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Arthropod fauna and rats in organic sugarcane in Tahiti

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Abstract

As organic sugarcane is promised to an important development in French Polynesia thank to the high-quality rum produced in this part of the world, preliminary studies on main biotic constraints were conducted on this crop between 2018 and 2021 to better apprehend their control. Visual observations at regular intervals and captures using different types of traps were carried out to collect and identify the arthropod fauna in Tahiti Island. With no surprise, stemborer insects were the most important pests of sugarcane in these different areas. We were also able to identify key predators and parasitoids that are important to preserve for natural control of these pests. Stem borers and rats are a big concern in most islands and like the other pests, we make propositions here to implement some tactics of agroecological crop protection.

Keywords: *Saccharum officinarum*, noble canes, arthropods, rats, Tahiti, organic agriculture.

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1. Introduction

No main agricultural crops (maize, soya, wheat, beans) is cultivated in French Polynesia due to the small size of the agricultural land owned by farmers, generally between 0.5 to 10 ha. However, the sugarcane sector has strong development potential in several islands of French Polynesia and mainly in Tahiti as rum sales from small specific productions are increasing worldwide. Actually, the studies conducted regarding arthropod fauna in the islands of French Polynesia were mainly related to vegetables and market gardening which are the only cash crops since the end of the twentieth century (Paulian, 1998). Despite the isolation and geographical remoteness of the islands of French Polynesia, an interesting entomological richness in term of insect species (harmful and useful) is observed and most of the insects and mites were probably introduced by humans through commercial routes or by so-called passenger traffics (Ryckewaert, 1984). In this context, the sugarcane areas are still modest, around 50 hectares in total (whom 10 hectares under organic certification standards) and this crop is conducted according to organic farming methods and produces an exceptional rum, with an IGP (Protected Geographical Indication) approach. In Polynesian farms, *Saccharum* spp. modern canes are grown with *Saccharum officinarum* noble canes (Vitrac et al., 2018a). The presence of noble canes guarantees a rum with a strong aromatic character (non-published data). The use of this type of canes, which are very sensitive to pests, diseases and weeds (Vitrac et al., 2018b), is unusual and it is mainly devoted to rum industry. In such a context of strong development of this crop in the near future, it is necessary to carry out a preliminary inventory of arthropod pests in order to prevent the crop from heavy damage and yield loss, especially regarding the high sensitivity of noble canes, the development of diseases and the resulting disturbance of the whole sector. This article does not mention weeds, a topic that has already been published (Vitrac *et al*., 2019a). The focus of this study was put on arthropods and rats, such as stem borers and their natural enemies: predators and parasitoids according to visual field inspections and the use of different types of traps to investigate the arthropod diversity. These studies, conducted between 2018 and 2021 have made possible their identification for the very first time in this particular context of organic certified and agroecological fields. As an example, it seems that organic conversion had an effect on the composition of saprophagous macrofauna fields in Martinique island (Coulis, 2021) where thousands of hectares of conventional sugarcane were grown for more than 30 years. Therefore, we wanted to know the type of arthropod fauna living and developing in the specific context of organic sugarcane. In the manual of crop protection published in Tahiti (Hammes *et al*., 1989; Hammes & Putoa, 1986), some insects such as *Rhabdoscelus obscurus* Boisduval were already mentioned as stem borer, but nothing regarding other borer species such as *Chilo saccariphagus* or *Tetramoera schistaceana* which causes important damages and yield losses in China (Pan *et al*., 2021). *C. sacchariphagus* and *Eldana saccharina* are also mentioned as key stem borers in Reunion Island (Goebel & Way, 2009) but these authors didn't mention *R. obscurus.* This situation is not unique and is similar to what is observed in other countries such as Australia and Fiji were no Lepidoptera stem borers are found but *R.obscurus* is present (Goebel & Salam, 2011). Moreover, the rats are in the list of key pests of sugarcane in Polynesia (Sechan, 1987; Hood et al., 1970). A preliminary study has already been conducted by Vitrac *et al*. (2018b), showing the high sensitivity of *S. officinarum* noble canes). In this study, preliminary results are presented about the biodiversity of arthropods and rats in sugar cane for the very first time and additional information is given on the biology of pests and their damage and explore possible avenues for an agroecological management plan, such as the push-pull technique, which use attractive plants around or inside the sugarcane fields to reduce pest populations by using selective treatments only done inside these special areas (Nibouche et al., 2019).

