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Authors: Mateos-Escudero, Marlene, Guzmán-Vásquez, Héctor Miguel, Lozano-Trejo, Salvador, Sánchez-García, José Antonio, and Pérez-León, María Isabel

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# White Grub Adults[1] Associated with Maize (*Zea Mays* L.) at Zaachila, Oaxaca, Mexico

Marlene Mateos-Escudero[2], Héctor Miguel Guzmán-Vásquez[3*], Salvador Lozano-Trejo[2], José Antonio Sánchez-García[3], and María Isabel Pérez-León[2]

**Abstract.** Results of a preliminary study on adult scarab beetles (Coleoptera: Scarabaeidae "Pleurosticti") associated with maize (*Zea mays* L.) at the municipality of Villa de Zaachila, Oaxaca, Mexico are presented. The objective was to identify species of the white grub complex associated with the crop. Samples were collected each month from March through August 2018. A blacklight trap in the center of the maize plot was used from 1900 to 2300 hours during 3 nights of the new moon period. In total, 1,429 specimens were captured, belonging to 12 species, four genera, four tribes, and three subfamilies of Scarabaeidae. Abundance was greatest in April, coinciding with the start of the rainy season. The genus *Anomala* Samouelle with five species was most abundant. *Anomala flavilla* Bates, 1888 was the most abundant species and together with *A. sticticoptera* Blanchard, 1850 were reported for the first time in the State of Oaxaca. An annotated checklist with data on distribution, elevation, and associated crops was presented. A key was provided for taxonomic identification of the species studied.

**Resumen.** Se presentan los resultados de un estudio preliminar sobre escarabajos (Coleoptera: Scarabaeidae "Pleurosticti") adultos asociados a cultivo de maíz (*Zea mays* L.) en el municipio de Villa de Zaachila, Oaxaca, México. El objetivo de este estudio fue identificar las especies del complejo gallina ciega asociadas a este cultivo. Se realizaron colectas mensuales entre marzo y agosto de 2018. Se colocó una trampa de luz negra en el centro de la parcela de maíz y se dejó actuar de las 19:00 a las 23:00 h durante tres noches del periodo de luna nueva. En total, se capturaron 1,429 especímenes, que pertenecen a 12 especies, cuatro géneros, cuatro tribus, y tres subfamilias de Scarabaeidae. La mayor abundancia se registró en el mes de abril coincidiendo con el inicio de la temporada de lluvias. El género mejor representado fue *Anomala* Samouelle con cinco especies. La especie con mayor abundancia en el estudio fue *Anomala flavilla* Bates, 1888, esta especie junto con *A. sticticoptera* Blanchard, 1850 se reportan por primera vez para el estado de Oaxaca. Se presenta una lista comentada con datos de distribución, elevación, y cultivos a los que se asocia cada especie. Adicionalmente, se proporciona una clave para la identificación de las especies estudiadas.

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[1]Coleoptera: Scarabaeidae "Pleurosticti"

[2]Instituto Tecnológico del Valle de Oaxaca. Ex-Hacienda de Nazareno, C.P. 71233, Santa Cruz Xoxocotlán, Oaxaca, México.

[3]Instituto Politécnico Nacional. Centro Interdisciplinario de Investigación para el Desarrollo Integral Regional Unidad Oaxaca. Hornos 1003. Col. Nochebuena, C. P. 71230, Santa Cruz Xoxocotlán, Oaxaca, México.

*Corresponding author: hemigv85@gmail.com

## Introduction

Maize (*Zea mays* L.) because of its economic, social, and cultural importance is the most important crop in Mexico. Average annual per-capita consumption (especially of tortillas) is 196.4 kg. Maize production is divided into white and yellow varieties. White maize is 86.94% of production and satisfies the entire national consumption by humans. Yellow maize is produced mostly to manufacture balanced feed for livestock but meets only 24% of national requirements (SAGARPA 2017).

Oaxaca State has potential to produce maize and is one of the most important genetic reservoirs in Mexico and the world. The State has 35 races of maize, which are 54% of those reported in Mexico (Rendón-Aguilar 2015). About 100 thousand hectares of rainfed maize with an average yield of 800 kg/ha (INIFAP 2017) are grown each year in the Central Valley region of Oaxaca. However, pests such as "white grub" complex (a main soil pest) damage the maize crop, which decreases production and consequently affects the economy for producers. Therefore, correctly identifying species of scarab beetles that are harmful or have potential to become pests of the crop is important. This information is key to developing successful control plans and methods. In addition, study of these species enhances knowledge of their biology, ecology, and diversity.

Scarab beetles (Scarabaeidae "Pleurosticti") are widely distributed in Mexico. They inhabit from sea level to 3,800 m of altitude, in natural and modified vegetation (Morón 1986); some species have become important pests of various crops, such as maize, rice (*Oryza sativa* L.), beans (*Phaseolus vulgaris* L), sugarcane (*Saccharum officinarum* L.), sesame (*Sesamum indicum* L.), agave (*Agave* L.), and coffee (*Coffea arabica* L.). The pest species (white grub) belong to different genera, among the most important for their abundance and frequency are: *Phyllophaga* Harris, *Macrodactylus* Latreille, *Cyclocephala* Dejean, *Anomala* Samouelle, and *Diplotaxis* Kirby (De la Paz et al. 2008, Guzmán-Vásquez and Martínez-Martínez 2020).

