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A Rapid Sampling of Ant Assemblages Diagnoses Soil Physicochemical Properties before Planting Chayote Monoculture

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Abstract

Ants respond fast to changes in soil conditions in agricultural fields. Thus, they represent a practical, cheap, clean, and accurate tool to diagnose soil fertility before planting a crop. This study assesses the capacity of richness, occurrence, and activity of ant assemblages to indicate soil physicochemical properties in chayote monoculture in Veracruz, Mexico. Sampling was performed in 15 1-ha plots and was replicated three times from August to October before planting the chayote. Ants were collected using pitfall traps, and the soil properties were texture, density, contents of organic matter (OM), nitrogen (N), phosphorous (P), pH, and electrical conductivity (EC). In total, 20,385 ant workers from 51 species, 28 genera, nine tribes and six subfamilies were collected. Species richness significantly explained the contents of OM, N, and P in a three-week sampling. Species occurrence explained clay percentage in the one-week sampling, N and P contents in the two-week sampling, and percentages of sand and silt in the three-week sampling. Ant activity predicted more soil properties in the one-week sampling than in those that lasted two and three weeks. Richness, occurrence, and activity of ant assemblages are valuable tools for diagnosing texture, OM, N and P contents, and soil pH before planting chayote monoculture. It contributes to understanding the role of ants in agricultural fields. Therefore, soil management practices should consider indication capacity of ant assemblages to ensure growth and development of morphological structures such roots, stems, leaves, shoots, and fruits of cultivated plants.

Introduction

Chayote, *Sechium edule* (Jacq.) Sw. (Cucurbitales: Cucurbitaceae), is a successful vegetable crop of high commercial value, which is grown under a monoculture system (Rodríguez-Larramendi et al., 2017; Vallejo et al., 2018). This important crop was presumably domesticated in central Mexico and Guatemala (Newstrom, 1986) and has a social, economic, cultural, environmental, and nutritious value (Pu et al., 2021). Although it is recently cultivated in North and South America, Southern Asia, Australia, and New Zealand (Rojas-Sandoval, 2022), Mexico is still considered the leading producer worldwide (García-Ramírez, 2021). Notably, great mountains region in central Veracruz State, Mexico have been highlighted as the most important production area (Hernández et al., 2013). For this reason, the assessment of cultivated land is crucial for maximizing yield and profitability of this monoculture.

Chayote crop requires soil with sandy loam texture and low clay percentage, a low bulk density, a pH between 5 and 7, high contents of organic matter (more than 4%) and macronutrients such N (170 – 200 mg/kg), P (100 – 400 mg/kg), and K (180 – 240 mg/kg) (Cadena-Iñiguez et al., 2007; Vazquez-Vargas, 2020). However, fields exhibit significant variations in soil physicochemical properties because they are exposed to high temperatures, frequent irrigation and

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are permanently in use for cropping (Avendaño-Arrazate et al., 2010; Guevara-Hernández et al., 2014). Consequently, producers need to diagnose soil fertility before planting this crop to identify requirement of fertilizer inputs or soil amendments carefully (Watson et al., 2006). The recommended laboratory analyses to assess soil fertility are costly, time-consuming, and produce hazardous waste due to the use of strong acids, strong bases, and other chemical reagents (Benedet et al., 2021). Thus, search, implementation, and evaluation of new alternative tools are needed to diagnose soil properties in a fast, practical, cheap, clean, and accurate manner.

Among the soil fauna, ant (Hymenoptera: Formicidae) species assemblages have been effectively used as indicators since their responses to soil modifications are relatively fast, predictable, and easy to detect and analyze (García-Martínez et al., 2015). They are a group of taxonomically and functionally diverse eusocial insects with dominant biomass and numerical abundance in monocultural production systems worldwide (Hölldobler & Wilson, 1990; Rojas, 2001). They are susceptible to environmental changes and vary as a function of habitat structural complexity (Widhiono et al., 2017). They are particularly useful in assessing agricultural management practices since variations in these assemblages might be related to changes in soil's physical, chemical, and biological properties (Chate, 2022; Ghobadi et al., 2016). In addition, species richness, occurrence, and activity of ant assemblages are measurements easily and inexpensively determined compared to soil properties characterizations (Silva et al., 2017). Based on this evidence, ant assemblages represent a promising tool for use as indicators of soil properties in monocultural cropping systems.

Soil-dwelling ants are perceived as geo-ecosystem engineers (Cammeraat & Risch, 2008). Some species can move and disperse among subterranean stratum, leaf-litter, and surface stratum (Wong & Guénard, 2017) to collect and disperse seeds, fragment litter, cycle nutrients, and regulate soil invertebrate populations (Bagyaraj et al., 2016). They are closely related to soil physical, chemical, and biological properties (Shi et al., 2023; Shukla et al., 2016). For instance, ant colonization and nest construction increase porosity and bulk density (Wang et al., 2019); meanwhile, the accumulation of food, food residues, and excreta of ants in their nests concentrate organic matter, nitrogen, and phosphorus (Frouz & Jilková, 2008). Due to this interplay between soil and ants, this faunistic guild has been considered a noteworthy indicator of soil fertility in agricultural lands.

Using biodiversity measurements of soil ant assemblages as rapid tools for diagnosing soil properties instead of an expensive physicochemical characterization of soil in the laboratory might have important implications for planning planting, production, and yield of chayote crops. Thus, this study aimed to assess the capacity of rapid diversity measures of ant assemblages to indicate soil physicochemical properties in chayote fields in central Veracruz, Mexico. First, we measure richness (the species number), occurrence (the number of times that a given species was collected), and activity (the total number of ant workers) of ant assemblages. Then, we analyze the variation in soil's physical (i.e., texture and density) and chemical properties (i.e., contents of organic matter, N and P, pH, and electrical conductivity). Finally, we assessed if ant assemblages, reflecting different levels of diversity, explained the variation in soil physicochemical properties. We posit that at least a measure diversity of ant assemblages might have a good-fit prediction for some soil physicochemical properties in chayote fields.

Materials and Methods

Study area

The study area is located on the central plain of the Tuxpango Valley in the municipality of Ixtaczoquitlan, Veracruz, Mexico (Figure 1). It experiences a warm, humid climate with a mean annual rainfall and a mean annual temperature of 2199 mm and 20 °C, respectively. The native vegetation is a tropical dry forest, or tropical semi-deciduous forest (Vargas-Rueda et al., 2021). However, the landscape is dominated by a human-use matrix (i.e., cultivated lands and human settlements) (Landero-Torres et al., 2014).

Sampling plot selection and design

In the study area, we randomly selected 15 plots (1 ha) for cultivating the chayote called "smooth green" or *Sechium edule* var. *virens levis* for over ten years. They were separated by a distance ranging from 1 to 8 km, between 771 and 853 m.a.s.l. This experimental unit distribution was shaped by land use patterns and land cover in the study area, the accessibility granted by the producers, and topographical irregularity. Each plot was divided into nine quadrats (≈ 33.33 × 33.33 m), and only five of them, distributed systematically in the center and the four corners of the plot, were used as sampling units. Sampling was conducted before planting to measure levels of specific soil properties that are immediately available and to predict fertilizer needs during the life of this crop. It was replicated three times but with different sampling efforts to assess its potential in applied rapid studies in agricultural areas: a) the first sampling only lasted one week, b) the second sampling lasted two weeks, and c) the third sampling lasted three weeks. We performed six one-week samplings to collect ants. Then, we observed that each one-week sampling provided an incomplete species inventory despite collecting many individuals. For this reason, we decided to group into three sampling with different sampling events (a one-week sampling, a two-week sampling, and a three-week sampling). This conceptual frame could show a pattern of increasing inventory completeness as a function of the number of sampling events in each sampling.