2. Materials and methods

2.1 Agricultural practices in organic sugarcane production

All the fields studied were organic certified for both European (UE) and Pacific rules (NOAB). Vitrac et al. (2019a) defined the following soil preparation and cultural practices: before planting, the soil was worked to a depth of 15 cm then furrowed in twin rows, close together: 50 cm and distant from each other of 1.60 m. This spacing of 1.60 m (inter row) allows the passage of a small 4x4 tractor of 16 Horsepower (HP) equipped with a rotary cutter with blades allowing the mechanical weeding over 1.1 m in width. The arrangement in double rows makes it possible to densify the planting, the double row having to end up merging into a single and wide row. Due to the scarcity of plant material from recent local surveys, planting was carried out with 8-week-old plants raised in the nursery from one-eye cuttings (Poser et al., 2020). The seedlings were manually transplanted into the furrows at 50 cm intervals and in staggered rows, their survival rate was close to 100%. The weeding on the row was carried out using a “serpette”, the local name for a small manual hoe. Organic compatible organo-mineral fertilization consisted of three inputs of distillery vinasses (20 t/ha, source of K), composted horse manure (5 t/ha, source of NP) and crushed dolomite (2 t/ha, source of CaMg), applied directly, mainly in the rows at the foot of the canes. These organic fertilizers were applied for the first time after the first post-planting weeding. Rainfall and temperatures were recorded using an automatic gauge between January 2018 and October 2020.

2.2 Experimental sites and observation plots

2.2.1 Afaahiti site

This site (17°45'15.8"S 149°15'24.1"W) was free of any crop and is representative of natural vegetation and biodiversity, allowing organic certification. A plot of modern RRV sugarcane variety (red color modern *Saccharum* spp. variety found locally, non-published data) was planted in April 2018 on 2 500 m^2 with a light slope of about 3%. Different trapping systems (soil surface, aerial) were installed in May 2018 in an experimental design of 12 plots (Figure 1) comprising a set of one pitfall trap (white cylinder plastic container of 1 liter) and one yellow sticky trap (50 × 30 cm fixed at 50 cm height) per plot. The pitfall traps were buried in the soil, filled with a 100ml of solution containing 10 g/l of saccharose and were covered by yellowish roof to avoid water from rainfall coming inside the trap. Yellow color was chosen because of its attractiveness regarding insects. The insects were captured, identified and counted. Material was discarded after counting and reinstalled at each period: 15/12/2018; 5/2/2019 only for pitfall traps and 25/3/2019; 15/5/2019; 15/7/2019 and 5/9/2019 for pitfall and sticky traps.

2.2.2 Toahotu site

This site (17°45'30.1"S 149°17'21.4"W) was the first plantation of organic certified sugarcane plants in 2013 on old pineapple fields stopped in 2007. It was renewed and grown with varieties of noble canes in 2016 on 3000 m^2, a plot where most of the research studies regarding noble varieties were usually conducted from 2016 (Vitrac et al., 2018b). In 2019, 3rd ratoon was in process. No insect traps (pitfall or sticky) were used on this site. Only borers were monitored. No statistical analysis was done regarding arthropods observations and inventory because of the high variability regarding the number of insects captured in our traps (unnatural distribution of populations).

