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Preventive, curative and persistent activities of *Lantana camara* and *Psidium guajava* essential oils against *Prostephanus truncatus* (Horn)

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Abstract

Within the framework of the search for alternative methods of struggle against the destruction of the maize by *P. truncatus* (Horn), the vegetable kingdom, in particular the aromatic plant, now offers enough possibilities. The essential oils extracted from these vegetable materials could constitute a credible alternative because less expensive and without major impact on the human health, the animals and on the environment. The present work concerns the bioactivity of the volatile extracts of two aromatic plants known in rural areas in Benin for the preservation of the agricultural products. The chemical compositions of essential oils extracted from *L. camara* and *P. guajava* leaves were studied by gas chromatography coupled with the mass spectrometry (GC/MS). Forty-eight compounds were identified representing 96.8% of

the *L. camara* leaves essential oil from Abomey-calavi. The main compounds (> 5%) are: β-caryophyllene (19.3%), sabinene (15.9%), (Z)-β-ocimene (11.2%), α-humulene (6.5%), germacrene-A (5.8%). The essential oil extracted from *P. guajava* leaves collected to Banigbe (Benin) contained fifty-one compounds corresponding to 97.7% of the total weight of the volatile extract. The major compounds (> 5%) of this essential oil are epi-β-bisabolol: 11.7%; β-caryophyllene: 10.9%; β-bisabolene: 7.5%. The different tests realized on local variety of the maize grain (Zea mays) "Massahouekoun" showed that these essential oils variously have shown larvicidal and ovicidal effects on larvae and eggs of *P. truncatus* adult. These activities caused a significant delay in the development of young *P. truncatus* due to the doses applied and also the active compounds of the essential oils studied.

Keyword: Larger Grain Borer; Massahouekoun; active compounds; larvicidal; ovicidal.

Introduction

The protection and the conservation of foodstuffs after harvest remain a major concern in the African countries in the south of Sahara and in Benin in particular [1, 2]. In the optics to stimulate and to make profitable the maize production, one of the important foodstuffs for human consumption in Benin, many efforts have been made in the agricultural structures procurement in synthetic pesticides, in fertilizers and in the improvement of the seed varieties. But these efforts upstream and which are not supported swallows at the level post-harvest are generally destroyed by some predators that *P. truncatus* who commit their crimes from the fields and pursue them into the storage structures. The weight losses are estimated between 15 to 35% of the harvests after six to eight months of storage [3, 4, 5, 6]. *P. truncatus*, also called the Large Grain Borer is a typical pest of the maize [7]. It attacks the whole grains by drilling husk or by digging a main gallery through the grain to penetrate there. The eggs are put down by females in the perpendicular changing rooms to the main galleries, dug in the grain, in which develop larvae [8, 9]. In rural farms, the control methods used by the farmers against this pest are mainly based on endogenous practices and the use of chemical insecticides. Indeed, the farmers seem to be convinced that these pesticides too expensive and sometimes prohibited are efficient against the Larger Grain Borer [10]. The impact on humans and on environment owed to the misuse or by ignorance, added to the socio-economic difficulties generated by their sale, distribution and the storage in countryside and urban city is a thought-provoking approach. Hardly of this report, the recourse to biopesticide by the essential oils use seemed a cheaper alternative, credible, with little otherwise no major impact on the environment [11-13]. It is in this idea order that we approach this work which objective is to study the chemical compositions of

L. camara and *P. guajava* essential oils and to evaluate their effects on *P. truncatus*.

Experimental

Plant material

The *Lantana camara* leaves in the fresh state were collected on the Abomey-calavi tray in June 2006 and those of *P. guajava* to Adjarra (Avrankou municipality) in May 2007. They were identified and certified to the Abomey-Calavi University National Herbarium and preserved in the laboratory between 18 and 20 ° C in the shade of the sunlight during all the extractions period. The maize grains "Massahouekoun", local variety, were collected to Zoundji (Akpro Misserete municipality). They were kept in a cold room at 6°C throughout the experimental period.