In Mexico, the white grub complex associated with maize has been studied mostly in the states of Chiapas, Jalisco, Michoacan, Puebla, and Sinaloa (Gómez et al. 1999, Ramírez-Salinas and Castro-Ramírez 2000, Díaz et al. 2006, Aragón-García et al. 2008, De la Paz et al. 2008, Pérez-Agis et al. 2008, Lugo-García et al. 2012). However, at Oaxaca the only known antecedent is one published by Bravo-Mosqueda (2003) on the diagnosis of white grub in Mixteca and Central Valley regions. Some species of white grub, mostly genera *Phyllophaga, Cyclocephala*, and *Anomala* have been documented in the Central Valleys (Hernández-Cruz et al. 2014; Guzmán-Vásquez 2016, 2018; Guzmán-Vásquez and Hernández-Cruz 2018; Guzmán-Vásquez et al. 2021; Hernández-Cruz et al. 2021). The aim of this study was to contribute to knowledge of the white grub complex and provide information that enables identification of adults associated with maize cultivation and is a basis for future studies at the municipality of Villa de Zaachila, Oaxaca and the region.

## Materials and Methods

The study was in a rainfed plot of maize at the municipality of Villa de Zaachila, Central Valley region of Oaxaca, Mexico (Fig. 1a,b), between coordinates 16° 56' 55" N and 96° 45' 7" W, at an altitude of 1,500 m above sea level. The climate is semi-dry semi-warm (BS0hw). The temperature fluctuates between 16 and 28°C. Rainfall varies between 600 and 800 mm per year (INEGI 2012). Natural vegetation (Tropical Deciduous Forest) (Fig. 1c) has been replaced almost entirely by agricultural activities, livestock, and human settlements. Among the main crops at the municipality are maize, alfalfa (*Medicago sativa* L.), bean, peanut (*Arachis hypogaea* L.), jicama (*Pachyrhizus erosus* [L.] Urb.), pumpkin (*Cucurbita* L.), walnut (*Juglans* L.), tomato (*Solanum lycopersicum* L.), and avocado (*Persea americana* Mill.).

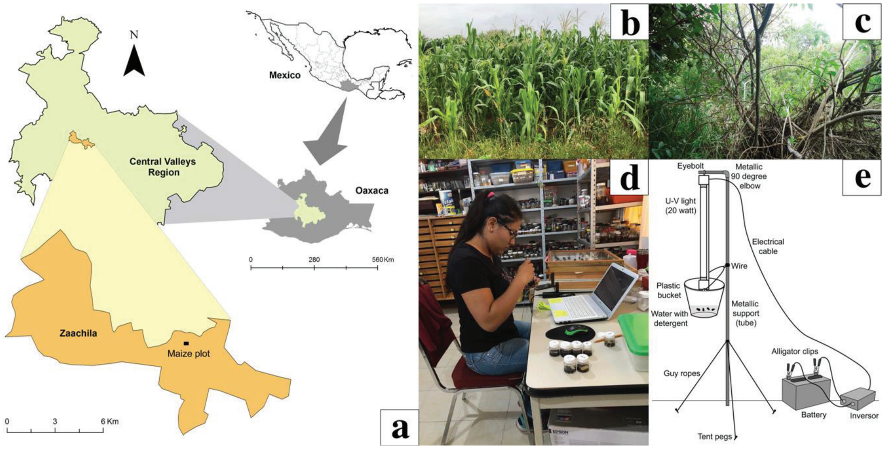


Fig. 1. a) Location of the study area, b) maize plot, c) tropical deciduous forest remnant, d) review of specimens in the insect collection of the CIIDIR-IPN, e) homemade blacklight trap model used to capture adults of the white grub complex in a maize crop at Villa de Zaachila, Oaxaca, Mexico.

Samples were collected monthly from March through August 2018. A blacklight trap with a metal support held a 20-watt UV light tube connected to a car battery by a Steren inverter INV-300. Under the lamp was a collecting bucket with 2 liters of water and approximately 5 g of powdered detergent to break the surface tension so beetles sank when they fell (Fig. 1e). The trap was in the center of the maize plot and used from 1900-2300 hours during 3 nights of the new moon period because there was more darkness and the trap more effectively attracted beetles because of positive phototropism. Specimens were preserved in 70% ethyl alcohol in vials to transport. All specimens were counted and separated by morphospecies (Fig. 1d). Representative samples of 10 specimens of morphospecies were sexed and mounted on entomological pins with labels. Observations were made with the aid of a Zeiss Stemi DV4 stereo-microscope. Taxonomic determination was by keys: Casey (1915), Vaurie (1960), Morón (1986), Delgado et al. (2000), Ratcliffe et al. (2013), Hernández-Cruz et al. (2014), and Guzmán-Vásquez and Martínez-Martínez (2020). Original species descriptions in Bates (1888) were reviewed. The specimens were deposited in the insect collection of Centro Interdisciplinario de Investigación para el Desarrollo Integral Regional Unidad Oaxaca of the Instituto Politécnico Nacional (CIIDIR-IPN). Taxonomic classification in the study used a proposal by Bouchard et al. (2011) that considered Dynastinae, Melolonthinae, and Rutelinae as subfamilies of Scarabaeidae. An annotated checklist of species was prepared based on exhaustive literature review and data from this study.