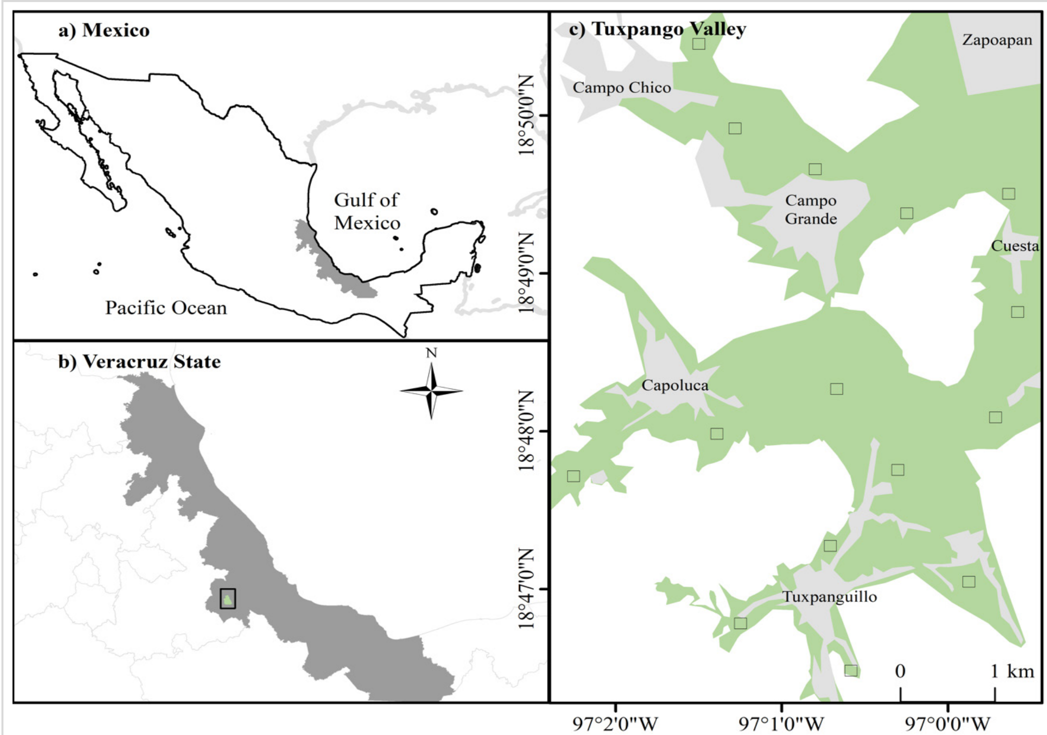

Fig 1. Study fields location in Tuxpango Valley, municipality of Ixtaczoquitlan, Veracruz, Mexico. The location of the study area (c), in the state of Veracruz (b) along with Mexico (a), is indicated in the map. The hollow squares represent the 15 1-ha crop fields before planting chayote where ants and soil were sampled, chayote crop distribution is shown as a green area, and human settlements as light gray area.

Ant sampling

A pitfall trap was set in each sampling unit, consisting of a colorless, cylindrical, plastic container 7.5 cm tall and 10 cm in diameter. This container was filled to one-fourth of its capacity with diluted propylene glycol and buried such that the opening was flush with the ground (Quiroz & Valenzuela, 1995). It was placed beneath a rain cover made from a plastic plate (26 cm diameter) held in place by bolts. All traps were recovered after seven days of exposure in the field. All collected ants were preserved in 100% ethanol, and one to three of the collected specimens per trap that differed morphologically were dry mounted. The key of (Mackay & Mackay, 1989) was used to identify ant genera along with several additional keys for species identification depending on the genus involved. Voucher specimens were deposited in the Ant Collection of the Facultad de Ciencias Biologicas y Agropecuarias Region Orizaba–Cordoba of the Universidad Veracruzana in Peñuela, Amatlan de los Reyes, Veracruz, Mexico.

Soil sampling and properties

In each sampling unit, five soil samples of 100 g were taken using a cylindrical soil corer with a diameter of 5 cm and a height of 10 cm (AccuCore TM) from the upper 10 cm soil layer (SEMARNAT, 2002). The five samples from each sampling unit were mixed to create a composite sample. Each was placed in a zip lock bag (31 x 20 cm), transported to the laboratory, and stored at 4 °C until processing in less than a month after collection. Each composite sample was sieved through a 5 mm mesh to remove stones, roots, litter, large debris, or clumps. These soil composite samples were spread over a tray under shade to air dry and remove excessive moisture at room temperature.

The soil physical properties measured were texture, with the Bouyoucos hydrometer method (percentage of clay, sand, and silt) and soil bulk density, using stainless steel cylinders following (Anderson & Ingram, 1993). The soil chemical properties determined were: 1) organic matter using chromate and sulfuric acid following the method of (Walkley & Black, 1934); 2) total N, which was measured with a CNHS autoanalyzer by pyrolysis and an infrared spectrophotometer (Spectronic, Milton Roy, USA); 3) total P, using sulfuric acid digestion and subsequent colorimetric determination (Bray & Kurtz, 1945); 4) soil pH, measured in H_2O at 1:2 ratio with a pH meter (Oakton Instruments, Vernon Hills, IL, USA); and 5) electrical conductivity, using a 1:5 w/v soil solution suspended in distilled water and a conductivity meter (Oakton Instruments, Vernon Hills, USA).

Data analysis

The total number of ant workers and species occurrences at each plot during each sampling measured ant activity and abundance, respectively (Garcia-Martinez et al., 2018; Longino, 2000). Species occurrences (i.e., the number of times a given species was collected in a pitfall trap during sampling) were considered proxies for relative ant abundance (Longino, 2000). Meanwhile, species richness is not sensitive to species abundances and thus gives disproportionate weight to rare species (Jost, 2006). The inventory completeness for each plot during each sampling was calculated using the sample coverage estimator ($\hat{C}n$), a less biased inventory completeness estimator than nonparametric methods. This estimator indicates the proportion of the "total community" represented by the trapped species, and when $\hat{C}n \approx 100\%$, sampling is complete given the effort and capture technique used (Chao & Jost, 2012). Values of $\hat{C}n$ were calculated using iNEXT package for R (Hsieh et al., 2016). To compare each measure among plots, we used 95% confidence intervals in which non-overlapping confidence intervals indicated significant differences.

We tested whether soil properties varied across plots with linear models. We specified plot as fixed-effect factor, and each soil physical and chemical property as continuous response variable (Bates et al., 2015). A Gaussian error distribution was appropriate for all response variables after testing for normality (Shapiro–Wilk test).

We followed univariate selection procedures for regression-based models to identify the influence of activity, species occurrence, and richness of ant assemblages on soil physical and chemical properties. These models assessed the independent effects of each ant assemblage characteristic on each soil property (i.e., a single univariate regression between a response and a predictor variable). We applied this test for all response variables (i.e., soil properties) after testing for normality (Shapiro–Wilk test). The models' goodness-of-fit was estimated as the proportion of variation in the dependent variable predicted by the statistical model using the coefficient of determination (R^2). The R^2 ranges from 0 to 1 and measures the prediction reliability of an outcome by a statistical model. All analyses were run using the R software version 4.1.3 (R Core Team, 2022).