Animal material

P. truncatus adults were taken to the International Institute of Tropical Agriculture (IITA / Benin). They were bred and maintained in the laboratory since January 2006 (T = 28°C ± 2°C, Relative Humidity = 80%). The insects selected for the realization of the biological assays were older than 60 days.

Chromatographical analysis

The essential oils were extracted by hydrodistillation (250 to 300g) for three hours using a Clevenger type apparatus. The volatile extracts were collected by simple decantation and dried over anhydrous sodium sulphate.

- GC/MS: The essential oils were analysed on a Hewlett-Packard gas chromatograph Model 7890, coupled to a Hewlett-Packad MS model 5875, equipped with a DB5 MS column (30m X 0, 25mm; 0, 25µm), programming from 50°C (5 min) to 300°C at 5°C/mn, 5 min hold. Helium as carrier gas (1, 0 mL/min) ; injection in split mode (1:30) ; injector and detector temperature, 250 and 280°C respectively. The MS working in electron impact mode at 70 eV; electron multiplier, 2500V; ion source temperature, 180°C; mass spectra data were acquired in the scan mode in *m/z* range 33-450.
- GC/FID: The essential oils were analysed on a Hewlett-Packard gas chromatograph Model 6890, equipped with a DB5 MS column (30m X 0, 25mm; 0, 25µm), programming from 50°C (5min) to 300°C at 5°C/min, 5min hold. Hydrogen was used as carrier gas (1, 0 mL/min); injection in split mode (1:60); injector and detector temperature, 280 and 300°C respectively. The essential oil is diluted in hexane: 1/30.

The compounds assayed by GC in the different essential oils were identified by comparing their retention indices with those of reference compounds in the literature and confirmed by GC-MS by comparison of their mass spectra with those of reference substances [14-16].

Preventive effect
The maize was arranged under three forms of conservation (maize with husk, maize without husk, shelled maize) and placed in the glass bottle. Each form of conservation independently of the others was subject to each of the doses (0 mL, 0.1 mL, 0.15 mL, 0.2 mL) in three repetitions in a complete random block device. Thus, 36 experimental units were organized for all three forms of conservation. Forty-eight hours later, three insects adult (two females and one male) [11], of the same age (60 days) and taken from the mass rearing were deposited on the maize contained in each glass bottle. During the observation period, the females laid eggs. In every twenty-four hours, an insect which died was replaced and recorded. At the end of six days, the insects were removed and the maize grains so infested were put in observation during 40 days for the control of the emergence rhythm of the offspring. In the control treatment no taste of essential oil has been filed. The data registered during this control have focused on:

- the number of insects dead and recorded during six days
- the number of emergent insects per day for 40 days.

Curative effect
The maize was treated with the essential oil after six days of infestation. The measured data were identical to those of the preventive essay.

Persistent effect
The persistent effect was evaluated by infesting samples of maize treated with essential oil 15 days previously. In each glass bottler, three insects (two females and one male) were introduced and followed every 24 hours for 40 days. During this monitoring, an insect which died was recorded and was not any more replaced. After 40 days the insects still alive were entirely rid of the various forms of conservation. The data measured during this essay were:

- the number of insects dead at the end of 40 days
- the number of emergent insects at the end of 40 days.

Statistical analysis
The results from the observations were treated statistically by the method of analysis of variance (ANOVA) by means of the software SAS V 9.1 [17]. The recorded data underwent a transformation square root in order to stabilize the variances and to standardize the population. The formula used is: $\sqrt{(X + 0,5)}$ with X = given rough (emerged or died) [18]. Then, it was proceeded a structuring of the averages using the test of Newman and Keuls [19]. The results of the statistical tests are regarded as significantly different, when the probability of ANOVA is lower or equal to 5%.