2.3 Observations of stem borers

In Afaahiti site, a sample of 6 stems for 12 plots (72 stems) were harvested at 3 periods of time (15/5/2019; 15/7/2019 and 5/9/2019) and were split open longitudinally to check the presence or absence of stem borers (Figure 1). Sampling in Toahotu site was conducted at the same period: 15/5/2019; 15/7/2019 and 5/9/2019. Six stems were harvested at 10 m, triplicates sampled on the same row, for the same variety, in the middle row to avoid border effects (18 canes per variety). Varieties were the following: 2 nobles *Saccharum officinarum* varieties found locally in 2014, JRP (yellowish color cane, non-published data) and RBV (light red purple striped color cane, non-published data) and 2 modern ones, RRV and B69566 (introduced from CIRAD Visacane in 2016). In Toahotu site, samples were also observed in September 2018. In this case 3 bunches of 30 stalks were harvested on 10m. Triplicates were also sampled on the same row, for the same variety, in the middle row to avoid border effects.

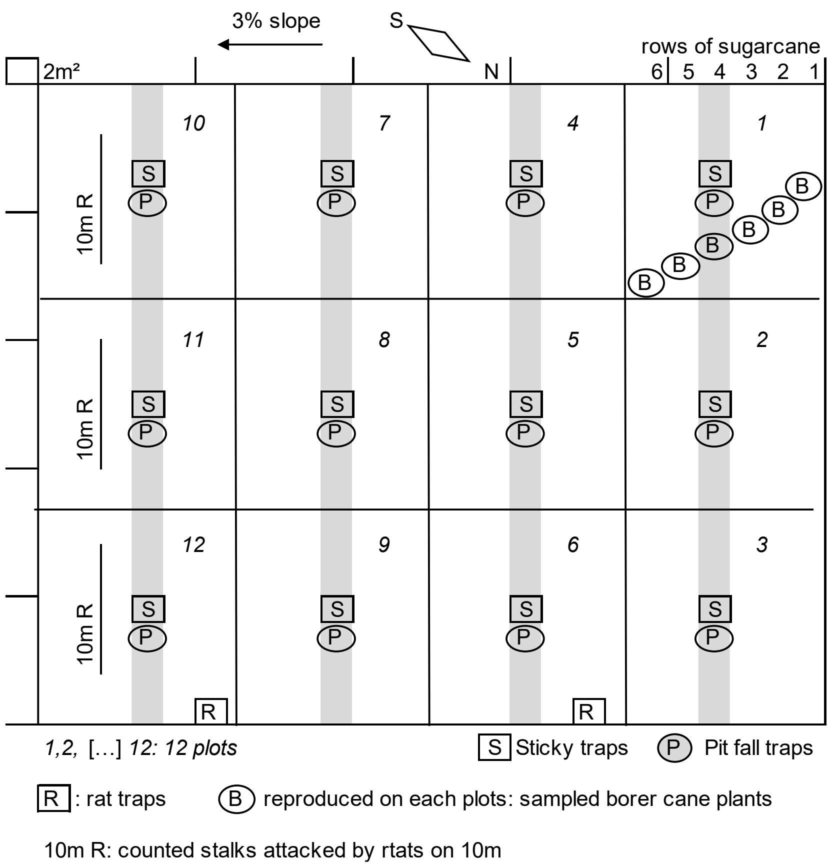

Figure 1: Afaahiti experimental plot. Arthropods (aerial and soil fauna) and rats were monitored during 10 months between December 2018 and September 2019 on this first organic certified plantation of modern RRV sugarcane variety.

2.4 Observations of rat populations

For both Afaahiti and Toahotu sites, two mechanical traps for rat control were installed in March 2019 on the 3rd ratoon of the variety B69566 every time in border of plots, close to the natural vegetation. These traps use a chemical pheromone to attract them and a mechanical killing system and allow us to count killed rats (electronic counter). Control and counting of killed rats were conducted every 2 weeks between April and October 2019, and then these killed rats were removed after each control. In addition, in July and September 2019, the stalks attacked by rats were counted on 3x10m inside the field on the middle row of each plot for each site (Figure 1). A treatment with Brodifacoum (0.005%) was applied in the first week of July 2019. The same procedure was applied one year before, in June and July 2018 in Toahotu site for four varieties, modern ones as RRV and B69566 and also two noble canes as JRP and RBV.