Results

In total, 20,385 ant workers from 51 species, 28 genera, nine tribes and six subfamilies were collected (Appendix 1). Subfamily Myrmicinae had the highest number of tribes, genera, and species. Genera *Pheidole* had the highest number of species (9 spp.), followed by *Solenopsis* (5 spp.), *Dorymyrmex* (3 spp.), and finally *Atta*, *Eciton*, *Ectatomma*, *Forelius*, *Gnamptogenys*, *Labidus*, *Neivamyrmex*, *Proceratium*, and *Tetramorium* (2 spp.). One species represented the 16 remaining genera. The most common and frequent species collected in the entire study was *Solenopsis geminata* (Fabricius).

A total of 42 species were collected during the first sampling (16% of total individuals), 35 during the second sampling (30.9%), and 51 during the third sampling (53.1%) (Appendix 1). Of 2,365 species occurrences, 17.2% were recorded in the first sampling, 28.5% in the second sampling, and 54.3% in the third sampling (Table 1). The average inventory completeness was 81.6% (range: 65.8 – 88.5%) in the first sampling, 88.3% (range: 79.3 – 95.8%) in the second

Table 1. Diversity measurements of soil ant assemblages collected in crop fields before planting chayote in Tuxpango Valley, Ixtaczoquitlan, Veracruz, Mexico. The estimation of inventory completeness includes 95% confidence intervals.

Plots\Samplings	Inventory completeness			Species richness			Species occurrences			Ant activity		
	1	2	3	1	2	3	1	2	3	1	2	3
1	80.2 ± 0.8	95.8 ± 0.7	97 ± 0.6	12	13	21	24	43	56	170	260	936
2	78.1 ± 0.8	79.3 ± 0.7	92 ± 0.5	12	14	23	27	28	60	217	324	868
3	80 ± 1.2	89 ± 0.9	92.7 ± 0.8	11	18	21	25	54	68	234	412	735
4	78.4 ± 0.6	90.8 ± 0.5	91.4 ± 0.5	16	20	22	37	65	57	231	310	936
5	65.8 ± 1.4	79.6 ± 1.5	87 ± 1	15	13	25	29	39	76	234	412	936
6	84.7 ± 1.5	91.8 ± 1.4	93.7 ± 1.1	14	16	23	31	61	95	207	409	472
7	87.3 ± 2.1	87.7 ± 1.3	89 ± 1.2	9	18	20	23	65	73	118	238	770
8	71.4 ± 1.9	90.6 ± 1.7	96.3 ± 1.5	11	13	17	21	41	80	118	897	976
9	85.7 ± 1.4	92.5 ± 1.2	96 ± 1.1	12	15	18	35	52	74	115	245	480
10	84.5 ± 2.5	92.5 ± 1.6	96.7 ± 1.4	8	16	20	18	53	90	120	259	450
11	88.5 ± 2.8	88.1 ± 2.5	95.9 ± 2.5	10	12	12	26	32	74	304	598	553
12	87.1 ± 3.9	89.8 ± 3.7	97.5 ± 3.4	12	13	15	30	38	120	283	471	566
13	84.3 ± 3.5	83.7 ± 3.1	99.1 ± 3.3	10	12	11	25	29	110	288	349	283
14	86.9 ± 3.6	83.9 ± 3.3	98.2 ± 3.4	12	14	13	30	37	112	317	576	876
15	81.4 ± 3.8	89.2 ± 3.6	99.3 ± 3.2	12	13	15	26	36	140	311	534	987

sampling, and 94.8% (range: 87.0 – 99.3%) in the third sampling. The overall inventory completeness, considering the entire study, was 99%.

Regarding soil physical properties to estimate texture, the percentage of clay (range: 32.67 – 66%), sand (32 – 67.33%), and silt (0 – 13.33) varied significantly among the studied fields (Table 2). Soil bulk density varied from 0.83 to 1.03 g/cm^3. Chemical properties such as organic matter content (1.69 – 5.59%), total N (84.50 – 279.50 mg/kg), total P (92.27 – 257.47 mg/kg), pH (4.60 – 7.39), and electrical conductivity (85.81 – 1,078.43 dS/m) also varied significantly.

In the first sampling, ant species richness did not significantly explain soil property. Species occurrence only significantly explained clay percentage ($t = 2.23$, $P = 0.04$, $R^2 = 0.27$, Fig 2a). Meanwhile, ant activity significantly explained pH ($t = 6.42$, $P < 0.01$, $R^2 = 0.74$, Fig 2b), organic matter content ($t = 4.82$, $P < 0.01$, $R^2 = 0.64$, Fig 2c), total P ($t = 5.60$, $P < 0.01$, $R^2 = 0.70$, Fig 2d), and total N ($t = 5.29$, $P < 0.01$, $R^2 = 0.68$, Fig 2e). In second sampling, species richness and ant activity did not significantly explain any soil property. Species occurrence significantly explained total P ($t = -2.29$, $P = 0.03$, $R^2 = 0.28$, Fig 2f) and total N ($t = -2.18$, $P = 0.04$, $R^2 = 0.26$, Fig 2g). In third sampling, species richness significantly explained organic matter content ($t = -3.53$, $P < 0.01$, $R^2 = 0.48$, Fig 2h), total P ($t = -4.79$, $P < 0.01$, $R^2 = 0.63$, Fig 2i), and total N ($t = -3.45$, $P < 0.01$, $R^2 = 0.47$, Fig 2j). Species occurrence significantly explained organic matter content ($t = 3.29$, $P < 0.01$, $R^2 = 0.45$, Fig 2k), total P ($t = 3.21$, $P < 0.01$, $R^2 = 0.44$, Fig 2l), total N ($t = 2.52$, $P = 0.02$, $R^2 = 0.32$, Fig 2m), sand percentage ($t = 2.24$, $P = 0.04$, $R^2 = 0.27$, Fig 2n), and silt percentage ($t = -2.26$, $P = 0.04$, $R^2 = 0.28$, Fig 2o). Finally, ant activity did not explain any soil property.

Discussion

The current study postulates species richness, species occurrences, and the number of individuals of ant assemblages as valuable tools for predicting or diagnosing texture, contents of organic matter, N and P, and soil pH before planting chayote monoculture. These findings also contribute to understanding the key role of these eusocial insects in tropical areas devoted to vegetable crops and probably other crops. We recorded a diverse myrmecofauna with different resource requirements and optimal environmental conditions due to the reduction of habitat complexity in sampled chayote fields (Batista et al., 2023; Estrada et al., 2023). The frequent disturbances of these crop fields include agrochemical use and removal of native plant species and provoke an oversimplification of available resources and microclimatic conditions (Deguine et al., 2021). For this reason, soil-dwelling ants' reassembly is largely characterized by generalist species with a few or no specific ecological requirements favored by this human activity. In this sense, collecting, sorting, and identifying morphospecies of those generalist ant species may represent a valuable tool for indicating soil properties in these croplands.

