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RESEARCH ARTICLE

CAN COFFEE VARIETY AFFECT THE POPULATION DYNAMICS OF COFFEE BERRY BORER (*HYPOTHENEMUS HAMPEI*) ON SAO TOME ISLAND

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Abstract

The coffee berry borer, *Hypothenemus hampei*, is serious limitation in organic coffee production in Sao Tome Island in the Gulf of Guinea, limited information regarding this species seasonal phenology on the islands limits the implementation of biological control.In the present study, seven coffee plantations were monitored over two years to describe infestation patterns, penetration rates into coffee berries, and mortality by the entomopathogenic fungus,*Beauveria bassiana* in two coffea species (*C. arabica* L.and *C. canephora*Pierre ex A. Froehner), according to 30-tree sampling of fruits following the "CENICAFÉ method". The results revealed that the borer position within the berries, infestation, and green berries with *Beauveria bassiana*were significantly affected by coffee variety. The infestation mean across all seven sites was (11.5±3.5%; mean ± standard error (SE)), with two sites showing mean infestation <5%. The highest infestation and *Beauveria bassiana*rates per branch monthly were observed in *C. arabica* L. (Red Caturra, Bourbon and Red Catuaí), compared with *C. canephora*Pierre ex A. Froehner (Robusta) in the months of lower rainfall. Borer immature stages (eggs, larvae and pupae) and adults were found throughout the sampling period. No CBB predator and parasitoids were observed in the survey. The population level and developmental rate indicated that the coffee borer met favorable environmental conditions in the studied areas and control measures are required for reducing damage.

Introduction:-

Coffee remains the most important export crop for many countries both in terms of the earnings and its impact on socio-economic life of the rural folk engaged in its production. Many African producer countries depend almost entirely on foreign exchange earnings from coffee exports, while large sections of their population earn their

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livelihood from coffee cultivation, processing and marketing establishments[1]. Agriculture is the most important economic sector in the West African island nation of Sao Tome and Principe, located on the Equator in the Gulf of Guinea. Here, coffee is the sixth most important export crop after cacao, copra, palm oil, copra oil, and pepper in the islands, thriving in the volcanic soils and equatorial climate[2]. In recent years, there has been a significant decline in coffee production due to phytosanitary problems[3], especially as a result of direct and indirect damage caused by different pest species. Among the most important insect pests in coffee plantations worldwide, the coffee berry borer (CBB), *Hypothenemus hampei* (Ferrari, 1867) (Coleoptera: Curculionidae, Scolytinae) is considered the most damaging, as it reduces both crop quality and yield[4,5,6]. This species is originated from Central African[7,8] and was first discovered in Sao Tome and Principe in 1929[9], but attributed little economic relevance at the time[10].

CBB life cycle is mainly influenced by temperature. The thermal tolerance range is between 20 and 30°C, so the CBB life cycle (from egg to adult) is only completed within this temperature range over a period of 23.3-53.7 days[11,12,13,14,15]. The larvae feeds on the endosperm (seed tissue), causing quantitative losses, such as premature fall in fruit and loss of weight of the beans, and qualitative losses, such as loss of the commercial value of the product due to perforated beans[16,17]. Theadult female entering the fruit, to making galleries in the seed for reproduction and it occurs at any stage of ripeness, from green to ripe or dry[18,19]. The damage caused by the CBB varies from country to country and region to region[20]. Depending on the infestation level, losses can reach 90-100% of the crop, as is the case in the East African[21,22,23]. In addition, due to the entry hole of the CBB into the fruit, several microorganisms[24] occur, including toxin-producing fungi that depreciate grain quality and can affect human health[25, 26, 27, 28, 29].

Environmental conditions, especially temperature and relative humidity, influence the development of the fruit[30,31] and the CBB[32,33,34]. The ripening period of the fruit or the duration of the CBB life cycle and its interactions will depend on the temperature variations of each region[31]. Coffee berries are susceptible to CBB attack when their dry weight is equal to or greater than 27%, which occurs when the fruit reaches more than 150 days of development, which depends on latitude and altitude[35].