Photographs of specimens were taken with a Canon Rebel T6 camera mounted on a Zeiss Stemi 508 stereo-microscope using EOS utility 3.10.0 software provided by the manufacturer (Canon, Inc.). Splicing used the focus-stacking technique with the Zerene Stacker 1.04 program, and final images were processed with Adobe Photoshop CC 2020. A map was produced by ArcGis 10.0. The blacklight trap drawing was made with Adobe Illustrator CC 2017.

Richness was estimated as the total number of species, and abundance as the total number of individuals captured monthly throughout the study period. Richness and abundance were compared with precipitation data from the site of the Comisión Nacional del Agua (CONAGUA, smn.conagua.gob.mx) to learn if precipitation affected phenology of the species. A range-abundance curve was used to determine dominance of species. To learn representativeness of each species in a sample, a relative abundance index (RAi) was obtained with the formula:

$$\mathrm{RAi}\ \% = \left(\frac{\mathrm{Ni}}{\sum \mathrm{Ni}}\right) \mathrm{X}\ 100$$

where RAi = relative abundance index, Ni = number of individuals of each species, $\sum \mathrm{Ni}$ = total number of individuals in the sample, and 100 = correction standard factor.

## Results

In total, 1,429 specimens of 12 species in four genera, four tribes, and three subfamilies of Scarabaeidae "Pleurosticti" were collected and reviewed (Tables 1-3). The best represented genus was *Anomala* Samouelle with 1,064 specimens (74.46% of total abundance) of five species (41.67% of total richness): *A. inconstans*

Table 1. Taxonomic Classification of the Scarabaeidae "Pleurosticti" Species Associated with the Maize Crop at Villa de Zaachila, Oaxaca

| Family | Subfamily | Tribe | Genus | Species |
|---|---|---|---|---|
| | Melolonthinae Leach, 1819 | Melolonthini Leach, 1819 | *Phyllophaga* Harris, 1827 | *Phyllophaga chiapensis* (Chapin,1935) |
| | | | | *Phyllophaga lenis* (Horn, 1887) |
| | | | | *Phyllophaga obsoleta* (Blanchard, 1850) |
| | | | | *Phyllophaga ravida* (Blanchard, 1850) |
| | | Diplotaxini Kirby, 1837 | *Diplotaxis* Kirby, 1837 | *Diplotaxis denticeps* Bates, 1887 |
| | | | | *Diplotaxis trapezifera* Bates, 1887 |
| Scarabaeidae Latreille, 1802 | Rutelinae MacLeay, 1819 | Anomalini Streubel, 1839 | *Anomala* Samouelle, 1819 | *Anomala denticollis* Bates 1888 |
| | | | | *Anomala donovani* Stephens, 1830 |
| | | | | *Anomala flavilla* Bates,1888 |
| | | | | *Anomala inconstans* Burmeister,1844 |
| | | | | *Anomala sticticoptera* Blanchard, 1850 |
| | Dynastinae MacLeay, 1819 | Cyclocephalini Laporte, 1840 | *Cyclocephala* Dejean, 1821 | *Cyclocephala lunulata* Burmeister, 1847 |

Burmeister, 1844, *A. donovani* Stephens, 1830, *A. sticticoptera* Blanchard, 1850, *A. denticollis* Bates, 1888, and *A. flavilla* Bates,1888 (Table 1). The most abundant species was *A. flavilla* with 830 individuals (58.08%) of the total, followed by *Phyllophaga lenis* (Horn, 1887) with 225 individuals (15.75%) and *A. sticticoptera* with 94 individuals (6.58%). In contrast, *Diplotaxis denticeps*, *A. donovani*, and *D. trapezifera* were least abundant with nine, seven, and two individuals, respectively (Table 2). Greatest richness was 11 species (91.66%) and abundance was 1,314 individuals (91.95%) in the month of April (Fig. 2, Table 2), followed by May with six species (50%) and 98 individuals (6.85%). In July and August, only one species was obtained with one individual each month.

*Anomala flavilla* and *A. sticticoptera* have new distribution records at Oaxaca (Table 3). According to the range-abundance curve, *A. flavilla* was the dominant species in the white grub complex in the maize crop at Villa de Zaachila (Fig. 3).

Table 2. Monthly Abundance and Richness of Adult Scarab Beetles of the White Grub Complex at Villa de Zaachila, Oaxaca. *Relative abundance index (RAi%)