Table 2. Soil physicochemical properties (mean ± SD) of crop fields before planting chayote in Tuxpango Valley, Ixtaczoquitlan, Veracruz, Mexico. The estimation of inventory completeness includes 95% confidence intervals.

Plots	Clay (%)	Sand (%)	Silt (%)	Soil bulk density (g/cm^3)	Organic matter (%)	Total N (mg/kg)	Total P (mg/kg)	pH	Electrical conductivity (dS/m)
1	56 ± 3.32	32 ± 3.16	12 ± 2.12	0.83 ± 0.01	1.69 ± 0.32	143 ± 31.89	92.5 ± 5.04	6.61 ± 0.06	255.23 ± 71.09
2	48.67 ± 3.61	38 ± 3.16	13.33 ± 1.87	0.83 ± 0.02	3.12 ± 0.55	162.5 ± 7.85	113.98 ± 111.63	6.41 ± 0.69	376.22 ± 294.45
3	40.67 ± 2	49.33 ± 3.84	10 ± 2	0.87 ± 0.03	3.25 ± 0.97	163 ± 48.44	120.69 ± 45.28	6.44 ± 0.6	130.68 ± 82.08
4	66 ± 3.61	33.33 ± 1.58	0.67 ± 0.71	0.84 ± 0.01	3.26 ± 0.15	136.5 ± 49.48	137.01 ± 10.57	6.6 ± 0.29	730.97 ± 95.94
5	64.67 ± 3.74	32.67 ± 1.58	2.67 ± 1.41	0.88 ± 0.01	3.77 ± 0.89	156 ± 27.66	163.21 ± 141.81	6.62 ± 0.29	221.4 ± 34.28
6	50 ± 3.67	48 ± 4.53	2 ± 1	0.98 ± 0.02	2.86 ± 0.64	188.5 ± 44.33	102.79 ± 28.61	6.36 ± 0.19	310.3 ± 228.85
7	58 ± 4.06	37.33 ± 3.16	4.67 ± 4.06	0.97 ± 0.02	3.64 ± 0.32	182 ± 15.96	143.06 ± 7.25	5.53 ± 0.21	162.87 ± 36.66
8	52 ± 3.54	44.67 ± 2.37	3.33 ± 2.46	0.96 ± 0.04	2.73 ± 0.55	139.17 ± 27.64	254 ± 1.41	4.6 ± 0.29	392.71 ± 371.72
9	56.67 ± 3.74	43.33 ± 3.94	0 ± 0	0.97 ± 0.02	2.34 ± 0.55	117 ± 27.63	254.19 ± 8.21	5.59 ± 0.63	394.57 ± 241.76
10	38 ± 4.37	56.67 ± 3.69	5.33 ± 1.58	0.90 ± 0.04	2.78 ± 0.99	84.5 ± 16.11	257.47 ± 15.95	4.8 ± 0.24	449.4 ± 294.85
11	60 ± 2.92	36 ± 1.58	4 ± 3.16	1.02 ± 0.02	4.88 ± 2.58	279.5 ± 21.06	92.27 ± 5.15	6.96 ± 0.47	1078.43 ± 824.41
12	62.67 ± 3.08	34 ± 3.16	3.33 ± 1.87	1.03 ± 0.02	4.42 ± 0.42	221 ± 21.07	92.5 ± 0.55	6.7 ± 0.22	432.53 ± 285.58
13	55.33 ± 2.24	40.67 ± 2.51	4 ± 1.58	0.91 ± 0.02	5.59 ± 0.42	243.83 ± 128.91	109.22 ± 7.93	7.39 ± 0.35	333 ± 163.63
14	60.67 ± 3.94	39.33 ± 4.12	0 ± 0	0.92 ± 0.02	4.68 ± 0.96	234 ± 47.82	194.53 ± 201.79	6.75 ± 0.21	166.69 ± 106.5
15	32.67 ± 4.3	67.33 ± 2.37	0 ± 0	0.91 ± 0.05	5.08 ± 0.49	254.17 ± 24.8	241.53 ± 159.08	7.07 ± 0.28	85.81 ± 21.76

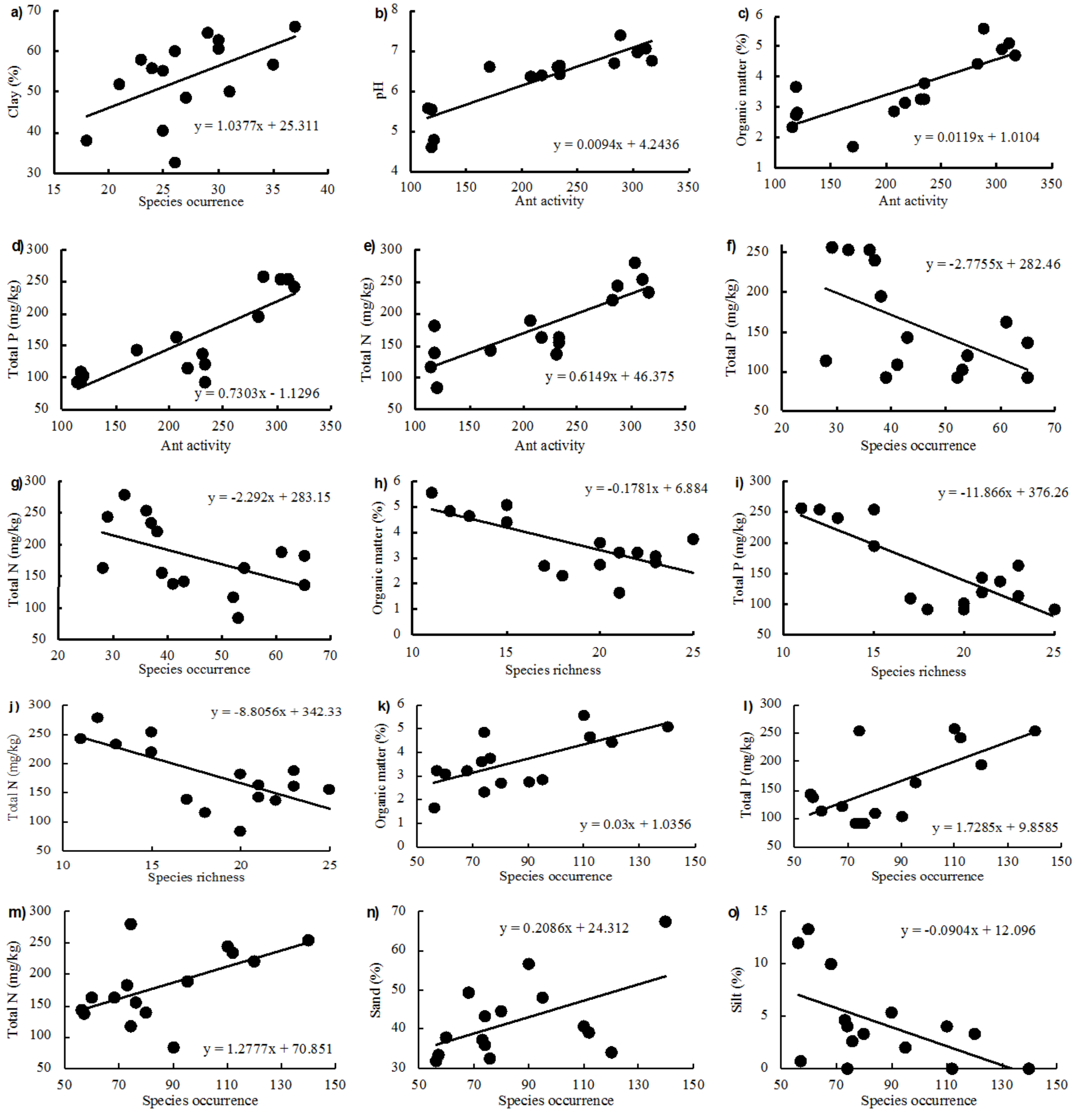

Fig 2. Linear regression models between ant diversity measures and soil properties of 15 1-ha crop fields before planting chayote in Tuxpango Valley, municipality of Ixtaczoquitlan, Veracruz, Mexico. In each model is indicated its regression equation. Sampling effort was of a week (a to e), two weeks (f and g) and three weeks (h to o).