Sanitation is by far the most important means of controlling CBB, and pesticide sprays (endosulfan and chlorpyrifos) are commonly used in many countries. Biological controls, although used in some regions, have never been that effective over multiple seasons due to the need to continuously release parasitoids or spray commercial strains of *Beauveria bassiana*. These biocontrols have promise but they have not been developed enough in most coffee-growing regions[11,36,52].Numerous CBB natural enemies were described, including: entomopathogenic fungi (*Beauveria bassiana* (Bals.) Vuill. and *Metarrizium anisopliae*(Metschnikoff))[37], nematodes (*Psyllotylenchus* (Tylenchida: Sphaerularioidea))[38,39,40], include that these are ant predators (*Azteca Instabilis, Crematogaster* spp., *Pheidole synanthropica* Longino, *Pseudomyrmex simplex* Smith, *Pseudomyrmex ejectus* Kempf, *Solenopsis picea* Emery, *Tapinoma* sp., and *Wasmannia auropunctata* Roger)[41,36,42], and include that these are parasitoid wasps (*Cephalonomy stephanoderis* Betrem, *Phymastichus coffea* LaSalle and *Prorops nasuta* Waterston)[43]. *C. stephanoderis*, *P. nasuta*, *P. coffea* and entomopathogenic fungus have been used more often to control the CBB[44, 45], due to the large scale production capacity for trade[45].

Biological control is the best option to control this pest, due to its economic and ecological efficiency, but all the factors that constitute the coffee ecosystem and its multiple interactions must be taken into account. It is essential to know the phenology of the crop in the different areas, especially that related to flowering periods and, therefore, the age of the fruits potentially susceptible to the CBB[18,46,35,47]. At the same time, it is necessary to know the biology and reproduction habits of the CBB, in order to determine the moments of greater susceptibility of the pest to the existing control practices, thus keeping it below the economic injury level[31,47]. In Sao Tome and Principe, the organic coffee plantation is predominant and the Biological Coffee Export Cooperative (CECAFEB) has shown enormous growth through the expansion of the domestic market.

In the present study, we sought to describe CBB population dynamics across seven coffee plantations spanning a range of 68-1051 m above sea level (masl) in Sao Tome Island. We collected data on CBB infestation, position and development within the coffee berry, and mortality by the entomopathogenic fungus *Beauveria bassiana*.

Table :- Details of experimental coffee plots in Sao Tome Island.

Location	Bem-Posta	Novo Destino	Poiso Alto	São Carlos	São Nicolau	Brigoma	CIAT/STP-BECI
District	Mé-Zochi	Mé-Zochi	Lobata	Mé-Zochi	Mé-Zochi	Lembá	Mé-Zochi
Coordinates (UTM)	235805.0 35496.0	235301.0 34253.0	238518.0 37273.3	233887.0 36244.0	218844.0 29163.0	235736.0 31005.0	238518.0 37273.3
Height above sea level (masl)	744	647	562	1051	914	68	324
Annual average temperature (ºC)	23	23	23	23	23	24	23
Average rainfall (mm)	1514.9	1514.9	1257.3	1257.3	1257.3	2472.0	1514.9
Relative humidity (%)	85.3	85.3	85.5	85.5	85.5	82.0	85.3
Plant distances (m)	2 x 2	1 x 2	2.5 x 2.5	2.0 x 2.0	3.0 x 3.0	3.5 x 5.0	3.0 x 3.0
Age (years)	4	4	3	40	40	15	11
Topography	Inclined	Inclined	Flat	Inclined	Inclined	wavy	Flat
Degree of sunlight	Shading	Shading	Full Sunlight	Slight shade	Shading	Shading	Slight shade
Variety	Red Caturra	Bourbon + Caturra	Robusta	Red Catuaí	Robusta	Robusta	Arabica
Area (ha)	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Notes: climate data coming from National Institute of Meteorology of Sao Tome and Principe							

Study Area:

Sao Tome Island is located at latitude 0° and longitude 6° 30' East with an area about 900 km² and is dominated by volcanic mountain, which culminates at 2024 masl. Sao Tome climate is sub-equatorial with very high rainfall. The average annual rainfall varies from 1000 mm in low zone (north and northeast) to more than 6000 mm in high zone (south and south-west). The driest months are June, July, and August and the wettest months are March, April, and May. The annual atmospheric humidity is 80% and annual average temperature at sea level is 25.4 °C[48,49].