2.5 Statistical analysis regarding stem borers and rats

Data was analyzed using the statistical software XLSTAT 19.4.45191. A population probability law (normal distribution) and descriptive statistical parameters such as mean and standard deviations were processed. Means comparison tests of Mann Whitney (samples<30) were used to compare borers populations between varieties sampled.

2.6 Sampling and identification of macrofauna

Rainfall and temperatures were recorded using an automatic gauge between January 2018 and October 2020 in Afaahiti site. In Figure (2), the successive weeding operations since planting are positioned in relation to the harvests and the monthly rainfall. All measurements were conducted on the row located on the middle of each plot (grey columns on Figure 1) to avoid border effects.

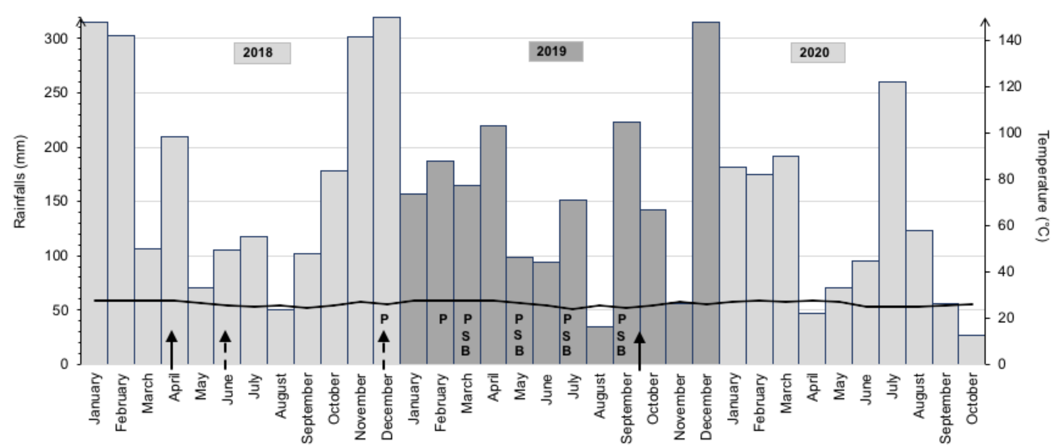

Figure 2: Pattern of rainfall and temperatures in Afaahiti site and successive operations since planting in April 2018 (black arrows show plantation and harvest in early October 2019). For all the macrofauna observations; P: pitfall traps; S: sticky traps; B: borers. Discontinued black arrows (June and December 2018) shows operations of maintenance (mechanical and manual weed removing).

All arthropods collected in the pitfall and sticky traps for 10 months were photographed at each period for each sample. For pitfall traps, samples were kept in 90° alcohol solution and identified by entomologists from CIRAD, based in Montpellier, using the database of images and morphological characteristics observed under a stereomicroscope. Regarding the borer species, stalks were split opened to visualize attacks and tunnels inside the internodes. Damaged stalks were counted, and the insects were collected and also kept in alcohol for further identification.

3. Results and Discussion

3.1 Arthropods

The arthropods levels and diversity are presented in Figure (3). In pitfall traps, 29 different arthropods were identified whom 15 of more than 1% represented 94.83% of the global amount. The 5 most abundant species represented 74.87% of the number of arthropods captured; they were composed of natural predators such as *Chelisoches morio* (25.07%) and Coleoptera Coccinelidae (22.79%) and also insect pests (Scolytidae, 8.63%). *C. morio* (Dermaptera, Forficulidae) was the main species captured. This species is an important natural predator of crop pests (Zhong *et al*., 2016). Spiders as generalist predators were also well represented in our catches (3.51%). It was the most representative group within the 10 species found between 1 and 5%. It is also observed the presence of the centipede *Scolopendra* sp. (Myriapoda) (0.89%) which is a generalist predator of many insect species. In the sticky traps, we identified 25 different arthropods whom 7 of more than 1% represented 88.15% of the global amount. *C. morio* was also captured (1.30%) in these traps where 87.47% are flies. It was also noticed that the presence of bees which are good pollinators is interesting in organic sugarcane fields free of pesticides.