| Species | March | April | May | June | July | August | Abundance | *RAi % |
|---|---|---|---|---|---|---|---|---|
| *Phyllophaga chiapensis* | - | 46 | 6 | - | - | - | 52 | 3.64 |
| *Phyllophaga lenis* | - | 225 | - | - | - | - | 225 | 15.75 |
| *Phyllophaga obsoleta* | - | 41 | 7 | - | - | - | 48 | 3.36 |
| *Phyllophaga ravida* | - | 15 | - | - | - | - | 15 | 1.05 |
| *Diplotaxis denticeps* | 7 | 2 | - | - | - | - | 9 | 0.63 |
| *Diplotaxis trapezifera* | 2 | - | - | - | - | - | 2 | 0.14 |
| *Anomala denticollis* | - | 64 | 10 | 2 | - | - | 76 | 5.32 |
| *Anomala donovani* | - | 6 | - | - | 1 | - | 7 | 0.49 |
| *Anomala flavilla* | 1 | 783 | 46 | - | - | - | 830 | 58.08 |
| *Anomala inconstans* | - | 44 | 13 | - | - | - | 57 | 3.99 |
| *Anomala sticticoptera* | - | 77 | 16 | - | - | 1 | 94 | 6.58 |
| *Cyclocephala lunulata* | - | 11 | - | 3 | - | - | 14 | 0.98 |
| Total | 10 | 1314 | 98 | 5 | 1 | 1 | 1429 | 100 |
| Richness (Spp.) | 3 | 11 | 6 | 2 | 1 | 1 | | |

Table 3. Annotated Checklist of the Scarab Beetles (Scarabaeidae "Pleurosticti") Associated with Maize Crop at Villa de Zaachila, Oaxaca, Mexico with Data of Distribution, Associated Crops, and References

| Species | Distribution | Associated crop | Reference |
|---|---|---|---|
| *Phyllophaga chiapensis* (Fig. 4a) Elevation: 620-1560 m | Mexico (Chis, Jal, Mich, Oax), Guatemala, Honduras, El Salvador, Costa Rica | Shade-grown coffee, sugar cane | Cano and Morón (1998), Cano (1999), Morón (2003), Morón et al. (2003), Pacheco-Flores et al. (2008), Evans and Smith (2009), Hernández-Cruz et al. (2014), Guzmán-Vásquez and Martínez-Martínez (2020) |
| *Phyllophaga lenis* (Fig. 4b) Elevation: 0-2500 m | USA, Mexico (Chs, Chih, Coah, Col, Gto, Jal, Cdmx, Mich, Mor, Nay, Oax, Pue, SLP, Sin, Son, Ver), Guatemala, Costa Rica | Maize, bean, sugar cane, amaranth, rice, | Morón et al. (1997), Cano (1999), Morón (2003), Morón et al. (2003), Pacheco-Flores et al. (2008), Evans and Smith (2009), Hernández-Cruz et al. (2014), |

| | | | |
|---|---|---|---|
| | | sesame, avocado | Cuate-Mozo et al. (2016a), Zaragoza-Ortega et al. (2016), Lugo-García et al. (2017), Hernández-Cruz et al. (2021) |
| *Phyllophaga obsoleta* (Fig. 4c) Elevation: 30-2667 m | USA, Mexico (Ags, Chis, Gto, Gro, Hgo, Jal, Mex, Mich, Mor, Nay, Oax, Pue, Sin, Tamps, Ver), Guatemala, Belize, Honduras, Nicaragua, El Salvador, Costa Rica, Panama, Colombia, Venezuela | Maize, sugar cane, roselle, amaranth, coffee, potato, broccoli, asparagus, alfalfa, statice, grasses, garlic, cantaloupe, strawberry, avocado | Coto et al. (1995), Shannon and Carballo (1996), Morón et al. (1997), Cano and Morón (1998), Cano (1999), Ramírez-Salinas and Castro-Ramírez (2000), Morón (2003), Morón et al. (2003), Delgado and Márquez (2006), Cano (2007), Pacheco-Flores et al. (2008), Evans and Smith (2009), Pérez-Torres et al. (2009), Hernández-Cruz et al. (2014), Cuate-Mozo et al. (2016a), Zaragoza-Ortega et al. (2016), Lugo-García et al. (2017), Hernández-Cruz et al. (2021) |
| *Phyllophaga ravida* (Fig. 4d) Elevation: 150-2500 m | USA, Mexico (Ags, Cdmx, Chis, Chih, Col, Dgo, Gto, Gro, Hgo, Jal, Mex, Mich, Mor, Nay, Oax, Puebla, Sin, Tlax, Ver), Guatemala, Belize, Costa Rica | Maize, sugar cane, tequila agave, roselle, amaranth, grasses, vegetables, statice | Morón et al. (1997), Cano and Morón (1998), Cano (1999), Ramírez-Salinas and Castro-Ramírez (2000), Morón (2003), Morón et al. (2003), Delgado and Márquez (2006), Cano (2007), Pacheco-Flores et al. (2008), Evans and Smith (2009), Pérez-Torres et al. (2009), Lugo-García et al. (2011b), Hernández-Cruz et al. (2014), Minor and Morón (2016), Cuate-Mozo et al. (2016a), Zaragoza-Ortega et al. (2016), Lugo-García et al. (2017) |
| *Diplotaxis denticeps* (Fig. 4e) Elevation: 2050-3350 m | USA, Mexico (Ags, Chih, Dgo, Cdmx, Mex, Hgo, Jal, Oax, SLP, Tlax, Zac) | Maize | Vaurie (1960), Morón et al. (1997), Morón et al. (2003), Delgado and Márquez (2006), Evans and Smith (2009), Minor and Morón (2016) |
| *Diplotaxis trapezifera* (Fig. 4f) Elevation: 620-1550 m | Mexico (Chis, Col, Dgo, Gro, Jal, Mor, Nay, Oax, SLP, Sin, Ver, Yuc), Guatemala, Belize, Nicaragua, El Salvador, Costa Rica | Tequila agave | Morón et al. (1997), Morón et al. (2003), Pacheco-Flores et al. (2008), Evans and Smith (2009), Lugo-García et al. (2011b) |
| *Anomala denticollis* (Fig. 4g) Elevation: 1500-1800 m | Mexico (Chis, Hgo, Pue, Oax), Guatemala | Maize, amaranth | Morón et al. (1997), Morón et al. (2003), Delgado and Márquez (2006), Pacheco-Flores et al. (2008), Ramírez-Ponce et al. (2009), Cuate-Mozo et al. (2016a), Cuate-Mozo et al. (2016b) |