The studies were conducted over 23 months (February 2018 through December 2019) in six coffee plantations of CECAFEB located in three regions (Districts) and one in the Center of Technological and Agricultural Investigation of Sao Tome and Principe-Experimental base of industrial crops (CIAT/STP-BECI). The cultural practices on these coffee plantations are: weeding, pruning and prophylactic harvesting, with no pesticide use.

São Nicolau and Brigroma: the agroforestry cultivation system prevails in the area with Robusta coffee trees associated with Erythrina, while in Poiso Alto Robusta coffee species is planted in an intensive cultivation system under full sunlight. São Carlos, CIAT/STP-BECI, Novo Destino and Bem-Posta: in these areas the agroforestry system of interplanting shade trees (Erythrina spp.) and some vegetables with coffee is predominant. More details of experimental coffee plantation are shown in Table 1.

Materials and Methods:-

Sampling borer populations:

The present study used the sampling procedure known as "Cenicafé method" in Colombia[50]. A brief description of the sampling method follows (1) divide the coffee farm into independent lots according to plantation age; (2) randomly select 30 coffee trees per lot (0.5–1.5 ha); (3) select a representative branch in the middle of the tree containing 30–100 developing berries (by visual estimation); (4) examine all green berries for CBB entry hole; (5) record the number of green berries, infested green berries and green berries with fungus *Beauveria bassiana*(EF)(equation 1);

Beauveria bassiana level(Total infested green berries with EF)/(Total counted coffee berry)*100% (1)
(6) repeat the process moving in a zig-zag pattern through the plantation; (7) calculate percent CBB infestation for each lot. In addition to infestation levels (equation 2),

Infestation level(Total infested green berries with CBB)/(Total counted coffee berry)*100% (2)

we assessed the position of the founding female CBB in the infested berries (equation 3).

Penetration rates(Total of coffee berry in position (AB or CD)/(Total counted coffee berry)*100% (3)
For penetration rates of CBB, ~3 infested green berries per branch were collected and dissected to assess the position of the CBB inside. Infested berries were categorized as AB or CD depending on whether the CBB had penetrated the endosperm (CD position) or remained nearer the surface (AB position)[51,52,53]. To determine the developmental stage of CBB and the presence of parasitoids or predators, 100 infested berries were collected per site/sampling date, where 20 were opened and examined under 20x magnification using a stereoscope for screening and counting the stages of the biological cycle of the CBB[52,53]. The other infested fruits were placed in plastic cages to observe the emergence of parasitoids. Samples were taken monthly during the two years of field trial.

Statistical analyses:
Data analysis was carried out with IBM SPSS Statistics 23. Analyses of variance (ANOVA) were performed with variety as independent variable and the treatment means were subjected to Tukey's HSD test ($p<0.05$), whenever appropriate. Correlation analysis (Pearson's; r) was performed between infested green berry, AB position and *Beauveria bassiana*to evaluate whether the presence of *Beauveria bassiana* is associated with the pest incidence assisting in its control and thus assisting in the eventual the decision-making process regarding CBB management.

Results:-

Field infestation levels of *Hypothenemus hampei*:
CBB-infested berries were observed in all sampling months, although the proportion of infested berries was higher overall in São Carlos (1051 masl) compared with coffee plantations in Brigroma (68 masl) ($p<0.001$). The highest infestation rates were recorded in São Carlos (20.0±3.9%; mean ± standard error (SE)) (1051 masl), and CIAT/STP-BECI (19.2±4.2%) (324 masl), but without significant differences ($p=1.00$). There were no significant differences ($p=0.70$) between Brigroma (2.3±0.6%) (68 masl), São Nicolau (7.1±1.6%) (914 masl), and Poiso Alto (3.7±0.8%) (562 masl). No significant differences ($p=0.99$) were observed between Bem-Posta (13.2±3.7%) (744 masl) and Novo Destino (14.6±3.5%) (647 masl). There were significant differences ($p=0.01$) between Bem-Posta (13.2±3.7%) (744 masl) and Brigroma (2.3±0.6%) (68 masl). The difference between Brigroma (2.3±0.6%) (68 masl) and Novo Destino (14.6±3.5%) (647 masl) was significant ($p=0.002$). Coffee variety and locality (elevation/microclimate/management) significantly affected infestation levels ($F=15.74$; gl=4; $p<0.001$). The highest infestation rates were recorded in *Coffee arabica*. L.A positive correlation was recorded between the CBB infestation level and *Beauveria bassiana*in field ($t=15.06$; $r=0.59$; $p=0.001$) (Table 2).