Species richness is a biodiversity measure commonly used to estimate the variety of species in a community, dependent on the recorded number of species (Moore, 2013). In our results, this measure only significantly predicted three soil properties (i.e., organic matter content, total P, and total N) in the third sampling, composed of three sampling weeks. Although this finding was unexpected, it is not surprising since inventory completeness increases as a function of ant sampling duration in the field (Hsieh et al., 2016). However, the low number of predicted soil properties may be related to the fact that none of the ant inventories reached a sample coverage of 100%. Particularly, prediction of organic matter content by species richness of a relatively complete inventory in three-weeks sampling event might be explained by the accumulation of certain ant species (Silva et al., 2017). For instance, some generalist and common species belonging to genera *Pheidole* (Wang et al., 2019), *Solenopsis* (Lafleur et al., 2005; Xi et al., 2010), and *Dorymyrmex* (Pirk et al., 2020). Some species, such as *Pheidole capellini* Emery, *Solenopsis invicta* Buren, and *Dorymyrmex tener* Mayr, have been suggested as indicators of soil organic matter, which, in turn, is associated with available macronutrient content (i.e., N, P, and K)

(Lafleur et al., 2005; Pirk et al., 2020; Wang et al., 2019). This relatively high impact of ant species on crop soils is due to the construction of nests and their higher foraging rates (Wong & Guénard, 2017). Thus, species richness of ant assemblages sheds light on a few soil properties only when inventory completeness is high in chayote crop fields. However, using this measure as a proxy of soil properties requires time and expertise to count 20,385 individuals and identify 51 species.

Using pitfall traps as a sampling technique is undoubtedly biased for estimating ant abundance due to their social behavior (e.g., spatial aggregation, nest location, and foraging trails) (Hacala et al., 2021). In this study, species occurrence was considered a proxy for their abundance, which has been suggested as a more realistic transformation indicating the number of ant nests in the community (Leponce et al., 2004; Longino, 2000). Our results show that this biodiversity measure significantly predicts more soil properties when ant sampling lasts longer. Indeed, species occurrence explains only clay percentage in the one-week sampling, total P and N in the two-week sampling, organic matter, total P and N, and percentages of sand and silt in the three-week sampling. The value of species occurrence to predict the physicochemical soil properties aforementioned (Frouz & Jilková, 2008) lies as much in its capacity to indicate the abundance of ant nests as in the bioengineering process around nests (Diamé et al., 2018; Sankovitz et al., 2019; Santamaría et al., 2020). However, this pattern is more clearly observed in large-scale samplings (Rocha-Ortega & García-Martínez, 2018; Silva et al., 2017) than in small-scale ones (Jacquemin et al., 2012). Given such a scenario, ant species occurrence represents a much more useful measure to diagnose crop soils' chemical and physical quality only when ant sampling effort is extensive in time and space.

Ant activity has been commonly considered a measure of the number of ant workers captured by pitfall traps in agricultural settings (Garcia-Martinez et al., 2018; Lasmar et al., 2017). It is mainly driven by the ants' locomotion, colony size, and avoidance of traps (A.N. Anderson, 1983; Bestelmeyer et al., 2000; Ivanov & Keiper, 2009). This study shows that ant activity predicted more soil properties in the first sampling of a week than in the second and third samplings, which lasted two and three weeks, respectively. This observed pattern is likely explained by the digging-in effect (Greenslade, 1973), which consists of exponential catches of ant workers in pitfall traps during the first days following installation. High captures of ant workers during the first sampling may be due to pitfall traps penetrating nest galleries or being set on foraging trails. Subsequently, ant workers explore territory when they identify microhabitat perturbations (Greenslade, 1973), and they are attracted to carbon dioxide emissions produced by dug soil (Schirmel et al., 2010).

Regarding the decrease in worker captures in samplings of more than a week, the most likely explanation is colony depletion (Greenslade, 1973). For several diversity studies, the number of ant workers is not a realistic diversity measure because this effect represents a disproportionate sampling bias (Jiménez-Carmona et al., 2019; Lasmar et al., 2017). However, this promising finding suggests that with a single, easy, rapid, and affordable count of the number of ant workers (not their identification) in a one-week sampling, producers or farm managers might diagnose pH, organic matter content, total P, and total N in the soil of crop fields.

This study provides evidence that the measurement of activity, abundance, and richness of edaphic ant assemblages doubtless have potential applications in the diagnosis and/or prediction of soil properties before planting chayote monoculture and likely other crops. We showed that ant activity indicates more chemical soil properties in a rapid sampling of only a week. In contrast, species occurrence indicates physical and chemical properties in a three-week sampling. We found that the ant activity, measured as several collected individuals, is helpful to indicate the most important soil properties (pH and contents of organic matter, N and P) for chayote crops. These results highlight the importance of ants as indicators of soil physicochemical properties over costly and time-consuming laboratory analyses to assess soil fertility. Understanding the indication capacity of ant assemblages of physical properties is crucial to assessing soil workability (the ease of tillage in the field), water and air retention, and hydraulic conductivity. Suppose ant assemblages predict soil chemical properties over short periods. In that case, a producer might have an overview of soil viability regarding pH and bioavailability of contents of organic matter and macronutrients for optimal crop nutrition. Since the use of measures of ant assemblages has a valuable role in diagnosing soil properties, crop management practices might include it to ensure the growth and development of morphological structures such as roots, stems, leaves, shoots, and fruits of cultivated plants.

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Authors' Contribution

R Sánchez-Gregorio and MA García-Martínez designed the experiment, performed experiments and analysis, and wrote the paper. YA Gheno-Heredia and NB Zilli-Ponce helped perform experiments and prepare the paper.

References

Anderson, A.N. (1983). Species diversity and temporal distribution of ants in the semi-arid mallee region of northwestern Victoria. Australian Journal of Ecology, 8: 127-137. https://doi.org/10.1111/j.1442-9993.1983.tb01600.x

Anderson, J.M. & Ingram, J.S.I. (1993). Tropical Soil Biology and Fertility: A Handbook of Methods. C.A.B. International. https://doi.org/10.2307/2261129

Avendaño-Arrazate, C.H., Cadena-Iñiguez, J., Arévalo Galarza, M. de L.C., Campos Rojas, E., Cisneros Solano, V.M. & Aguirre Medina, J.F. (2010). Las variedades del chayote mexicano, recurso ancestral con potencial de comercialización. In Grupo interdisciplinario de investigación en *Sechium edule* en México. A.C.

