *S.* nr. *pseudopacificus* exhibits a body length ranging from 5.7–7.5 mm, pale yellow to light orange-yellow in color, reddish-brown to silvery brown with red tinge eye color, and a relatively narrow median longitudinal white band running from the vertex to scutellum. Additionally, its mesonotum is largely orange laterally, pale yellow basal compartment with brown margins, whitish vertex except for the brown band between the median, and lateral carinae that runs down to the frons. Moreover, it has orange clypeus, yellowish-brown genae, and yellow antennae. Forewings are hyaline, lightly granulated with pale brown veins toward the apical margin, and extended beyond the tip of the abdomen. The legs are yellow, and the abdomen is orange except for the pygofer, which is yellow in color.

Here, the number of the instar stages – as well as the longevity of *S.* nr. *pseudopacificus* reared in corn – were determined. Specifically, the number of instar stages of *S.* nr. *pseudopacificus* were observed during the present work. The duration of each developmental stage and the longevity of *S.* nr. *pseudopacificus* from its nymphal period until the adult stage was also determined. The limitation of this work is that the *S.* nr. *pseudopacificus* adults used were from three different sites from one farmer's field only and do not represent insect species that may be found in other parts of the country.

MATERIALS AND METHODS

Maize Cultivation for Rearing

The study was conducted in Dagupan Weste, Tabuk City, Kalinga, Philippines from the fourth week of March until the third week of May 2021. Six sweetcorn seeds (cultivar HI-BRIX XL F1, Allied Botanical Corp.) were individually sown on plastic planting bags (6.5 in height x 8 in diameter), following the manufacturer's instructions.

Watering of the corn plants followed a 2-d interval schedule during the seedling stage and was eventually done daily during the latter stages of growth. Moreover, the application of complete fertilizer was carried out every 2 wk throughout the development of the plants. The plants were exposed to direct sunlight for most hours of the day. This sweet corn plant will be used for rearing test insects.

Insect Collection

A total of 150 macropterous *S.* nr. *pseudopacificus* adults were collected at three different sites of the 20,000-m^2 local cornfield in Dagupan Weste, Tabuk City, Kalinga. The geographical location is 17.4802° N, 121.4542° E 50 m; 17.4802° N, 121.4542° E 65 m; 17.4802° N, 121.4542° E 75 m; 17.4802° N, 121.4542° E 70 m; 17.4802° N, 121.4542° E 55 m. The macropterous adults were manually collected from each site using a cylindrical plastic container (14 in long and 1 in diameter) and transferred to mesh-covered glass jars. Fifty (50) adults were collected on 21 Mar 2021 for Replicate 1 and another 100 on 22 Mar 2021 for Replicates 2 and 3. The 25 insect pairs were moved to the 3-wk-old sweetcorn plants per pot.

Morphological Identification

Five adult *S.* nr. *pseudopacificus* Kirkaldy collected using insect nets and plastic tubes were kept in small glass vials and killed by submerging to 95% ethyl alcohol. Identification was done at the Institute of Weed Science, Entomology, and Plant Pathology; College of Agriculture and Food Science; University of the Philippines Los Baños. Species were recognized by caput and wing morphologies. The wings of the specimens were removed with forceps and placed under a Petri dish with ethanol. Morphological examinations for adult specimens and photography of wings were done using the Euromex Nexius zoom stereomicroscope (NZ 1903 P). Specimens were identified up the nearest taxa as possible using available published taxonomic literature. Photographs of habitus were taken using the ToupCam XCAM Full HD Camera. Identification of specimens was confirmed using keys published by Metcalf (1943), Muir (1916), and Dupo and Barrion (2009).

Insect Cages

Individual cages for the six corn plants were constructed using bamboo sticks, floral wire, and mesh cloth. A square top frame made of bamboo sticks with lengths of 14 in and 1 and ¾ yd of mesh cloth was utilized in making each cage. Three potted corn plants situated in an area exposed to direct sunlight were used for rearing the collected insects. Fifty (50) *S.* nr. *pseudopacificus* adults, 25 pairs, were immediately transferred after collection on each of the caged 3-wk-old corn plants having 6–8 leaves and were given an oviposition period of 1 wk. The insects were then removed and transferred to fresh corn plants on the eighth day.