Table 2:- Infestation levels of coffee berry borer (CBB), positions of the CBB (AB-CD) and *Beauveria bassiana*(EF), in Bem-Posta, Novo Destino, Brigroma, CIAT/STP-BECI, São Carlos, São Nicolau, and Poiso Alto, Sao Tome Island between February 2018 through December 2019.

Localities	Variety	Elevation	CBB	AB	CD	EF
			Mean ± SE			
Brigroma	Robusta	Low	$2.3±0.6^{b}$	$0.5±0.1^{c}$	$0.5±0.1^{d}$	$0.1±0.0^{b}$
CIAT/STP-BECI	Arabica	Medium	$19.2±4.2^{a}$	$1.7±0.3^{ab}$	$1.6±0.3^{b}$	$4.5±1.4^{a}$
Novo Destino	Bourbon + Caturra	High	$14.6±3.5^{ab}$	$1.8±0.4^{ab}$	$1.7±0.3^{ab}$	$1.4±0.6^{b}$
Poiso Alto	Robusta	High	$3.7±0.8^{b}$	$1.0±0.2^{bc}$	$0.6±0.2^{d}$	$0.2±0.1^{b}$
Bem-Posta	Red Catura	High	$13.2±3.7^{ab}$	$2.0±0.5^{a}$	$1.4±0.3^{c}$	$2.1±1.4^{ab}$
São Nicolau	Robusta	High	$7.1±1.6^{b}$	$1.6±0.2^{b}$	$0.8±0.1^{cd}$	$1.0±0.5^{b}$
São Carlos	Red Catuaí	High	$20.0±3.9^{a}$	$1.9±0.3^{ab}$	$2.3±0.3^{a}$	$2.0±0.6^{ab}$
Mean total	…	…	11.5±3.5	1.5±0.3	1.3±0.3	1.6±0.9
Correlation			**	**		**

Notes: CBB = % Infestation of CBB, EF = % CBB infected by *Beauveria bassiana*, AB and CD = % of CBB penetration inside berry (AB and CD positions). Correlation ** (positive). Low-Elevation (68 masl), Medium (324

masl) and High-Elevation (>562 masl).
† Mean followed by the same letter in the column are not significantly different by the Tukey HSD test (p<0.05).

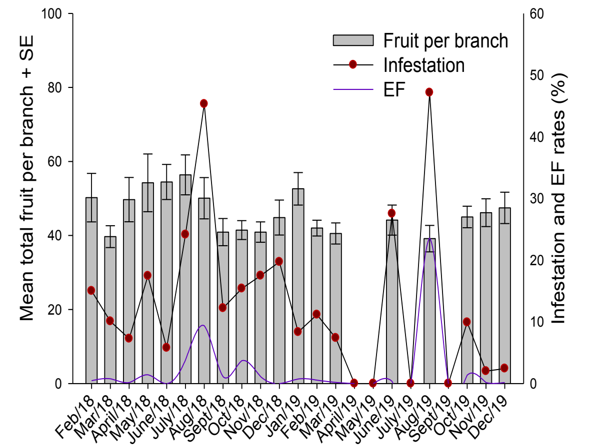

Figure 1. Mean of fruit per branch, infestation level and mortality of the *Hypothenemus hampei* associated with *Beauveria bassiana*per month in Bem-Posta between February 2018 through December 2019.