Results and discussion

Yields and chemical compositions of *L. camara* and *P. guajava* leaves essential oils:
The contents of *L. camara* and *P. guajava* leaves essential oils were

respectively 0.023% and 0.54%. According to these two values, *P. guajava* leaves, at the harvest time, contained more essential oil than those of *L. camara*. The chemical compositions of the two plants were given in the following table (Table I). The chromatographic analyzes performed showed 37 compounds representing 95.6% of the total weight of *P. guajava* essential oil whereas in *Lantana camara* volatile extract, 41 compounds corresponding to 96.8% of the weight of this essential oil were identified. *L. camara* essential oil was richer in hydrogenated terpenes (77.1%) than that of *P. guajava* (56.0%). The rate in oxygenated compounds of the *P. guajava* essential oil was 37.0%. β-caryophyllene (19.3%), sabinene (15.9%), (Z)-β-ocimene (11.2%), α-humulene (6.5%), germacrene-A (5.8%) were the major compounds of *L. camara* essential oil. These same compounds, especially β-caryophyllene, sabinene and α-humulene had been previously reported in *L. camara* leaves essential oils studied by Rabendra Balandra in 2011 [20], Oluwadayo Sonibare and Effiong in 2008 [21]. On the other hand the present chemical composition differs from that studied by Sousa *et al.* in Brazil in 2012 which mentions, except the β-caryophyllene, other major compounds namely bicyclogermacrene (26.1%), germacrene-D (19.2%), valencene (12.0%) [22]. This difference was more significant in comparison for the major compounds (β-caryophyllene: 13.57%, α-caryophyllene: 11.76%, 10.88% germacrene-D, isocaryophillene: 9.59% γ-muurolene: 6.85% γ-elemene: 5.65%) of Bangladesh *L. camara* leaves essential oil [23]. *P. guajava* essential oil contained epi-β-bisabolol (11.7%), β-caryophyllene (11.0%), β-bisabolene (7.5%), β-curcumene (4.2 %) as dominant compounds. The major compounds reported in the present work were significantly different from those reported by Fasola *et al.* in the *P. guajava* stem-bark volatile extract of Nigeria. Indeed, the main compounds identified in this extract were hydrocarbons, amines, amides, esters accompanied by 3, 6-dioxa-2, 4, 5, 7-tetraoctane, 2, 2, 4, 4, 5, 5, 7, 7-octamethyl (11.67%) and cyclononane (10.66%) [24]. It is the same of the volatile extract of the leaves of *P. guajava* investigated in India and of chemical composition dominated by methyl hexadecanoate (9.32%), propyl benzene (9.52%), methyl tetradecyl acetate (12.86%), 3, 6, 9-nonadecatriene (15.37%), methyl octadecanoate (22.18%), methyl 2, 6, 10-trimethyltridecanoate (28.86%) [25].

Table I : Chemical compositions of the essential oils of *P. guajava* and *L. camara* leaves

Constituent	KI	Pg	Lc
		(%)	
tricyclene	929	1.7	0.4
α-pinene	935	-	2.3
Camphene	946	-	1.2
Benzaldehyde	959	2.5	-
Sabinene	973	-	15.9
β-pinene	979	-	1.9