Bagyaraj, D.J., Nethravathi, C.J. & Nitin, K.S. (2016). Soil biodiversity and arthropods: Role in soil fertility. In Economic and Ecological Significance of Arthropods in Diversified Ecosystems: Sustaining Regulatory Mechanisms. https://doi.org/10.1007/978-981-10-1524-3_2

Bates, D., Mächler, M., Bolker, B. & Walker, S. (2015). Fitting linear mixed-effects models using lme4. Journal of Statistical Software, 67: 1-48. https://doi.org/10.18637/jss.v067.i01

Batista, I., Machado, D.L., Correia, M.E.F., Spinelli, M.H. M. & Corá, J.E. (2023). Soil macrofauna correlations with soil chemical and physical properties and crop sequences under no-tillage. Revista Brasileira de Ciência Do Solo, 47: e0230006.

Benedet, L., Acuña-Guzman, S.F., Faria, W.M., Silva, S.H.G., Mancini, M., Teixeira, A.F. dos S., Pierangeli, L.M.P., Acerbi Júnior, F.W., Gomide, L.R., Pádua Júnior, A.L., Souza, I.A. de, de Menezes, M.D., Marques, J.J., Guilherme, L.R.G. & Curi, N. (2021). Rapid soil fertility prediction using X-ray fluorescence data and machine learning algorithms. Catena, 197. https://doi.org/10.1016/j.catena.2020.105003

Bestelmeyer, B.T., Agosti, D., Leeanne, F., Alonso, T., Brandão, C.R.F., Brown, W.L., Delabie, J.H.C. & Silvestre, R. (2000). Field techniques for the study of ground-living ants: an overview, description, and evaluation. In D. Agosti, J.D. Majer, A. Tennant & T. Schultz (Eds.), Field techniques for the study of ground-living ants: an overview, description, and evaluation (1st ed., pp. 122-144). Smithsonian Institution Press.

Bray, R.H. & Kurtz, L.T. (1945). Determination of total, organic, and available forms of phosphorus in soils. Soil Science, 59: 39-45. https://doi.org/10.1097/00010694-194501000-00006

Cadena-Iñiguez, J., Arévalo-Galarza, L., Soto-Hernandez, M. & Avendaño-Arrazate, C. H. (2007). Production, genetics, postharvest management and pharmacological characteristics of *Sechium edule* (Jacq.) Sw. Fresh Produce, 1: 41-53.

Cammeraat, E.L.H. & Risch, A.C. (2008). The impact of ants on mineral soil properties and processes at different spatial scales. Journal of Applied Entomology, 132: 285-294. https://doi.org/10.1111/j.1439-0418.2008.01281.x

Chao, A. & Jost, L. (2012). Coverage-based rarefaction and extrapolation: Standardizing samples by completeness rather than size. Ecology, 93: 2533-2547. https://doi.org/10.1890/11-1952.1

Chate, S. (2022). Correlations between soil properties and ant population in agricultural habitat at Aurangabad Maharashtra, India. Applied Ecology and Environmental Research, 20: 1103-1111. https://doi.org/10.15666/aeer/2002_11031111

Deguine, J.P., Aubertot, J.N., Flor, R.J., Lescourret, F., Wyckhuys, K.A.G. & Ratnadass, A. (2021). Integrated pest management: good intentions, hard realities. A review. In Agronomy for Sustainable Development, 41:38. https://doi.org/10.1007/s13593-021-00689-w

Diamé, L., Rey, J.-Y., Vayssières, J.-F., Grechi, I., Chailleux, A. & Diarra, K. (2018). Ants: Major functional elements in fruit agro-ecosystems and biological control agents. Sustainability, 10: 1-18. https://doi.org/10.3390/su10010023

Estrada, M.A., Pereira, J.R., Almeida, Â.A. de, Vargas, A.B. & Almeida, F.S. (2023). Ant functional groups and their effects on other insects in organic and conventional cropping areas. EntomoBrasilis, 16: e1018. https://doi.org/10.12741/ebrasilis.v16.e1018

Frouz, J. & Jilková, V. (2008). The effect of ants on soil properties and processes (Hymenoptera: Formicidae). Myrmecological News, 11: 191-199.

Garcia-Martinez, M.A., Presa-Parra, E., Valenzuela-González, J.E. & Lasa, R. (2018). The fruit fly lure ceratrap: An effective tool for the study of the arboreal ant fauna (Hymenoptera: Formicidae). Journal of Insect Science, 18: 1-6. https://doi.org/10.1093/jisesa/iey078

García-Martínez, M., Martínez-Tlapa, D.L., Pérez-Toledo, G.R., Quiroz-Robledo, L.N., Castaño-Meneses, G., Laborde, J. & Valenzuela-González, J.E. (2015). Taxonomic, species and functional group diversity of ants in a tropical anthropogenic landscape. Tropical Conservation Science, 8: 1017-1032. https://doi.org/10.1177/194008291500800412

García-Ramírez, E.J. (2021). Efectividad in vitro de fungicidas naturales en el control de enfermedades postcosecha de chayote. In Doctoral dissertation. Colegio de Postgraduados.

Ghobadi, M., Agosti, D., Mahdavi, M., Jouri, M.H. & Majer, J. (2016). Ants visible from space influence soil propertes and vegetaton in steppe rangelands of Iran. Sociobiology, 63: 063-1068. https://doi.org/10.13102/sociobiology.v63i4.1195

Greenslade, P.J.M. (1973). Sampling ants with pitfall traps: Digging-in effects. Insectes Sociaux, 20. https://doi.org/10.1007/BF02226087

Guevara-Hernández, F., Rodríguez-Larramendi, L., Gómez-Castro, H., Pinto-Ruiz, R., Rodríguez-Galván, G., & Perezgrovas Garza, R.A. (2014). Criterios locales para selección de semillas de chayote (*Sechium edule* Jacq. Sw.) en zonas rurales de Chiapas, México. Acta Agronómica, 64: 343-353. https://doi.org/10.15446/acag.v64n2.39776

Hacala, A., Gouraud, C., Dekoninck, W. & Pétillon, J. (2021). Relative efficiency of pitfall vs. bait trapping for capturing taxonomic and functional diversities of ant assemblages in temperate heathlands. Insects, 12: 307. https://doi.org/10.3390/insects12040307

Hernández, G.O., Ponce, G.V., Íñiguez, J.C. & Galarza, M. de L.A. (2013). Etiología de la Marchitez de Plantas de Chayote (Sechium edule) en el Estado de Veracruz. Revista Mexicana de Fitopatología, 31: 161-169.