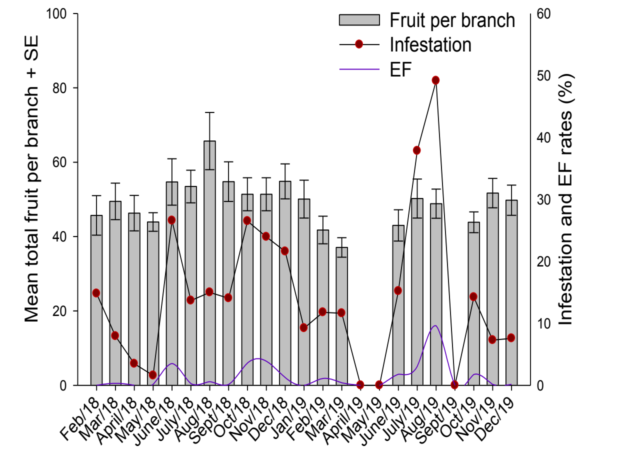

Figure 2. Mean of fruit per branch, infestation level and mortality of the *Hypothenemus hampei* associated with *Beauveria bassiana*per month in Novo Destino between February 2018 through December 2019.

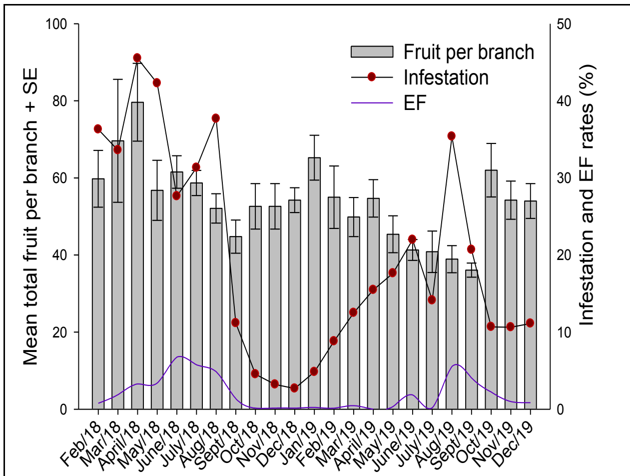

Figure 3. Mean of fruit per branch, infestation level and mortality of the *Hypothenemus hampei* associated with *Beauveria bassiana*per month in São Carlos between February 2018 through December 2019.

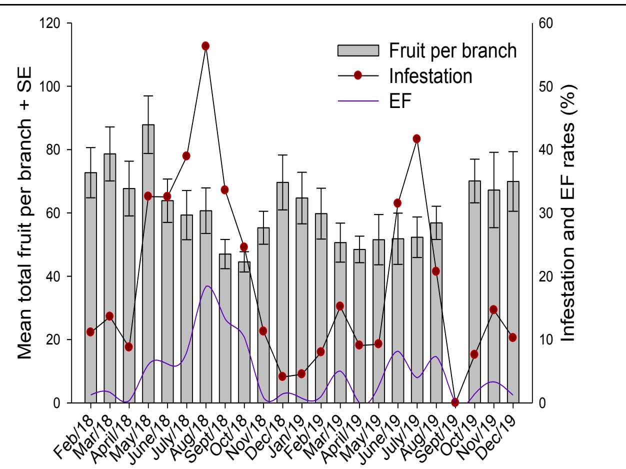

Figure 4. Mean of fruit per branch, infestation level and mortality of the *Hypothenemus hampei* associated with *Beauveria bassiana*per month in CIAT/STP-BECI between February 2018 through December 2019.

C.arabica L. flowering was observed in March, May, July, August, September, November and December, while fruiting was observed throughout the sampling period in São Carlos, but was no observed in April, May, July and September in Bem-Posta, in April, May and September in Novo Destino, and in September in CIAT/STP-BECI (Figures 1, 2, 3 and 4). *C. canephora*Pierre ex A. Froehner(Robusta)flowering was observed from February to December, while fruiting was observed throughout the sampling period in Brigroma and São Nicolau, but was not observed in July and August in 2019 in Poiso Alto (Figures 5, 6 and 7).