6-methyl-5-hept-5-en-2-one	981	0.2	-
Myrcene	991	0.2	1.8
p-mentha-1(7),8-diene	999	0.3	2.5
α-terpinene	1015	-	0.3
p-cymene	1021	0.3	-
Limonene	1028	20.7	0.2
1,8-cineole	1029	0.1	1.6
(Z)-β-ocimene	1037	-	11.2
(E)-β-ocimene	1050	-	1.2
γ-terpinene	1057	-	0.6
cis-sabinene hydrate	1070	-	0.9
Terpinolene	1083	-	0.4
trans- sabinene hydrate	1098	-	0.9
cis-p-menth-2-en-1-ol	1122	-	-
Camphor	1146	0.7	1.4
Borneol	1171	-	0.2
terpinen-4-ol	1177	-	1.9
α-terpineol	1192	-	1.1
methyl geranate	1316	0.2	-
Eugenol	1348	-	1.3
α-copaene	1374	3.9	0.4
β-elemene	1384	-	0.6
β-caryophyllene	1419	6.3	19.3
β-copaene	1428	-	0.4
α-*trans*-bergamotene	1429	0.3	-
α-humulene	1454	1.2	6.5
Sesquisabinene	1459	-	0.2
γ-muurolene	1472	0.5	-
germacrene-D	1480	-	0.2
β-selinene	1488	3.1	-
α-selinene	1491	2.8	-
bicyclogermacrene	1493	-	1.4
germacrene-A	1498	-	6.0
δ-cadinene	1522	0.8	0.6
δ-cuprenene	1546	-	0.9
germacrene-B	1555	-	1.0
(E)-nerolidol	1556	0.9	3.5
caryophyllene alcohol	1574	0.4	0.6
sesquisabinene (E)-hydrate	1578	-	0.6
caryophyllene oxide	1580	2.7	0.8
β-copaen-4-α-ol	1584	0.3	-
guaïol	1591	0.4	-

epi-globulol	1606	0.4	-
humulene epoxyde II	1607	1.2	0.8
1,10-di-epi-cubenol	1619	0.3	-
1-epi-cubenol	1631	3.7	2.1
β-acorenol	1635	2.4	-
epi-α-cadinol	1639	-	0.4
epoxy-allo-alloaromadendrene	1633	1.6	-
epi-α-muurolol	1641	1.4	-
α-muurolol	1644	2.3	-
selin-11-en-4-α-ol	1660	9.9	-
14-hydroxy-9-epi-(E)-caryophyllene	1668	0.9	-
nerolidyl acetate	1678	-	1.3
α-bisabolol	1683	0.2	-
(2Z, 6Z)-farnesol	1709	4.3	-
(2Z, 6E)-farnesol	1710	10.0	-
(2E, 6E)-farnesol	1742	6.0	-
benzyl benzoate	1764	0.5	-
Total		95.6	96.8

Pg = *Psidium guajava*; Lc = *Lantana camara*; KI = Kovats Indice; exp = experimental

Comparative effects of *L. camara* and *P. guajava* essential oils on *P. truncatus* living on maize:

The tables II to VII below showed the statistical averages induced by each essential oil on *P. truncatus* alive on a shape of preservation given of the maize. In these tables, the statistical averages were compared by column. The Table II shows the evolution of the mortality rates evolution and emergence engendered by *P. truncatus* in the presence of *L. camara* essential oil. The essential oil of *L. camara*, did not exhibit a toxic effect on the *P. triuncatus* adults existence during the oviposition period (six days) for the three conservation methods evaluated (Table II). The mortality averages recorded for the doses 0.1; 0.15 and 0.2 mL was significantly similar to those of the control. At the emergence, the applied doses (0.1; 0.15 and 0.2 mL) caused low rates of emergent insects, but different from the control. However, *L. camara* essential oil has prevented the development of eggs put down by the females of *P. truncatus* and of their larvae newly formed. This essential oil thus possessed ovicidal and larvicidal effects. The local variety of maize without husk "Massahouekoun" submitted to the *P. truncatus* pressure by different methods was treated with *L. camara* essential oil. The low averages of mortality recorded and aggregated in this Table III showed a relatively low toxicity of *L. camara* essential oil on *P. truncatus* adult. The *L. camara* volatile extract thus showed a weak insecticidal effect against *P. truncatus* adult living on maize without husk. This finding was in adequacy with the