Data Gathering and Analysis

The number of nymphs and exuviae was obtained daily by counting. The highest population of first instar nymphs was assumed to be the total number of F1 populations that emerged. To determine the duration of each life stage, the day of the first appearance of nymphs up to the day of the appearance of exuviae was assumed to be the period for a new developmental stage. The number of exuviae of each stage was obtained and assumed to be the number of nymphs that developed successfully into the next stage. The total number of adults *S.* nr. *pseudopacificus* was counted. Gathering of the total number of insects was done every day until the plant showed wilting and eventually die. Analysis of variance was used to analyze the differences in longevity of the insects as affected by the duration of the life stages. Non-parametric statistics were also run to understand if the population number of insects in the replicates is affected by the number of insects per life stage and temperature.

RESULTS

Insect Morphological Identification

Morphological identification of planthoppers was done, and Table 1 indicates the list of *S.* nr. *pseudopacificus* specimens used. From the collected samples, four out of five were females. *S.* nr. *pseudopacificus* planthoppers

Table 1. List of *S.* nr. *pseudopacificus* Kirkaldy specimens used in the study. The specimens were from Dagupan Weste, Tabuk City, Kalinga.

Specimen no.	Genus	Species	Sex	Length (mm)	Width (mm)
UPLBIWEP HEM-00001	*Stenocranus*	*pseudopacificus*	Female	5.22	1.20
UPLBIWEP HEM-00002	*Stenocranus*	*pseudopacificus*	Female	5.20	1.21
UPLBIWEP HEM-00003	*Stenocranus*	*pseudopacificus*	Female	5.21	1.20
UPLBIWEP HEM-00004	*Stenocranus*	*pseudopacificus*	Female	5.23	1.19
UPLBIWEP HEM-00005	*Stenocranus*	*pseudopacificus*	Male	5.50	1.00

had length and width values that varied from 5.20–5.23 mm and 1.19–1.21 mm respectively in females, while the male planthopper had a width of 1.00 mm and a maximum length of 5.50 mm.

Caput. The caput of the planthopper is pale yellow to light orange-yellow in color with a relatively narrow median longitudinal white band running from the vertex to its scutellum. Compound eyes are reddish-brown to silvery brown with a red tinge while ocelli are black. Its vertex is slightly longer than wide, widest basal, frontally narrowed, and projected in front of the compound eyes. Vertex is whitish in color and slightly broader in the apex. The frons has reddish-brown bands found between the median and lateral carinae on the head running down to the base. The clypeus is orange and tricarinate, while the genae are yellowish-brown. The planthoppers possess short bulbous antennae with pedicel or antennal segment II longer than the scape or antennal segment I. Figures 1A and B show the dorsal views of male and female *S.* nr. *pseudopacificus,* respectively.

Figure 1. Dorsal view of male (A) and female *S.* nr. *pseudopacificus* Kirkaldy (B).

Thorax. The forewings of *S.* nr. *pseudopacificus* are hyaline and lightly granulated with pale brown veins toward the apical margins and are extended beyond the tip of the abdomen by as much as 1.63x the length of the abdomen. Figures 2A and B show the left and right wings of *S.* nr. *pseudopacificus*, respectively. It possesses a yellow leg where its basitarsus is as long as or a little longer than the combined length of the other two tarsal segments. Figures 3A and B show the lateral views of male and female *S.* nr. *pseudopacificus*, respectively.

Abdomen. The abdomen of *S.* nr. *pseudopacificus* is orange except for its yellow pygofer, which is subquadrate basally to moderately oblong in shape. Figures 4A and B shows the ventral view of male and female respectively. Its laterodorsal angle is almost at midlength and is U-shaped on the apical end; its parameres are unique with a large contiguous base, which forms thin spur with apically diverging tips, continues apically as a slender process, and is curved outward laterally. Its anal segment has pair of horn-like processes curved towards the inside of the pygofer. Its aedeagus is long and slender plus half-coiled subapically, forming a transverse structure between the horn-like process of the anal segment.