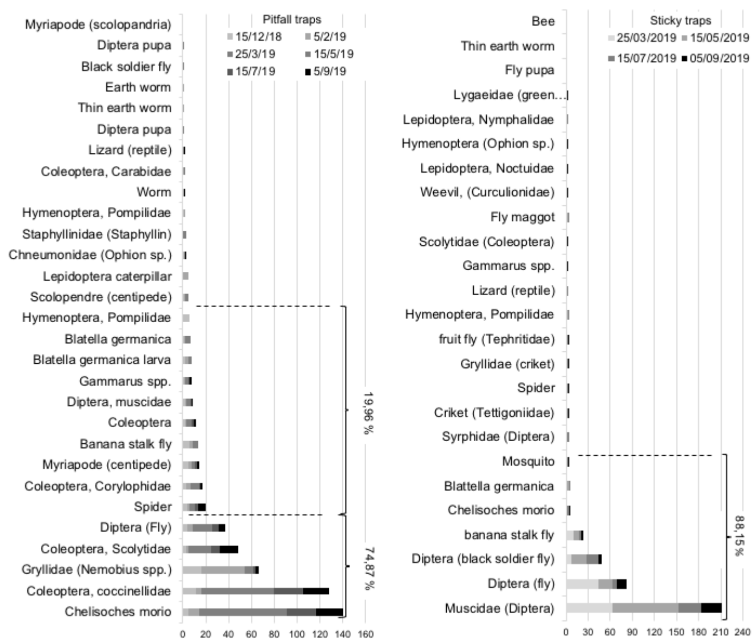

Figure 3: Cumulative numbers of arthropods (abundance) from pitfall (left) and sticky (right) traps with different levels from grey to black for each period of sampling.

A global amount of 992 arthropods collected in this context of organic agriculture during the 10 months of sampling and regarding the observations, we found 14 orders and 33 families (Table 1). Atencio et al. (2019) also found a great diversity in similar context of agroecological sugarcane plantations with 4735 insects collected for 26 months.

Table 1: Identification of arthropods captured in our traps in Tahiti.