chemical composition (Table I) of *L. camara* essential oil poor in phenolic compounds often responsible for insecticidal and repellent activities as it is the case for the *P. racemosa* and *C. odorata* essential oils in a previous study [26]. The new insects rates recorded at the end of 40 days were low contrary to the control according to the mean values obtained in curative, preventive and persistent methods. The delay in the emergences development would be the result of the molecules with ovicidal and / or larvicidal action, acting in synergy or not, present in *L. camara* essential oil. In the table IV where were recorded the mean values of *P. truncatus* mortality and emergence, the insecticidal effect performance of *L. camara* essential oil was rather remarkable. In the curative treatment, the mortality averages were not significantly different. It's the same in preventive and persistent methods. On the other hand, the treatments 0.1, 0.15, 0.2 mL have produced so much of emerging for every conservation method. In curative method, the lowest emergence (0.33) was produced by the dose of essential oil (0.2 mL) that is the sufficient quantity to stop the infestation of the maize grains after the oviposition. For the doses 0.1 mL and 0.2 mL in a preventive mode, the averages emergence 13.33 and 14.33; statistically similar, were very different from that obtained (1.67) to the dose 0.15 mL. This difference between the averages was probably due to an egg deposited by *P. truncatus* females during the treatment 0.15 mL. In the persistent method, the emergent rates were low and were the consequence of the time effect (15 days) of *L. camara* essential oil on maize grains which offered no more rather good conditions for the development of eggs produced. The insect's mortality during the oviposition period was less important at the level of the substrates treated with *P. guajava* essential oil in curative, preventive and persistent methods (Table V). The registered averages do not exhibit the volatile extract insecticidal or repellent effect on adult *P. truncatus*. In curative treatment, the rate (39.00) of emergent generated by the processing 0.1 mL was significantly different from the control (143.33) and very high compared to the averages produced by the doses 0.15 and 0.2 mL. However, the emergences engendered in the maize ears treated with these last doses (0.15 and 0.2 mL) were weak and statistically identical after 40 days. An ovicidal and / or larvicidal of *P. guajava* essential oil was thus to be indicated of this fact. In the analysis of the preventive method results, the emergence averages significantly different from that of the control were observed for the quantities 0.1, 0.15 and 0.2 mL. *P. guajava* essential oil showed for these last treatments a low ovicidal and larvicidal against *P. truncatus* eggs and larvae. The same observations was made in persistent method. The results in the table VI concerned the mortalities and the emergence averages of *P. truncatus* living on maize without husk. In curative method, enough new insects were recorded although the doses 0.15 and 0.2 mL were important. This observation was the consequence of the development of certain eggs produced by some insects inside the raids. These raids were also a physical factor facilitating the increase of the emergent insects in preventive and persistent methods. The statistical results of the table VII shows

very low averages of adult mortality of *P. truncatus* living on the shelled maize for all the forms of conservation. The absence of raid and husk to which was added the low anti-infective character sesquiterpenes alcohol from *P. guajava* essential oil has contributed to the insect's survival during the oviposition period. The *P. guajava* essential oil showed neither insecticidal effect, nor repellent on *P. truncatus*. The females thus left eggs which produced later emergences according to the preservation mode used. In curative treatment, the statistical similarities noted between the average values for the doses 0.1, 0.15 and 0.2 mL were different from that of the control ($P < 0.0004$). The *P. guajava* volatile extract has demonstrated actions delaying the pest development. The trend seems to be the same for the persistent method but the effect of the doses 0.1, 0.15 and 0.2 mL has significantly reduced the registered averages. In the preventive method, the treatments 0.1 and 0.2 mL produced emergences statistically identical but different from those of the control and from the dose 0.15 mL. This result did not guarantee in our opinion an efficiency of the *P. guajava* essential oil in front of *P. truncatus* because the substratum shape was not enough adapted to the pest biology.