Longevity and Life Stages

The current life stage of the insects, as well as the duration of each life stage, were determined by the appearance of insect exuviae. The data obtained daily was tabulated and the duration of each life stage, as well as the number of nymphal stages, was inferred and summarized in Table 2. Eggs from the three replicates have an incubation period of 11–12 d. The highest observed duration of egg incubation was in Replicate 2 with a period of 12 d. Exuviae were first observed after 4 d; hence, the duration for the first nymphal stage (N1) can be deduced equivalent to this number of days. N1 in Replicates 1 and 2 lasted 4 d and 5 d for replicate 3. Second instar nymphs (N2) have a 3–6-d duration, while that for N3 was observed to be 6–7 d. The duration of N4 was 2–6 d, while the adult stage was observed to be 9–13 d. The insect completes

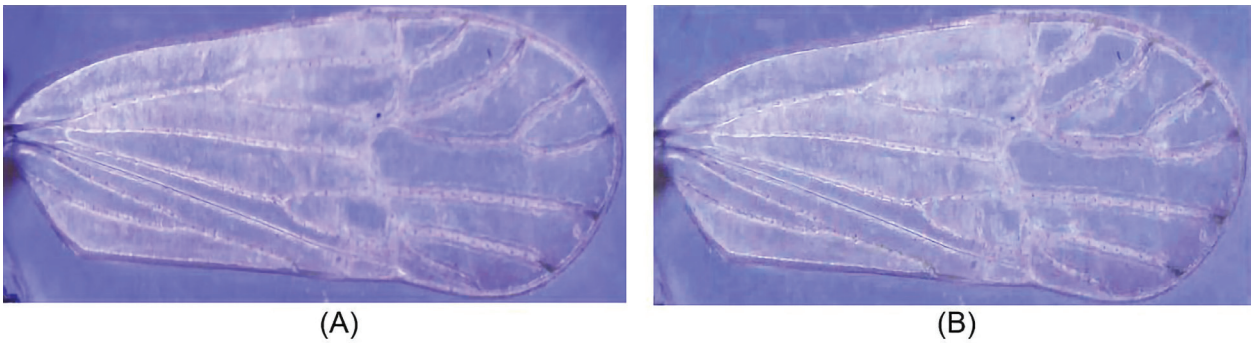

Figure 2. Left (A) and right (B) wings of *S.* nr. *pseudopacificus* Kirkaldy.

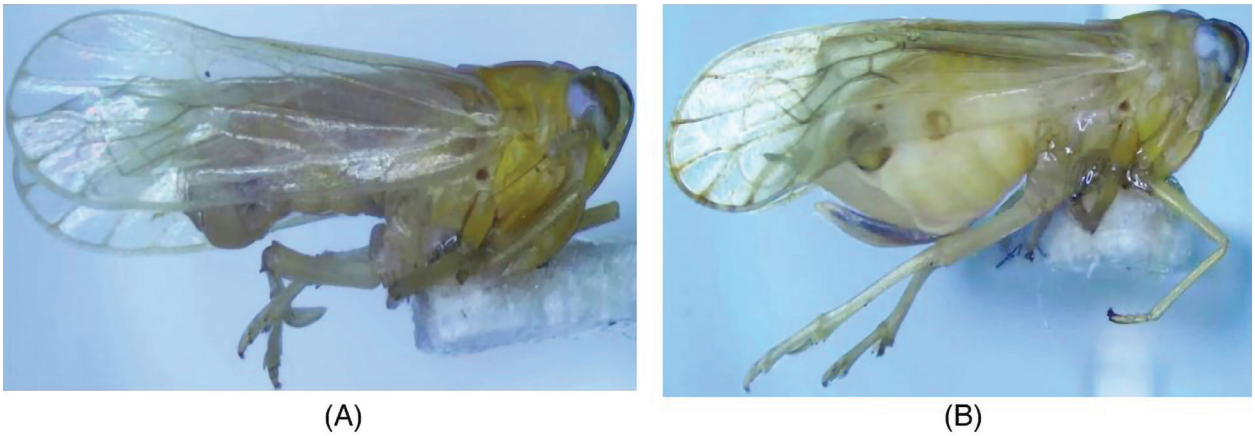

Figure 3. Lateral view of male (A) and female *S.* nr. *pseudopacificus* (B).