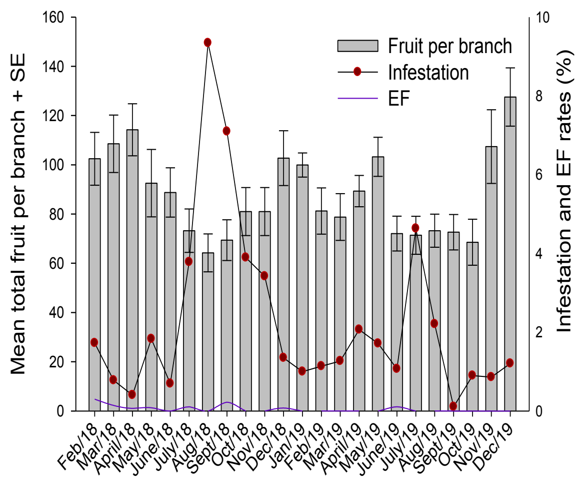

Figure 5. Mean of fruit per branch, infestation level and mortality of the *Hypothenemus hampei* associated with *Beauveria bassiana*per month in Brigroma between February 2018 through December 2019.

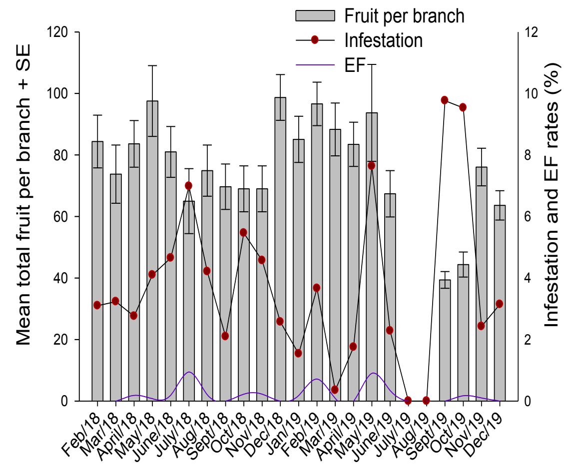

Figure 6. Mean of fruit per branch, infestation level and mortality of the *Hypothenemus hampei* associated with *Beauveria bassiana*per month in Poiso Alto between February 2018 through December 2019.

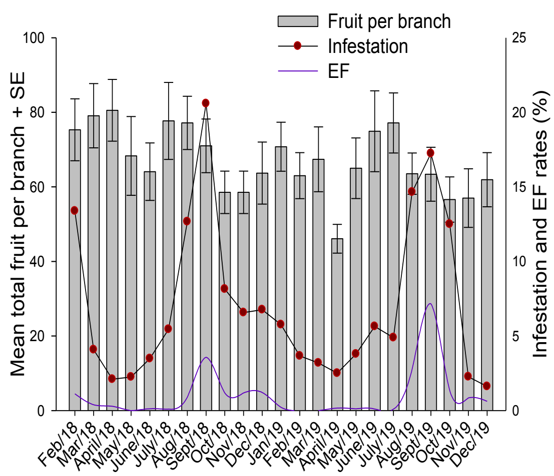

Figure 7. Mean of fruit per branch, infestation level and mortality of the *Hypothenemus hampei* associated with *Beauveria bassiana*per month in São Nicolau between February 2018 through December 2019.

Berry penetration by *Hypothenemus hampei*:

The highest CBB rates in position AB were observed in Bem-Posta (2.0±0.5%) (744 masl) compared with Brigroma (0.5±0.1%) (68 masl). There were no significant differences between CBB rates (position AB) in Novo Destino (1.8±0.4%) (647 masl) ($p=1.00$), São Carlos (1.9±0.3%) (1051 masl) ($p=0.99$), and CIAT/STP-BECI (1.7±0.3%) (324 masl) ($p=0.99$). In CD position, São Carlos (2.3±0.3%) (1051 masl) presented the highest rates and Brigroma (0.5±0.1%) (68 masl) the lowest. There were no significant difference ($p=0.99$) between CBB rates (position CD) in Brigroma (0.5±0.1%) (68 masl) and Poiso Alto (0.6±0.2%) (562 masl). Coffee variety and locality (elevation/microclimate/management) significantly affected CBB rates in position (AB-CD) ($F=6.51$; gl=6; $p<0.001$). The highest CBB rates in position (AB-CD) were recorded in *Coffee Arabica*. L.(Table 2).