Hölldobler, B. & Wilson, E.O. (1990). The Ants. In Harvard University Press (Vol. N1). http://www.amazon.co.uk/Ants-Bert-H?lldobler/dp/3540520929

Hsieh, T.C., Ma, K.H. & Chao, A. (2016). iNEXT: an R package for rarefaction and extrapolation of species diversity (Hill numbers). Methods in Ecology and Evolution, 7: 1451-1456. https://doi.org/10.1111/2041-210X.12613

Ivanov, K. & Keiper, J. (2009). Effectiveness and biases of winkler litter extraction and pitfall trapping for collecting ground-dwelling ants in northern temperate forests. Environmental Entomology, 38: 1724-1736. https://doi.org/10.1603/022.038.0626

Jacquemin, J., Drouet, T., Delsinne, T., Roisin, Y. & Leponce, M. (2012). Soil properties only weakly affect subterranean ant distribution at small spatial scales. Applied Soil Ecology, 62: 163-169. https://doi.org/10.1016/j.apsoil.2012.08.008

Jiménez-Carmona, F., Carpintero, S. & Reyes-López, J.L. (2019). The digging-in effect on ant studies with pitfall traps: influence of type of habitat and sampling time. Entomologia Experimentalis et Applicata, 167: 906-914. https://doi.org/10.1111/eea.12834

Jost, L. (2006). Entropy and diversity. Oikos, 113: 363-375. https://doi.org/10.1111/j.2006.0030-1299.14714.x

Lafleur, B., Hooper-Bùi, L.M., Mumma, E.P. & Geaghan, J.P. (2005). Soil fertility and plant growth in soils from pine forests and plantations: Effect of invasive red imported fire ants Solenopsis invicta (Buren). Pedobiologia, 49: 415-423 https://doi.org/10.1016/j.pedobi.2005.05.002

Landero-Torres, I., Madrid-Ñeco, I., Valenzuela-González, J.E., Galindo-Tovar, M.E., Leyva-Ovalle, O.R., Murguía-González, J., Lee-Espinosa, H.E. & Garcia-Martinez, M.Á. (2014). Myrmecofauna from Three Ornamental Agroecosystems with Different Management and a Forest Remnant in Ixtaczoquitlán, Veracruz, Mexico. Southwestern Entomologist, 39: 783-796. https://doi.org/10.3958/059.039.0409

Lasmar, C.J., Queiroz, A.C.M., Rabello, A.M., Feitosa, R.M., Canedo-Júnior, E.O., Schmidt, F.A., Cuissi, R.G. & Ribas, C.R. (2017). Testing the effect of pitfall-trap installation on ant sampling. Insectes Sociaux, 64: 445-451. https://doi.org/10.1007/s00040-017-0558-7

Leponce, M., Theunis, L., Delabie, J.H.C. & Roisin, Y. (2004). Scale dependence of diversity measures in a leaf-litter ant assemblage. Ecography, 27: 253-267. https://doi.org/10.1111/j.0906-7590.2004.03715.x

Longino, J. T. (2000). What to do with the data. In D. Agosti, J. Majer, E. Alonso & T. R. Schultz (Eds.), Ants: standard methods for measuring and monitoring biodiversity (1st ed., Vol. 1, pp. 186-203). Smithsonian Institution Press.

Mackay, W.P. & Mackay, E. (1989). Clave de los géneros de hormigas en México. In L.N. Quiroz-Robledo & M.P. Garduño-Hernández (Eds.), Memorias del II Simposio Nacional de Insectos Sociales (pp. 1-82). Sociedad Mexicana de Entomología.

Moore, J.C. (2013). Diversity, Taxonomic versus Functional. In Encyclopedia of Biodiversity: Second Edition. https://doi.org/10.1016/B978-0-12-384719-5.00036-8

Newstrom, L.E. (1986). Studies in the origin and evolution of chayote, Sechium edule (Jacq.) Sw. (Cucurbitaceae) (Mexico, Costa Rica, Guatemala) [University of California, Berkley]. In Doctoral dissertation. https://search.proquest.com/docview/303395375?accountid=27575

Pirk, G.I., Elizalde, L., Lescano, M.N. & Werenkraut, V. (2020). Essential but invisible: non-apparent but widespread ant nests favour soil nutrients and plant growth in semi-arid areas. Ecological Entomology, 45: 1408-1417 https://doi.org/10.1111/een.12925

Pu, Y.T., Luo, Q., Wen, L.H., Li, Y.R., Meng, P.H., Wang, X.J. & Tan, G.F. (2021). Origin, Evolution, Breeding, and Omics of Chayote, an Important Cucurbitaceae Vegetable Crop. Frontiers in Plant Science, 12: 739091 https://doi.org/10.3389/fpls.2021.739091

Quiroz, R.L. & Valenzuela, G.J. (1995). A comparison of ground ant communities in a tropical rainforest and adjacent grassland in Los Tuxtlas, Veracruz, Mexico. *S*outhwestern Entomologist, 20: 203-213.

R Core Team. (2022). R: A language and environment for statistical computing. In R Foundation for Statistical Computing.

Rocha-Ortega, M. & García-Martínez, M. (2018). Importance of Nesting Resources and Soil Conditions for the Recovery of Ant Diversity During Secondary Succession in a Tropical Rainforest. Tropical Conservation Science, 11: 1-14. https://doi.org/10.1177/1940082918787063

Rodríguez-Larramendi, L.A., Guevara-Hernández, F., Saldaña, R.A.C., Salas-Marina, M.Á., Gómez-Castañeda, J.C., De Los

Ángeles Fonseca-Flores, M., Valle-Ruíz, L. & Basterrechea-Bermejo, J. (2017). Traditional knowledge on integrated pest and weed management in chayote (*Sechium edule* (Jacq.) Sw.) crops from localities of Chiapas, Mexico. Acta Agronomica, 66: 466-472. https://doi.org/10.15446/acag.v66n4.57294

Rojas-Sandoval, J. (2022). Sechium edule (chayote) - Invasive species, Host plant, Crop. CABI Compendium, CABI Compe. https://doi.org/10.1079/cabicompendium.49493

Rojas, P. (2001). Las hormigas del suelo en México: Diversidad, distribución e importancia (Hymenoptera: Formicidae). Acta Zoológica Mexicana, 1: 238. https://doi.org/10.21829/azm.2001.8401851

Sankovitz, M.A., Breed, M.D. & McCreery, H.F. (2019). Effects of Formica podzolica ant colonies on soil moisture, nitrogen, and plant communities near nests. Ecological Entomology, 44: 71-80. https://doi.org/10.1111/een.12677

Santamaría, C., Lachaud, J.P. & Armbrecht, I. (2020). Effects of nest building by the dominant hunting ant, Ectatomma sp. 2 (E. ruidum complex), on Andean coffee plantations. Pedobiologia, 79: 150626. https://doi.org/10.1016/j.pedobi.2020.150626

Schirmel, J., Lenze, S., Katzmann, D. & Buchholz, S. (2010). Capture efficiency of pitfall traps is highly affected by sampling interval. Entomologia Experimentalis et Applicata, 136: 206-210. https://doi.org/10.1111/j.1570-7458.2010.01020.x

SEMARNAT. (2002). Secretaría de Medio Ambiente y Recursos Naturales. Norma Oficial Mexicana NOM-021-RECNAT-2000, Que establece las especificaciones de fertilidad, salinidad y clasificación de suelos. Estudios, muestreo y análisis. Diario Oficial de La Federación, 1-67. http://dof.gob.mx/nota_detalle.php?codigo=717582&fecha=31/12/2002

Shi, L., Liu, F. & Peng, L. (2023). Impact of Red Imported Fire Ant Nest-Building on Soil Properties and Bacterial Communities in Different Habitats. Animals, 13: 2026. https://doi.org/10.3390/ani13122026

Shukla, R.K., Singh, H. & Rastogi, N. (2016). How effective are disturbance – tolerant, agroecosystem – nesting ant species in improving soil fertility and crop yield? Applied Soil Ecology, 108: 156-164. https://doi.org/10.1016/j.apsoil.2016.08.013

Silva, E.F., Corá, J.E., Harada, A.Y. & Sampaio, I.B. M. (2017). Association of the occurrence of ant species (Hymenoptera: Formicidae) with soil attributes, vegetation, and climate in the brazilian savanna northeastern region. Sociobiology, 64: 442-450. https://doi.org/10.13102/sociobiology.v64i4.1209

Vallejo, V.E., Afanador, L.N., Hernández, M.A. & Parra, D.C. (2018). Efecto de la implementación de diferentes sistemas agrícolas sobre la calidad del suelo en el municipio de cachipay, cundinamarca, colombia. Bioagro, 30: 27-38.