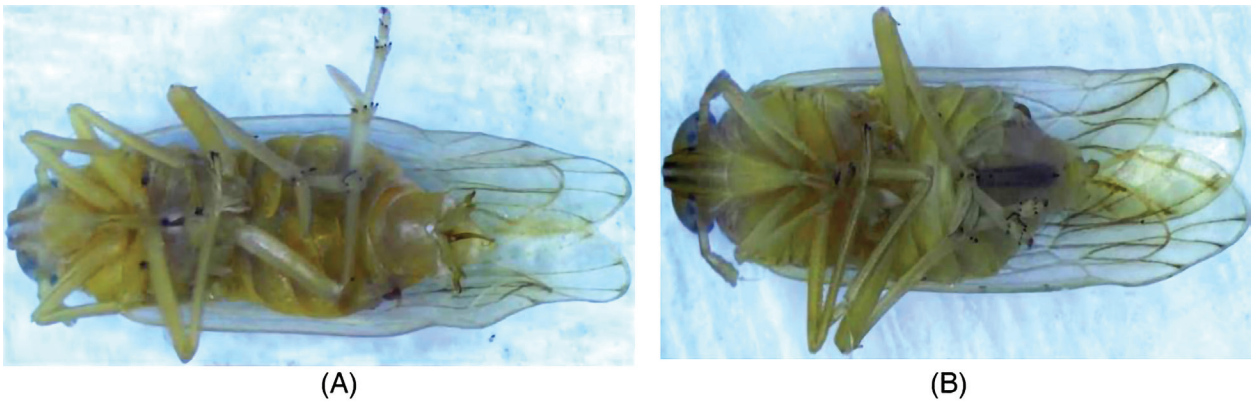

Figure 4. Ventral view of male (A) and female *S.* nr. *pseudopacificus* Kirkaldy (B).

Table 2. Observed duration of each life stage of *S.* nr. *pseudopacificus*

Replicates	Duration each stage (days)*						Longevity (nymph to adult)
	Egg	1st nymph (N1)	2nd nymph (N2)	3rd nymph (N3)	4th nymph (N4)	Adult	
1	11	4	3	6	2	9	24
2	12	4	5	7	2	12	30
3	11	5	6	7	6	13	37
Total days	**11–12^{a}**	**4–5^{bc}**	**3–6^{bc}**	**6–7^{b}**	**2–6^{c}**	**9–13^{a}**	**24–37**

*The same letters indicate no significant similarity in the duration of life stage, and different letters imply otherwise.

its life cycle from 24–37 d excluding the egg incubation stage. The number of *S.* nr. *pseudopacificus* throughout the experimental period varied among the three replicates (Appendix I). The number of insects reached almost 1,400, but the population decreased afterwards. Survival rate of the insects may be associated with the fluctuating temperatures during the months of April and May (Appendix II).