| | | | |
|---|---|---|---|
| *Anomala donovani* (Fig. 4h) Elevation: 765-1656 m | Mexico (Chis, Col, Mex, Gro, Hgo, Jal, Mich, Mor, Nay, Oax, Pue, SLP, Sin, Son, Tamps, Ver) | Maize, sugar cane | Morón et al (1997), Morón et al (2003), Delgado and Márquez (2006), Muñoz-Hernández et al. (2008), Pacheco-Flores et al. (2008), Cuate-Mozo et al. (2016b) |
| *Anomala flavilla** (Fig. 4i). Elevation 1125-1550 m | Mexico (BCS, Chis, Col, Dgo, Jal, Nay, Sin, Tamps) | Sesame, amaranth | Morón et al. (1997), Morón et al. (2003), Pacheco-Flores et al. (2008), Cuate-Mozo et al. (2016b), Lugo-García et al. (2017) |
| *Anomala inconstans* (Fig. 4j) Elevation: 600-2123 m | Mexico (Chis, Gro, Gto, Hgo, Jal, Mex, Mich, Mor, Nay, Oax, Pue, SLP, Ver), Guatemala, Nicaragua, Costa Rica, Panama, Colombia, Peru, Brazil | Maize, tequila agave, bean, yucca, coffee, statice, gladiola, spikenard, amaranth, loquat | Coto et al. (1995), Morón et al (1997), Ramírez-Salinas and Castro-Ramírez (2000), Morón et al. (2003), Delgado and Márquez (2006), Cano (2007), Pacheco-Flores et al. (2008), Lugo-García et al. (2011b), Rivera-Gasperín et al. (2013), Ratcliffe et al. (2015), Cuate-Mozo et al. (2016a), Cuate-Mozo et al. (2016b), Rodrigues et al. (2019), Hernández-Cruz et al. (2021) |
| *Anomala sticticoptera** (Fig. 4k) Elevation: 700-2242 m | Mexico (Chis, Hgo, Pue, QR, Ver), Belize, Guatemala, Costa Rica | Maize, amaranth. | Morón et al (1997), Ramírez-Salinas and Castro-Ramírez (2000), Morón et al. (2003), Delgado and Márquez (2006), Cano (2007), Pacheco-Flores et al. (2008), Cuate-Mozo et al. (2016a) |
| *Cyclocephala lunulata* Burmeister, 1847 (Fig. 4l) Elevation: 0-2200 m | USA, Mexico (Ags, BCS, Camp, Chis, Coah, Col, Cdmx, Mex, Gto, Gro, Hgo, Jal, Mich, Mor, Nay, Oax, Pue, Qro, QR, SLP, Sin, Son, Tab, Tamps, Ver, Yuc, Zac), Guatemala, Belize, El Salvador, Honduras, Nicaragua, Costa Rica, Panama, Colombia, Venezuela, Guiana, French Guiana, Brazil, Bolivia, Ecuador, Peru, Paraguay, Argentina, Trinidad and Tobago | Maize, amaranth, sesame, tequila agave, mango, guava | Coto et al. (1995), Morón et al. (1997), Morón et al. (2003), Delgado and Márquez (2006), Pacheco-Flores et al. (2008), Lugo-García et al. (2011b), Ratcliffe et al. (2013), Ratcliffe et al. (2015), Cuate-Mozo et al. (2016a), Lugo-García et al. (2017), Guzmán-Vásquez et al. (2021) |

* = New state records. Ags = Aguascalientes, BCS = Baja California Sur, Camp = Campeche, Chis = Chiapas, Chih = Chihuahua, Cdmx = Ciudad de Mexico, Coah = Coahuila, Col = Colima, Dgo = Durango, Mex = Estado de Mexico, Gto = Guanajuato, Gro = Guerrero, Hgo = Hidalgo, Jal = Jalisco, Mich = Michoacan, Mor = Morelos, Nay = Nayarit, Oax = Oaxaca, Pue = Puebla, Qro = Queretaro, QR= Quintana Roo, SLP = San Luis Potosi, Sin = Sinaloa, Son = Sonora, Tab = Tabasco, Tamps = Tamaulipas, Tlax = Tlaxcala, Ver = Veracruz, Yuc = Yucatan, Zac = Zacatecas