Order	Family	Genus	Species	Common name	Feeding	Role
Coleoptera	Curculionidae	*Rhabdoscelus*	*obscurus*	Cane weevil	Sugarcane	Pest
Coleoptera	Cetonidae	*Protaecia*	*fusca*	Mottled flower	Flowers, fruits	Pest
Coleoptera	Elateridae	*Chalcolepidius*	*silbermanni*	Click beetle	Roots	Pest
Coleoptera	Carabidae			Carabid beetle	Invertebrates	Predator
Coleoptera	Scolytidae	*Xyloborus*	*perforans*	Borer beetle	Wood	Pest
Coleoptera	Nitidulidae	*Carpophilus*	*humeralis*	Pineapple beetle	Pineapple, cane	Pest
Coleoptera	Staphylinidae			Small rove beetle	Invertebrates	Predator
Lepidoptera	Noctuidae	*Spodoptera*	*mauritia*	Armyworm	Leaves	Pest
Lepidoptera	Nymphalidae	*Melanitis*	*leda solendra*	Evening brown	Leaves	Pest
Lepidoptera	Crambidae	*Marasmia*	*trapezalis*	Leafeater moth	Leaves	Pest
Lepidoptera	Lycaenidae	*Lampides*	*boeticus*	Azuré porte-queue	Leaves	Pest
Hemiptera	Plataspidae	*Brachyplatys*	*subaeneus*	Black bean bug	Sap sucking	Pest
Dermaptera	Chelisochidae	*Chelisoches*	*morio*	Earwigs	Invertebrates	Predator
Neuroptera	Chrysopidae	*Chrysoperla*	*congrua*	Green lacewings	Invertebrates	Predator
Dyctioptera	Iridopterigydae	*Tropidomantis*	*tenera*	Preying mantis	Invertebrates	Predator
Orthoptera	Tettigoniidae	*Conocephalus*	*longipennis*	Meadow grasshopper	Invertebrates	Predator
Diptera	Tephritidae	*Euaresta*	*bella*	Fruit fly	flowers, fruits	Pest
Diptera	Syrphidae			Hover fly	Invertebrates	Predator
Diptera	Dolichopodidae			Green fly	Invertebrates	Predator
Hymenoptera	Vespidae	*Polistes*	*olivaceus*	Hornets	Invertebrates	Predator
Hymenoptera	Sphecidae	*Pryonix*	*spp*	Thread-waisted wasp	Invertebrates	Predator
Hymenoptera	Ichneumonidae	*Ophion*	*spp*	Parasitic wasp	Invertebrates	Predator
Hymenoptera	Formicidae	*Solenopsis*	*geminata*	Fire ant	Invertebrates	Predator
Blattodea	Blatellidae	*Blatella*	*germanica*	German cockroach	Invertebrates	Predator
Hemiptera	Lygaeidae	*Nysius*	*spp*	False chinch bug	Sap sucking	Pest
Hemiptera	Delphacidae	*Peregrinus*	*maidis*	Corn planthopper	Sap sucking	Pest
Hemiptera	Derbidae	*Cedusa*	*spp*	Blue panthopper	Sap sucking	Pest
Hemiptera	Pseudococcidae	*Saccharicoccus*	*sachari*	Pink mealybugs	Sap sucking	Pest
Hemiptera	Pseudococcidae	*Antonina*	*graminis*	Grey mealybugs	Sap sucking	Pest
Hemiptera	Aleyrodidae	*Neomaskellia*	*bergii*	Sugarcane whitefly	Sap sucking	Pest
Myriapoda	Scolopendridae			Scolopendra	Invertebrates	Predator
Myriapoda				Centipede	Invertebrates	Predator
Arachnida	Tetragnathidae			Spider	Invertebrates	Predator
Arachnida	Salticidae	*Plexippus*	*paykulli*	Spider	Invertebrates	predator

It is admitted that arthropods diversity and abundance are low under conventional sugarcane agriculture, but studies are scarce and even mineral or organic fertilization does have significant effects on diversity and amounts on invertebrate populations (Chi et al., 2020). Moreover Coulis (2021) found no significant difference between organic (in conversion) and conventional fields regarding the diversity of soil macrofauna. However, these studies were limited to the saprophagous macrofauna and didn't consider the arthropod biodiversity of the aerial parts of sugarcane as we did in this present study. In addition, the impact of pesticides in the upper part of the vegetation is generally higher as most of flying predators and parasitoids live there and their activity is obviously limited by the use of chemical spraying (Sánchez-Bayo, 2011). Loranger et al. (1998) showed the influence of pesticides under different agricultural systems in a similar context in Martinique and their clear impact on reducing arthropods' presence and activity. But as agriculture is still underdeveloped in Tahiti, an interesting richness in terms of insect species is generally observed (Hammes et al., 1989; Ryckewaert, 1984) even if the use of pesticides can be very high locally (Ryckewaert, 2004). It indicates to us a good level of biodiversity in our organic cultivated sugarcane fields.

3.2 Stem borers

The main species of stemborer found in Tahitian sugarcane is *Rhabdoscelus obscurus* Boisduval (Figure 4) already mentioned by Hammes et al. (1989). No other borer species were observed. The infestation levels are indicated in Table (2). They are about 6,1% for the lower average of 1,1 canes infested by 18 samples and 51.7% for the highest (RBV, Toahotu, 2018). These percentages are representative about what Goebel *et al.* (2005) found in South Africa: between 7,3 and 26,1% of infested canes. Considering all the results, the noble variety RBV is the most infested, followed by B69566 (unauthorized under IGP approach in 2022). Damage levels by *R. obscurus* increased from May to September following the maturation of the canes. At this stage, cane stems are ready to be harvested and RBV variety could be used only to attract *R. obscurus* without any other treatments. It is similar to push-pull strategy used by Nibouche *et al*. (2019) with *Erianthus arundinaceus* as a trap crop for the sugarcane stem borer *Chilo sacchariphagus*. The difference is that no treatment is needed and RBV variety can be used as a useful plant which could be harvested at the same time as the rest of the fields contrary to B69566 which is not authorized under IGP approach in 2022. It is possible to cultivate it because of its good ratoon (Vitrac et al., 2019b) and we could plant for example 1 to 10 rows of canes. Another way of control, added to the use of RBV variety, could be to find a specific parasitoid like Pan *et al.* (2021) did, using *Trichogramma* and sex pheromones for trapping and control *Chilo sacchariphagus* and *Tetramoera schistaceana.*