A diagram of the assumed life cycle of *S.* nr. *pseudopacificus* was presented in Figure 5. From the observations, *S.* nr. *pseudopacificus* has four nymphal stages. Eggs were observed to be deposited mainly on the midrib on the underside of the corn leaves (Appendix IIIA). However, minimal egg oviposition was also observed on the stem of the plants. Oviposition sites of *S.* nr. *pacificus* were indicated by the appearance of

Figure 5. The suggested life cycle of *S.* nr. *pseudopacificus*: Eggs, four nymphal stages, and an adult stage. The adult insect in the figure is a female macropter.

a white waxy substance (Appendix IIIC). The white waxy substance found is similar to that in *S. pacificus* (Hasibuan *et al.* 2021). Similarly, nymphs – especially the N1 and N2 nymphs – were observed to be found usually on the abaxial side of leaves but not necessarily on the midrib. Insects at the later nymphal stages were observed to be feeding on the top surface of leaves, as well as along the stem. Adults were found anywhere on the sweetcorn plants and were usually active in the mornings and late afternoons. Furthermore, based on observations, newly hatched nymphs are initially light orange in color and turn white after a few hours. N1 and N2 nymphs are also white in color; however, N4 nymphs are light to dark brown.

DISCUSSION

There are no new reports of *Stenocranus* near *pseudopacificus* (corn planthopper) in the Philippines since the early 1900s. However, there were reports of *Stenocranus pacificus* in corn-growing areas of Region 12 in the last quarter of 2003. By the first quarter of 2004, almost all corn-growing areas of Mindanao were reported to be infested by the planthopper – expanding from Region 12 (Central Mindanao, Philippines) to Regions 9, 10, 11, ARMM, and Caraga. In August 2006, the corn planthopper was observed in Pili, Buhi, Iriga, Legaspi, and other municipalities of Camarines Sur (Dumayo *et al.* 2007). Three years after, the insect was observed in Occidental Mindoro, La Union, and Ifugao (Cayabyab *et al.* 2009). Since then, there were no scientific data or recent information published about the insect pest.

Recently, however, the Bureau of Plant Industry reported the corn planthopper to be consistently in its top three list of pests in the first quarter of 2021 and has been in the constant monitor of the regional crop protection centers since the first quarter of 2020.

The Kalinga province has corn as one of its main agricultural products. When the presence of corn planthopper was detected in small corn farms in the first quarter of 2021, we explored further its initial morphological identification and study its life stages and longevity. Our results showed that the corn planthopper is *Stenocranus* nr. *pseudopacifius* and not *Stenocranus pacificus* as we initially predicted. We expect the insect species submitted to us to be *S. pacificus*, but it was not. The result is inconclusive as we plan to further validate our identification using molecular techniques.

Our results serve as preliminary data for the study of this new report of *S.* nr. *pseudopacificus.* As it is a closely related species of another corn planthopper, *Peregrinus maidis* Ashmead, we take interest in this insect pest because it may be a potential vector of corn pathogens. Where the insect was observed and located, corn plants were characterized to be stunted, some chlorotic stripes on the leaves were detected, and the presence of sooty mold was observed. These characteristics may be caused by a virus-like Maize mosaic rhabdovirus transmitted by *P. maidis* (Barandoc-Alviar *et al.* 2017). Hopper burn was also detected in some corn plants where pest infestation was severe.

In determining the life stages of *S.* nr. *pacificus,* we also collected data on the number of insects in the duration of the corn plant life. The number of insects declines after the first nymphs (N1) emerge. This was expected as not all N1 insects survive to molt into the next stage. The presence of natural enemies in the cages may have also contributed to the decline of the insect population. Spiders were later detected on the caged plants. Araneae species have been identified as one of the natural enemies, specifically a generalist predator of Stenocraninae planthopper – *Stenocranus pacificus* (Nelly *et al.* 2017; Swibawa *et al.* 2018). Fluctuations in the population of insects were observed during the later stages of development. A mixture of the F1 and F2 generations was already observed in the last 2 wk of data collection and observation.

Temperature influences the number of developmental stages in insects. In the central US where the temperature is colder, *P. maidis* undergoes five nymphal stages but only four in temperate countries like the Philippines (Alviar, unpublished 2021). Extremely low and high temperatures result in the low survival rate of said insect, as well as abnormal development – where the fourth instar directly molted into adults skipping the fifth instar nymph stage (Tsai and Wilson 1986). Additionally, Tsai and Wilson proved that *P. maidis* develop at the optimum temperature of 21.1–26.7 °C. *S.* nr. *pseudopacificus* has been found here to have four nymphal stages. In a similar study by Dumayo *et al.* (2007), they showed that another Stenocraninae hopper – *S. pacificus* – undergoes four instar stages (3-4-4-4). *S.* nr. *pacificus* can live from 24–37 d and the longest duration of the developmental stage is when it is already adult. It will be interesting to further explore the population dynamics of this insect species as adult wing polymorphism exists in this species. The number of brachypterous or macropterous insects in a population varies depending on the food source.