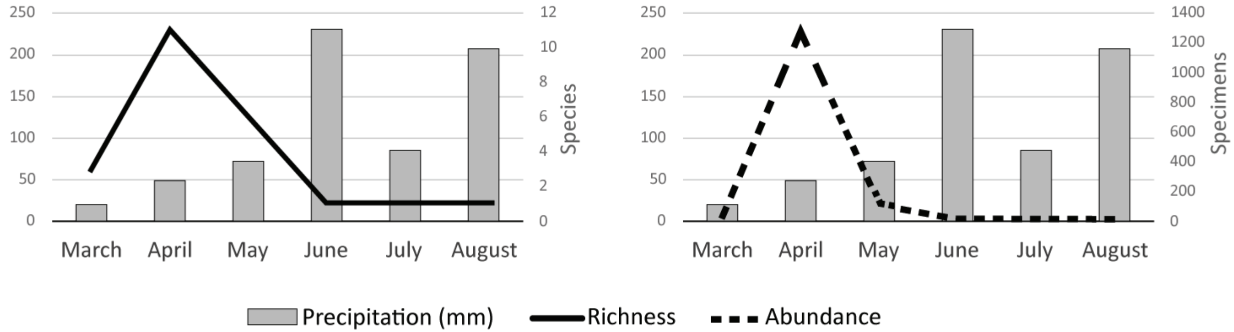


Fig. 2. Richness and abundance of scarab beetles of the white grub complex compared with monthly precipitation (mm) in a maize crop at Villa de Zaachila, Oaxaca.

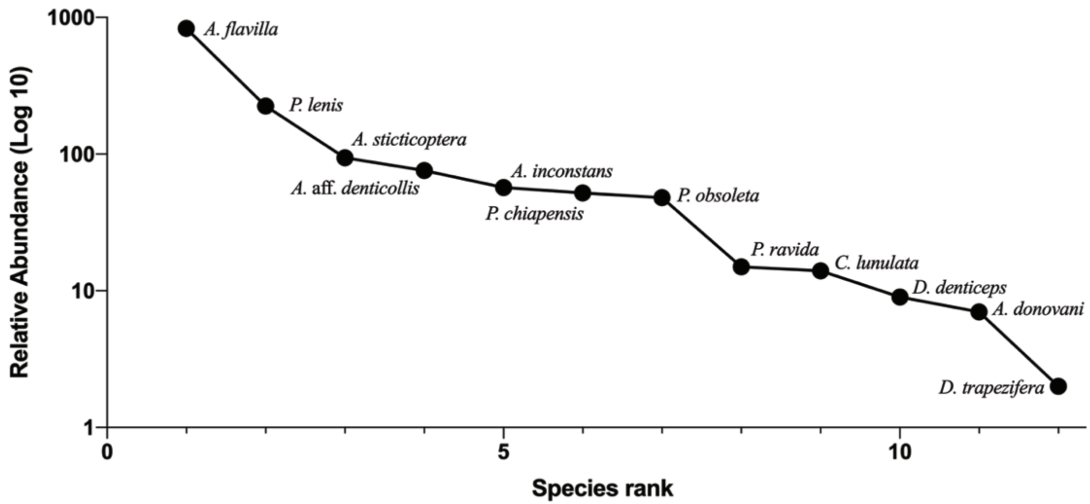


Fig. 3. Rank-abundance curve for adult scarab beetles of the white grub complex associated with a maize crop from March to August 2018 at Villa de Zaachila, Oaxaca, Mexico.

**Key to the adult species of white grub complex (Coleoptera: Scarabaeidae) associated to maize crop in Villa de Zaachila, Oaxaca, Mexico**

1 Meso and metatarsal claws of equal length and shape. Antennae usually with ten segments …………………………………………………………………2

1' Meso and metatarsal claws different in length and shape. Antennae with nine segments ……………………………***Anomala***…………………………………8

2 Males with clearly coarse protarsal claws. Apex of the mandibles visible in dorsal view. Clypeus subtrapezoidal, with the sides converging towards the apex. Pronotum and elytra yellow or straw-colored, usually with reddish-brown macules ………………***Cyclocephala***………………***C. lunulata*** **Burmeister, 1847** (Fig. 4l)

2` Males with non-coarse protarsal claws. Other characters different from the previous option ……………………………………………………………………3

3 Usually, species of medium to large size (length > 10 mm). Procoxae wide, transverse and not very prominent. Pygidium longer than wide ……………………………***Phyllophaga***…………………………………………4

3` Usually, small species (length < 10 mm). Procoxae narrow, conical, and very prominent. Oval pygidium ……………………***Diplotaxis***……………………………… 7

4 Bifid or cleft claws ……………………………………………………………… 5

4` Unidentated claws ……………………………………………………………… 6

5 Slender, elongated, yellow or straw-colored body. Tarsi with abundant ventral setae. Barely evident third protibial tooth. Males with antennal club equal to or slightly shorter than the previous six antennomeres ………………………………………………***P. chiapensis*** **(Chapin, 1935)** (Fig. 4a)

5` Robust dark brown or reddish color body. Tarsi with scarce ventral setae. Evident third protibial tooth. Males with antennal club longer than the previous six antennomeres …………………………***P. obsoleta*** **(Blanchard, 1850)** (Fig. 4c)

6 Males with anal plate with a bidentate process on the anterior border and pygidial plate with abundant short setae. Pronotum with slightly acuminate posterior angles. Dorsal surface dull and setose, yellowish-reddish coloration ……………………………………………………………***P. lenis*** **(Horn, 1887)** (Fig. 4b)