Natural enemies:

*Beauveria bassiana*was present in all localities in Sao Tome Island. The highest rate of green berries with *Beauveria bassiana*was found in CIAT/STP-BECI (4.5±1.4%) (324 masl), and the lowest in Brigroma (0.1±0.0%) (68 masl). However, there were no significant diferences between Poiso Alto (0.2±0.1%) (562 masl) ($p=1.000$), São Nicolau (1.0±0.5%) (914 masl) ($p=0.92$), Brigroma (0.1±0.0%) (68 masl) ($p=0.20$), and Novo Destino (1.4±0.6%) (647 masl) (p=0.72). In addition, there were no significant differences (p=1.00) between São Carlos (2.0±0.6%) (1051 masl) and Bem-Posta (2.1±1.4%) (744 masl). Coffee variety and locality (elevation/microclimate/management) significantly affected green berries with *Beauveria bassiana* (F=5.88; gl=6; p<0.001). The green berries with *Beauveria bassiana*were recorded in *Coffee arabica* L. (Table 2). The highest rates of green berries with *Beauveria bassiana*per branch monthly was observed in *C. arabica* L. (Red Caturra, Bourbon and Red Catuaí) (Figures 1, 2, 3 and 4) compared with *C. canephora*Pierre ex A. Froehner(Robusta) (Figures 5, 6 and 7). No CBB predator and parasitoids were observed in the survey.

Immature stages and adult of *Hypothenemus hampei* in developing coffee berries:
Immature stages (eggs, larvae and pupae) and adults of CBB were found throughout the sampling period. There were no differences among localities in average number of eggs (F=0.74; gl=6; p=0.62), larvae (F=1.42; gl=6; p=0.21) and pupae (F=1.48; gl=6; p=0.19) present in green, ripe and mature berry, but there was significant differences (F=3.42; gl=6; p=0.003) on the average number of CBB adults (Table 3).

Table 3:- Mean of immature stages (eggs, larva and pupas) and adult of CBB observed in 20 coffee berries in Bem-Posta, Novo Destino, Brigroma, CIAT/STP-BECI, São Carlos, São Nicolau, and Poiso Alto, Sao Tome Island between February 2018 through December 2019.

Localities	Variety	Elevation	Eggs	Larvae	Pupae	Adults
			Mean ± SE			
Brigroma	Robusta	Low	21.5±4.2^{a}	43.1±11.0^{a}	12.0±3.7^{a}	25.6±5.9^{a}
CIAT/STP-BECI	Arabica	Medium	20.8±4.9^{a}	28.1±9.9^{a}	10.4±3.9^{a}	23.2±4.2^{ab}
Novo Destino	Bourbon + Caturra	High	20.6±6.5^{a}	20.3±7.4^{a}	3.7±1.5^{a}	13.7±1.4^{b}
Poiso Alto	Robusta	High	27.6±7.6^{a}	38.5±10.5^{a}	8.0±3.0^{a}	22.5±3.0^{ab}
Bem-Posta	Red Catura	High	17.3±4.5^{a}	30.3±10.7^{a}	8.5±3.9^{a}	17.0±2.6^{ab}
São Nicolau	Robusta	High	21.9±5.1^{a}	26.1±6.8^{a}	5.9±2.7^{a}	14.7±3.1^{ab}
São Carlos	Red Catuaí	High	27.2±8.0^{a}	40.1±10.7^{a}	11.4±4.4^{a}	15.6±2.9^{ab}

† Mean followed by the same letter in the column are not significantly different by the Tukey HSD test (p<0.05).
Low-Elevation (68 masl), Medium (324 masl) and High-Elevation (>562 masl).