CONCLUSION

Stenocranus. nr. *pseudopacificus* is a relatively new pest of corn; thus, it is one of the least studied planthoppers when it comes to bio-ecological characteristics. This study is a new report of the existence of *S.* nr. *pseudopacificus* in the Philippines. The longevity of *S.* nr. *pseudopacificus* – including the number of nymphal stages it undergoes, as well as the duration of its life stages – were determined. Life history and developmental stages are similar to closely related corn planthopper, *P. maidis*. However, to further validate the results of this study, sample collection should be carried out in different corn-producing areas in the country. Moreover, it is suggested that the experiment should be performed at temperatures representing the geographical areas of the different insect collection sites. We suspect that the duration of each nymphal stage may slightly vary.

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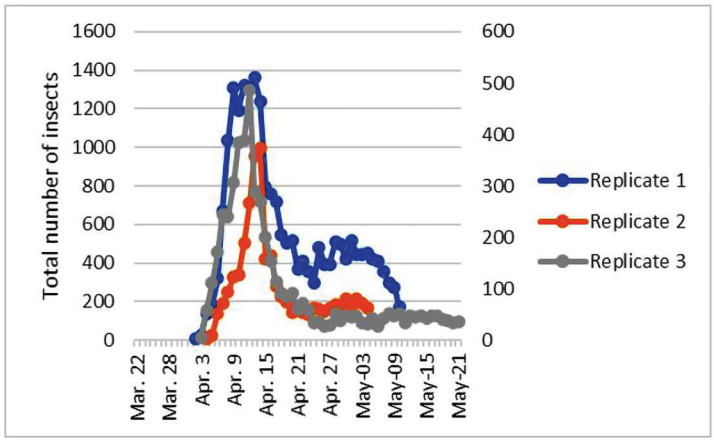
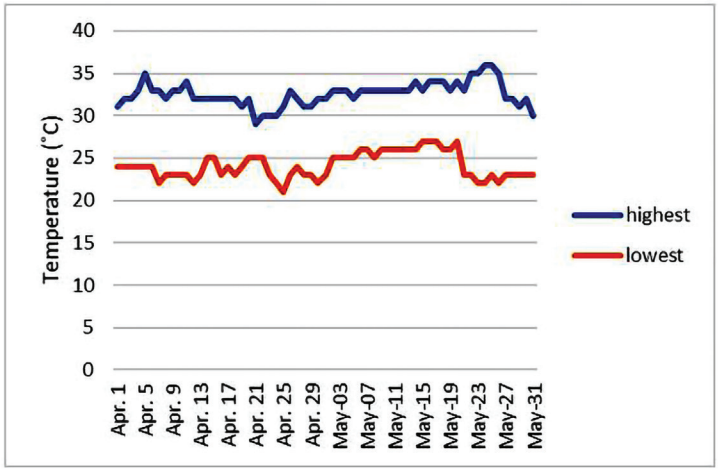
APPENDICES



Appendix I. The total number of insects in each replicate from April–May 2021.



Appendix II. Temperature ranges from April–May 2021 in Tabuk, Kalinga Philippines. The temperature at its lowest does not reach 20 °C and highest not more than 36 °C. (https://www.accuweather.com/en/ph/tabuk-city/263617/may-weather/263617?year=2021)

Appendix III. Eggs (red arrow) deposited along the midribs on the underside of leaves (A), fourth instar *S.* nr. *pseudopacificus* nymph (B), and female *S*. nr. *pseudopacificus* laying egg (C).