6` Males with anal plate without bidentate process and pygidial plate without setae. Pronotum with strongly acuminate posterior angles. Dorsal surface glabrous and shiny, reddish-brown color ……………………***P. ravida*** **(Blanchard, 1850)** (Fig. 4d)

7 Slender reddish-brown body with dense punctuation. Clypeus apex with four evident teeth, the two middle teeth more prominent than those at the ends ……………………………………………………***D. denticeps*** **Bates, 1887** (Fig. 4e)

7` Slightly robust body, reddish in color, with fine and dense punctuation. Clypeus apex notched in a V shape, with two teeth, one in each anterior angle ……………………………………………………***D. trapezifera*** **Bates, 1887** (Fig. 4 f)

8 Pronotum and elytra of the same color, which can be yellow or straw. Pronotum usually with one or two dark macules. Elytra with or without dark macules …….9

8' Pronotum and elytra of different color. Dark-colored pronotum, without macules. Yellow or straw elytra, usually with small dark spots of irregular shape and size ………………………………………………………………………………10

9 Pronotum with two macules or dark stripes that start at its anterior border and generally extend until before reaching the posterior margin. Yellow or straw-colored elytra. Small species (length < 10 mm) ...***A. flavilla*** **Bates, 1888** (Fig. 4i)

9' Pronotum with a dark macule. Elytra straw colored or sometimes almost totally dark, usually with a macula at the base of each humerus. Large species (length > 10 mm) ……………………………***A. inconstans*** **Burmeister, 1844** (Fig. 4j)

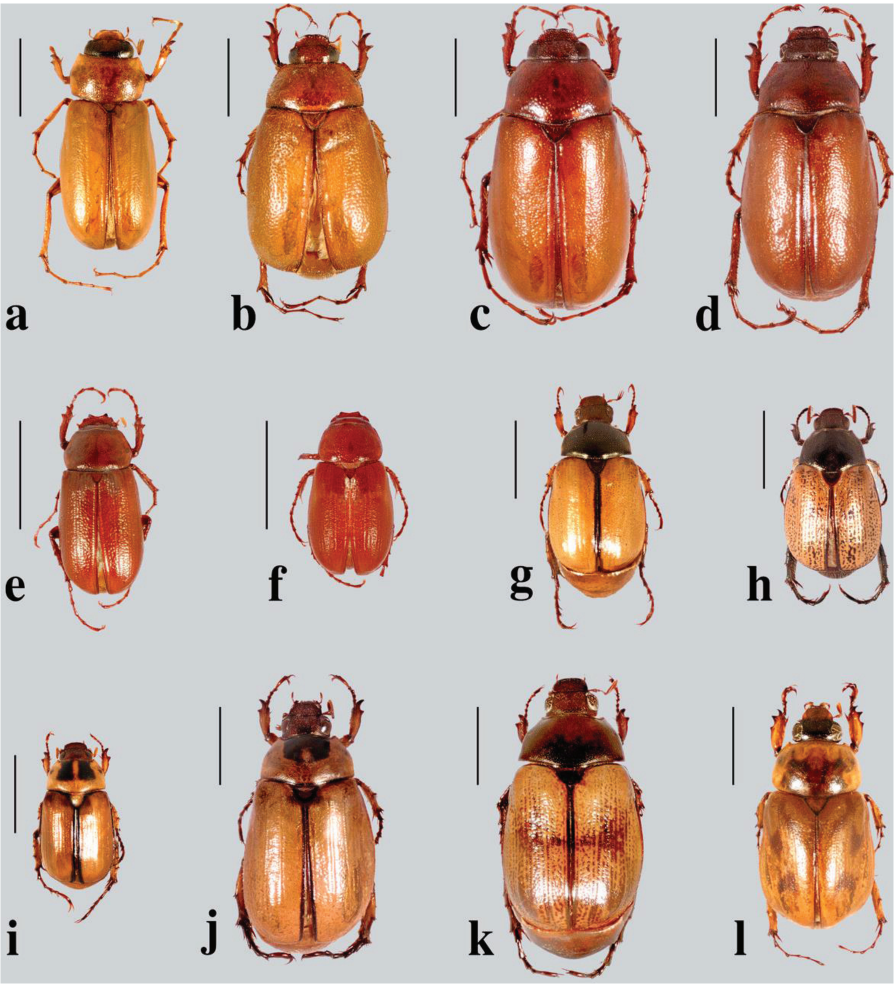


Fig. 4. Adult males of white grub complex associated to maize crop in Villa de Zaachila, Oaxaca, Mexico. a) *Phyllophaga chiapensis*; b) *P. lenis*; c) *P. obsoleta*; d) *P. ravida*; e) *Diplotaxis denticeps*; f) *D. trapezifera*; g) *Anomala denticollis*; h) *A. donovani*; i) *A. flavilla*; j*) A. inconstans*; k) *A. sticticoptera*; l) *Cyclocephala lunulata*. All scale bars = 5 mm.