Figure 4: *Rhabdoscelus obscurus* (Coleoptera, Curculionidae) Boisduval: adults on the left and larva on the right (black and white scale in mm) and inside an infested cane. Comparison of damaged stalks with the presence of holes and healthy canes (in middle). Photos of the author (2019).

In Table (2), we observed that no RRV canes were infested by stem borers in Afaahiti in 2019 for the 72 canes sampled for the whole period. This result is surprising because in Toahotu site RRV variety was infested in 2018 and in 2019 (3rd ratoon). We can thus hypothesize that some contexts (like Afaahiti in 2019) are free of stemborers regarding the first plantation. We can also note the low level of infested JRP variety. This is the major potential of *S. officinarum* noble cane variety regarding the Polynesian rum industry (Vitrac et al., 2019b). Noble varieties produce less sugar and less biomass than modern varieties (Vitrac et al., 2019b), especially in the early season of June and July. At this stage, B69566 and RRV modern varieties present a Brix of 1 degree more than noble RBV and JRP and higher concentrations in sucrose make them more attractive for pests including stem borers in this case. With a push-pull approach, we could implement an experiment comprising several rows of B69566 (unauthorized under IGP approach in 2022) outside the fields to be harvested, to attract stem borers and detect their presence by using mechanical + pheromone trapping as an efficient warning system.

Table 2: Number of canes infested by stem borers on experimental sites.

Site	15/05/2019		15/07/2019		05/09/2019	
	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation
Afaahiti 2019						
RRV	0	-	0	-	0	-
Toahotu 2019						
RRV	0	- ns	2.1	0.52 *	3	0.55 **
B69566	2.3	0.52 **	4.3	0.52 **	1.1	0.41 *
JRP	0	- ns	1.2	0.41 *	1.1	0.41 *
RBV	3.3	0.55 **	1.1	0.41 *	3.2	0.55 **
Toahotu 2018	15/9/18					
RRV	5.3	1.5 *				
B69566	5.3	1.5 *				
JRP	1.3	1.2 **				
RBV	9.3	3.1 ***				

3.3 Rats

As weeds are the main constraints during the vegetation period of sugarcane (Vitrac et al., 2019a), rats are the most damaging pests during the maturation period particularly on noble canes where rat damage can totally destroy the cane stalks before harvest (Vitrac et al., 2018b). The identified rat killed by traps by morphological approach (Séchan, 1987) was *Rattus exulans*. No *Rattus Norvegicus*, *Rattus rattus* or mice were observed. In 1970, Hood *et al.* have already shown the big impact of rats (*Ratttus exulans*) on Hawaian Polynesian plantations aged of 15 months, with 5% of stalks attacked by month. This period can be compared to our plantation in the period of July. The Figure (5) shows the levels of trapped rats which increased from April to July and then decreased after the treatment in September. It seems that the response to Brodifacoum treatment was more effective in Toahotu site. Newly strip damaged are still quite high in September for both sites due to the increase of rat populations from June where the sugar maturation generally starts. Brodifacoum (and other raticides) treatment is accepted under organic certified following a specific protocol: several plastic tubes containing the rat baits are placed inside the fields, and two or three days after bait consumption, these plastic tubes are removed. As an alternative to these baits, a local mixture can be done to produce natural baits, using *Glyricidia sepium* which is present in Tahiti and French Polynesia (Berkelaar, 2011). It has the same effect as chemical products such as Brodifacoum stopping the synthesis of K vitamin. We can see in Table (3) the low level of attacked JRP variety as it was observed for borers. Noble varieties produce less sugar and less biomass than modern varieties (Vitrac *et al*., 2019b) (even if such a difference is not significant in our context), especially in the early season of June and July.