Vargas-Rueda, A.F., Rivera-Hernández, J.E., Álvarez-Aquino, C., Salas-Morales, S.H., Alcántara-Salinas, G. & Antonio Pérez-Sato, Y. (2021). Floristic composition of disturbed tropical montane cloud forest and its ecotones in the National Park Cañón del Río Blanco, Veracruz, Mexico. Acta Botanica Mexicana, 128: 1-37. https://doi.org/10.21829/abm128.2021.1715

Vazquez-Vargas, A.M. (2020). Diseño de un sistema de riego y fertirriego por goteo para chile dulce (Capsicum annuum) y para un área experimental de chayote (Sechium edule) en Santiago, Paraiso, Cartago. Tecnologico de Costa Rica, 1: 1-125.

Walkley, A. & Black, I.A. (1934). An examination of the method for determing soil organic matter and a proposed modification of the chromic acid method. Soil Science, 37: 29-38.

Wang, S., Li, J., Zhang, Z., Chen, M., Li, S. & Cao, R. (2019). Feeding-strategy effect of Pheidole ants on microbial carbon and physicochemical properties in tropical forest soils. Applied Soil Ecology, 133: 177-185. https://doi.org/10.1016/j.apsoil.2018.10.006

Watson, C.A., Atkinson, D., Gosling, P., Jackson, L.R., & Rayns, F.W. (2006). Managing soil fertility in organic farming systems. Soil Use and Management, 18: 239-247. https://doi.org/10.1111/j.1475-2743.2002.tb00265.x

Widhiono, I., Pandhani, R.D., Darsono, Riwidiharso, E., Santoso, S. & Prayoga, L. (2017). Ant (Hymenoptera: Formicidae) diversity as bioindicator of agroecosystem health in northern slope of mount slamet, central java, Indonesia. Biodiversitas, 18: 1481-1486. https://doi.org/10.13057/biodiv/d180425

Wong, M.K.L. & Guénard, B. (2017). Subterranean ants: Summary and perspectives on field sampling methods, with notes on diversity and ecology (Hymenoptera: Formicidae). Myrmecological News, 25: 1-16.

Xi, Y.B., Lu, Y.-Y., Zeng, L. & Liang, G. (2010). Influence of Solenopsis invicta Buren on the physical and chemical properties of soils in litchi orchards. [in Chinese]. Natural Enemies of Insects, 2010.

Appendix 1. Soil myrmecofauna associated with crop fields before planting chayote in Tuxpango Valley, Ixtaczoquitlan, Veracruz, Mexico. The numbers indicate the observed species occurrences.

Ant species \ Samplings	First	Second	Third
Subfamily Dolichoderinae Forel			
Tribe Leptomyrmecini Emery			
1. *Dorymyrmex bicolor* Wheeler, 1906	17	17	53
2. *Dorymyrmex flavus* McCook, 1880	22	25	67
3. *Dorymyrmex insanus* (Buckley, 1866)	6	10	20
4. *Forelius damiani* Guerrero & Fernández, 2008	8	6	38
5. *Forelius pruinosus* (Roger, 1863)	9	8	61
6. *Linepithema dispertitum* (Forel, 1885)	12	19	44
Subfamily Dorylinae Leach			
Tribe Dorylini Leach			
7. *Neivamyrmex mandibularis* (Smith)	0	2	5
8. *Neivamyrmex tristis* (Forel)	0	3	3
9. *Nomamyrmex esenbeckii* (Westwood)	0	9	17
Tribe *Insertae sedis*			
10. *Eciton burchellii* (Westwood, 1842)	2	3	7
11. *Eciton vagans* (Olivier)	0	1	4
12. *Labidus coecus* (Latreille, 1802)	0	14	20
13. *Labidus praedator* (Smith, 1858)	2	13	25
Subfamily Ectatomminae Emery			
Tribe Ectatommini Emery			
14. *Ectatomma ruidum* (Roger, 1860)	12	17	34
15. *Ectatomma tuberculatum* (Olivier, 1792)	3	4	5
16. *Gnamptogenys bisulca* Kempf & Brown, 1968	6	4	12
17. *Gnamptogenys striatula* Mayr, 1884	6	5	14
Subfamily Myrmicinae Lepeletier			
Tribe Attini Smith			
18. *Acromyrmex octospinosus* (Reich, 1793)	2	12	33
19. *Apterostigma mexicanum* Lattke	8	3	11
20. *Atta cephalotes* (Linnaeus, 1758)	0	7	7
21. *Atta mexicana* (Smith, 1858)	2	18	23
22. *Cyphomyrmex rimosus* (Spinola, 1851)	5	5	8
23. *Mycetophylax andersoni* (MacKay & Serna, 2010)	15	16	18
24. *Mycocepurus smithii* (Forel, 1893)	3	8	4
25. *Pheidole albipes* Wilson, 2003	6	10	11
26. *Pheidole anastasii* Emery	10	19	26
27. *Pheidole gangamon* Wilson, 2003	15	17	26
28. *Pheidole mooreorum* Wilson, 2003	9	18	27
29. *Pheidole obtusopilosa* Mayr, 1887	11	17	28
30. *Pheidole punctatissima* Mayr, 1870	24	22	59
31. *Pheidole sabina* Wilson	7	13	16
32. *Pheidole* sp.	10	9	17
33. *Pheidole subarmata* Mayr, 1884	15	10	28
34. *Strumigenys margaritae* Forel, 1893	0	2	7
35. *Wasmannia auropunctata* (Roger, 1863)	10	9	12
Tribe Crematogastrini Forel			
36. *Cardiocondyla emeryi* Forel, 1881	16	26	44
37. *Carebara* sp.	3	25	28
38. *Tetramorium bicarinatum* (Nylander, 1846)	9	18	23
39. *Tetramorium spinosum* (Pergande, 1896)	0	0	2
Tribe Solenopsidini Forel			
40. *Megalomyrmex silvestrii* Wheeler	20	19	30
41. *Solenopsis azteca* Forel	7	10	36
42. *Solenopsis castor* Forel, 1893	2	7	15
43. *Solenopsis geminata* (Fabricius, 1804)	57	111	154
44. *Solenopsis picea* Emery, 1896	9	13	27
45. *Solenopsis* sp.	6	14	53
Subfamily Ponerinae Lepeletier			
Tribe Ponerini Lepeletier			
46. *Leptogenys quiriguana* Wheeler, 1923	0	8	9
47. *Neoponera apicalis* (Latreille)	6	7	16
48. *Odontomachus laticeps* Roger, 1861	4	12	20
49. *Pachycondyla harpax* (Fabricius, 1804)	6	8	12
Subfamily Proceratiinae Emery			
Tribe Proceratiini Emery			
50. *Proceratium mancum* Mann	3	19	21
51. *Proceratium mexicanum* De Andrade	2	1	5