10 Large species (length > 15 mm). Elytra glabrous, dark reddish or straw-colored, usually with dark asymmetric macules and rows of very marked points. Pygidium without setae ….....……....……….…..…***A. sticticoptera* Blanchard, 1850** (Fig. 4k)

10` Small species (length ≤ 12 mm). Elytra glabrous, dark reddish, yellow, or straw-colored with or without dark macules. Pygidium with setae ……….....................…11

11 Elytra with or without small isolated macules and with irregular rows of very marked dark spots. Pygidial plate covered by abundant short setae and long

setae at the apex. Pronotum 1.5 times wider than its length, dark iridescent in color, with clearly visible punctuation, deep and very dense ……..........................................................***A. donovani* Stephens, 1830** (Fig. 4h)

11\` Elytra generally with diffuse macules on the apex, lateral edges and humerus, surface with rows of very fine points. Pygidial plate only with long setae at the apex. Pronotum almost twice as wide as its length, dark iridescent in color, with very fine and dense punctuation, barely visible, lateral borders with thin, yellowish, and irregular macules …..……..…***A. denticollis* Bates**, **1888** (Fig. 4g)

## Discussion

Twelve species were in the white grub complex associated with maize at Zaachila, Oaxaca. Richness was greater than that reported in similar studies in which seven and 10 species were associated with the maize crop in the states of Chiapas, Jalisco, and Sinaloa (Gómez et al. 1999, Ramirez-Salinas and Castro-Ramirez 2000, Díaz et al. 2006, Lugo-García et al. 2012). This possibly was because irregular topography of the State of Oaxaca allowed diversification, coupled with distribution, ecological preference, and ability of species of white grub to adapt to occupy different environments (Hernández-Cruz et al. 2014, Guzmán-Vásquez et al. 2021). Richness of species in a white grub complex is related to the amount of disturbance or conservation of the habitat (Hernández-Cruz et al. 2014), which coincides with our results because the area studied was very disturbed by agricultural and livestock activities.

*Anomala flavilla* was dominant in the complex, a species that according to Lugo-García et al. (2011a) and Cuate-Mozo et al. (2014) has a facultative philo-rhizophagus habit, so it does not necessarily feed on roots if the soil has enough decomposing organic matter on which to feed. Thus far, it has not been reported as an important pest in Mexico. *Anomala* was the best represented genus in the study, which contrasts with studies where species in the genus *Phyllophaga* were most abundant, representative, and dominant in the white grub complex (Díaz et al. 2006, Aragon-García et al. 2008, Aragón-Sánchez et al. 2018). *P. chiapensis, P. obsoleta, P. lenis, P. ravid*a, and *A. inconstans* have been cited frequently as important agricultural pests in different regions of Mexico (Aragón-García et al. 2005, Lugo-García et al. 2011b, Hernández-Cruz et al. 2014, Guzmán-Vásquez 2016). The presence of such species is a potential risk to the maize crop (Hernández-Cruz et al. 2014). However, in this study except for *P. lenis*, the species were not abundant and were not an obvious risk to the crop. This might be caused by several factors including agroecological management (traditional and low-tech) of the crop which in turn allowed a complex system with different interactions, mainly interspecific for example between pests and controllers (predators and parasitoids) that play an important role in balancing the system. It also is due to preferences and food habits of the beetles, most of them phyto-saprophagous, while larvae are mainly saprophagous, rhizophagous, and only a few are strict rhizophagous. If soil is rich in organic matter, the larvae will have enough food. But, if the quantity and quality of the food decrease, the larvae feed on roots of the crop (Ramírez-Salinas and Castro-Ramírez 2000, Morón et al. 2016, Lugo-García et al. 2017).

Peak richness and abundance were in April, coinciding with the beginning of the rainy season (Fig. 2). This is related to the phenology and duration of the biological cycle of the beetles, which are synchronized with the beginning of the rainy season when adults emerge from pupae and rise to the surface of the soil (Cano

2007, Kirmse and Ratcliffe 2019). They later fly and perch on leaves, stems, and flowers to feed and mate, and the cycle begins again, as documented for species of *Phyllophaga, Anomala*, and *Cyclocephala* (Morón et al. 1997; Ratcliffe et al. 2013; Hernández-Cruz et al. 2016, 2021). Proportional increase in richness and abundance of beetles with increase in rainfall is also because of increased availability of food the following months (Acosta-González et al. 2017). Precipitation and phenology of beetles of the white grub complex at Villa de Zaachila are related.

A dichotomous key is useful for correct identification and determination of adult species of the white grub complex (Guzmán-Vásquez and Martínez-Martínez 2020) associated with the maize crop. The key also can be used in neighboring municipalities with similar physical-environmental and agroecological characteristics.

It is necessary to continue monitoring the maize crop at Villa de Zaachila and other municipalities because, although the species of white grub currently are not a risk to maize production, future populations might increase and exceed the damage threshold. In addition to adults, it is necessary to study immature stages, because knowing interactions that favor their presence, aspects of biology, ecology, birth rate, mortality, population density and dynamics, behavior and eating habits allow integrating adequate controls that do not affect beneficial species or other ecologically important soil organisms (Lugo-García et al. 2017). Studies also are needed in other crops and municipalities or regions to understand and compare associated white grubs, because the species frequently vary by type of soil, crop, vegetation, or land use and physical-environmental variables of each locality or region.

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