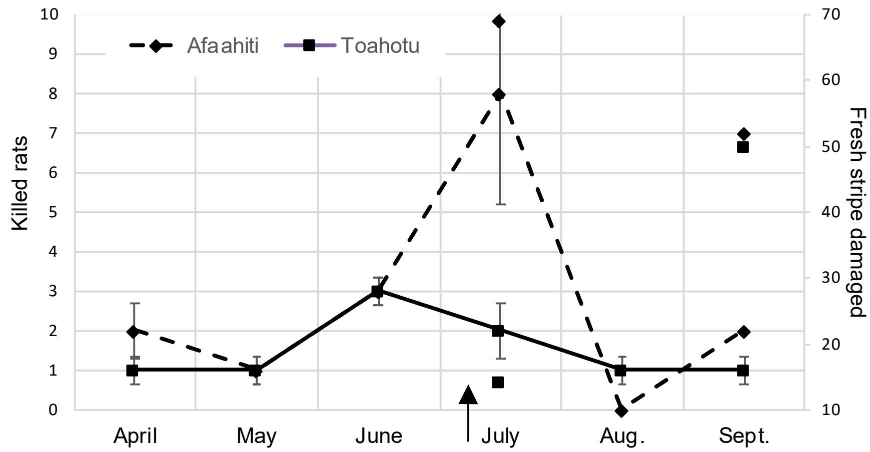

Figure 5: (Evolution of killed rats by mechanical trapping. The black arrow indicates a treatment using Brodifacoum 0,05% in early July 2019 for both sites.

At this stage, B69566 and RRV modern varieties present a Brix of 1 degree more than noble RBV and JRP. With a push-pull approach, we can implement an experiment comprising some rows of B69566, which is significantly more attacked than the other varieties (Table 3), outside the fields (because unharvestable under IGP approach in 2022), to attract rats and detect their presence by using mechanical and pheromone trapping as an efficient warning system.

Table 3: Rat damages in Toahotu site in 2018 and Brix degrees.

Toahotu 2018	June					July				
	Rat damages			Brix		Rat damages			Brix	
	Total	Average	Standard deviation	Average	Standard deviation	Total	Average	Standard deviation	Average	Standard deviation
RRV	31	10,33	3,06	13,70	2,14	23	7,67	3,21	16,32	0,32
B69566	36	12,00	8,72	14,92	1,92	52	17,33	4,62	15,01	1,80
JRP	0	-	-	15,55	1,05	0	-	-	14,50	1,14
RBV	0	-	-	12,24	1,07	0	-	-	15,20	0,09

4. Conclusion

In this study, we identified the main arthropods problems in the context of organic sugarcane in Tahiti. We also generated for the first time in French Polynesia a preliminary list of arthropods, comprising insect pests, natural predators, and parasitoids in this agrosystem. An interesting functional biodiversity is present, and its richness is mainly due to the organically certified fields cultivated by small producers. At the moment, the whole area of sugarcane in Tahiti and other islands of French Polynesia is not strengthened by pests and diseases. However, sugarcane areas will probably grow rapidly, and it is of utmost importance to encourage organic cultivation that will be able to preserve biodiversity in a sustainable way. A knowledge base system associated with a decision support system for pest management (Martin *et al*., 2020) should be an integrated method to follow for the sustainable production of noble canes. Having considered this, it is not forgotten that these old varieties were first abandoned because of their susceptibility to diseases (Vitrac *et al*., 2018a) and replaced by modern *Saccharum* spp. varieties. A better knowledge of the potential of these noble canes and their uses is the first step to building a highly valuable agroecological context to provide the best sugarcanes to this rum industry. The push-pull approach using different types of sugarcane and also companion plants should be further tested and proposed as an agroecological crop protection strategy.

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