Discussion:-

We investigated the population dynamics and infestation rates of the coffee berry borer in the Sao Tome Island, but due to irregular flowering we were unable to determine the number of seasonal CBB generations is unclear, we found infested green berry in all months sampled, and particularly from late May through October during the weeks following the main harvesting season and the formation of new green berries. The mean infestation across all seven sites was (11.5±3.5%), with two sites showing infestation <5% (Table 2), a value below the 5% economic injury level which estimated by several authors[54,55,56]. In this context, the pest was a limiting factor of organic coffee production in Sao Tome Island during the study period. Several factors can influence the CBB population dynamics, among them: precipitation, temperature, shading, altitude and harvest[56,57]. On the other hand, combinations of environmental factors and cultural practices such as daily rainfall, coffee variety, age of planting, and amount of CBB also influence the infestation[58]. In this trial the infestation rates differed across sites maybe due to a combination of elevation/microclimate/management and variety. *Coffea arabica* L. is more tolerant than *C. canephora*Pierre ex A. Froehner (Robusta) to the CBB,in contractssome studies report higher infestation and CBB populations in robusta[60,61,62], while others report higher numbers in arabica. *Coffea arabica* L. (var. Caturra) is more susceptible to the CBB[63], but in this trial *C. arabica* L. (var. Red Catuaí) was more susceptible. CBB infestation level between 7% and 52% were recorded in shading coffee plantations[64,65]. CBB infestation levels between 4% and 26% were recorded in full sunlight coffee plantationin PuertoRico[65]. Similar result (4%) was recorded in Poiso Alto (full sunlight).

On the other hand the incidence of *Beauveria bassiana*was rather low in Sao Tome Island. Under natural conditions, the *Beauveria bassiana*occurs parasitizing low percentage of CBB[66]. The *Beauveria bassiana*rates effected CBB varied from 0.23% to 0.47% in Rondônia, therefore lower than in other regions of Brazil[67]. CBB mean mortality by the *Beauveria bassiana*across the entire 2016–2017 season in Ka'u was twice that observed in Kona (12% vs. 6%, respectively) in Hawaii[52]. However, the use of commercial formulations to control CBB infestations could be envisaged, if further research clarifies the conditions, and modalities of application.

Infestation level and green berries with *Beauveria bassiana*per coffee branch were directly proportional. This was evidenced by the positive correlation observed (Table 2).The highest infestations and activity of *Beauveria bassiana*were recorded in the months of lower rainfall in Sao Tome Island, particularly from late May through October during and in the weeks following the main harvesting season formation of new green berries (Figures 1,2,3,4,5,6,7 and Table 4). The highest periods of berry infestation occurred from March to May, and again in late October through the end of harvesting in December. Although the highest green berries with *Beauveria bassiana*occurred in September–October in Hawaii and Puerto Rico[52]. The highest periods of berry infestation was observed in May in Mina Gerais State[68].

We also found the highest mean number of eggs in Poiso Alto (562 masl), and larvae, pupae, and CBB adults in Brigroma (68 masl) (Table 3). Maybe due to a combination of elevation and microclimate existent in these sites. Higher reproduction and dispersion of the CBB were found in low-elevation in Hawaii[51]. A lower occurrence of the CBB was observed in the high-elevation in Southern Colombia[69]. On the other hand, a decrease in the CBB population was observed at altitudes above 800 masl in Costa Rica[70]. A greater borer development was recorded in locations at 1.200 masl, with average temperatures above 21°C and less development in locations above 1.600 masl, with average temperatures below 19°C in Colombia[71]. A higher prevalence of the borer was recorded in coffee plantations located in low-elevation in southwestern Ethiopia[72].

Conclusions:-

From the results obtained, it can be concluded that the occurrence of CBB adults is a continuous process throughout the fruit ripening period, with a constant flow of new adults infesting fruit. The population dynamics of the CBB and infestation level show that there are more suitable periods for adopting practices aimed at reducing the CBB population in Sao Tome Island. *Coffea arabica* L. was more susceptible to CBB attack than *C. canephora*Pierre ex A. Froehner(Robusta). *Beauveria bassiana*activity was more remarkable from late May through Octoberwhen the humidity is lower in Sao Tome Island. The CBB finds favorable conditions in the areas studied and probably in the other sites of Sao Tome Island.

Author Contributions:

Miclay Carvalho generated the idea for the paper, conducted field research, analyzed the data, and write the paper. Alex Lopes and Luís Santos helped conduct field research. Albino Bento, Pedro A Casquero, and Raul Narciso C. Guedes revised the manuscript for technical and scientific accuracy and organization.

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Author Contributions:-

The authors declare no conflict of interest.

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