Table II: averages of *P. truncatus* dead and emerged on the maize in husk treated with *L. camara* essential oil

Essential oil doses (mL)	curative method		preventive method		persistent method	
	died	emerged	died	emerged	died	emerged
0.0	0±0(0.71)a	112.33±10.52(10.60)a	0.33±0.33(0.88)a	111.00±5.86(10.55)a	2.00±1.00(1.48)a	103.00±1.73(10.17)a
0.1	0.33±0.33(0.88)a	0.33±0.33(0.88)b	0±0(0.71)a	1.67±0.88(1.39) b	2.33±0.33(1.68)a	0±0(0.71)b
0.15	0±0(0.71)a	4.33±3.38(1.89)b	0±0(0.71)a	0.67±0.33(1.05) b	2.67±0.33(1.77)a	8.67±6.76(2.52)b
0.2	0±0(0.71)a	1.33±1.33(1.18)b	0±0(0.71)a	0.33±0.33(0.88)b	3.00±0.00(1.87)a	0.33±0.33(0.88)b
Probability	0.44ns	< 0.0001 ***	0.44ns	< 0.0001***	0.6054ns	< 0.0001***
CV (%)	19.92	25.18	19.92	12.68	20.93	29.05

*ns = not significant at 5%; *** = very highly significant difference (0.1%). The averages enter brackets arise raw data. The averages followed by the same letter were not significantly different at the beginning of 5% (Newman and Keuls test). CV = covariance*

Table III: averages of *P. truncatus* dead and emerged on the maize without husk treated with *L. camara* essential oil

Essential oil doses (mL)	curative method		preventive method		persistente method	
	died	emerged	died	emerged	died	emerged
0.0	0±0(0.71)a	112.00±21.55(10.50)a	0±0(0.71)a	97.67±4.84(9.90) a	1.33±0.67(1.29)a	113.33±13.84(10.63)a
0.1	0.33±0.33(0.88)a	21.33±9.06(4.47)b	0±0(0.71)a	19.67±2.18(4.48)ab	0.67±0.67(0.99)a	4.00±4.00(1.65)b
0.15	0.33±0.33(0.88)a	7.33±6.84(2.18)b	1.00±1.00(1.09)a	23.00±15.69(4.03)ab	1.67±0.67(1.44)a	14.67±7.42 (3.39)b
0.2	0±0(0.71)a	23.00±13.57(4.11)b	0±0(0.71)a	19.67±19.17 (3.19)b	2.00±0.58 (1.56)a	26.33±13.42 (4.44)b
Probability	0.60ns	< 0.01**	0.44ns	0.045*	0.468ns	< 0.0057***
CV (%)	26.64	42.55	41.78	47.41	32.83	44.38

*ns = not significant at 5%; *** = very highly significant difference (0.1%); ** = very highly significant difference (1%); * = very highly significant difference (5%). The averages enter brackets arise raw data. The averages followed by the same letter were not significantly different at the beginning of 5% (Newman and Keuls test. CV = covariance*

Table IV : averages of *P. truncatus* dead and emerged on the shelled maize treated with *L. camara* essential oil

Essential oil doses (mL)	curative method		preventive method		persistent method	
	died	emerged	died	emerged	died	emerged
0.0	0±0(0.71)a	104.33±4.81(10.23) a	0±0(0.71)a	114.67±4.33(10.73)a	2.33±0.67(1.65)a	87.33±8.67(9.35)a
0.1	0.33±0.33(0.88)a	10.00±5.29(2.85)b	1.33±0.88(1.27)a	13.33±7.79(3.21)b	1.67±0.67(1.44)a	0.67±0.67(0.99)b
0.15	0±0(0.71)a	2.66±1.45(1.64)b	1.00±0.58(1.17)a	1.67±0.88(1.38)b	2.67±0.33(1.77)a	0±0(0.71)b
0.2	0±0(0.71)a	0.33±0.33(0.88)b	0.33±0.33(0.88)a	14.33±14.33(2.67)b	1.33±0.88(1.27)a	1.00±0.58(1.17)b
Probability	0.44ns	< 0.0001***	0.342ns	0.0023**	0.4642ns	< 0.0001***
CV (%)	19.92	27.35	39.19	46.31	26.19	17.14

*ns = not significant at 5%; *** = very highly significant difference (0.1%); ** = very highly significant difference (1%). The averages enter brackets arise raw data. The averages followed by the same letter were not significantly different at the beginning of 5% (Newman and Keuls test. CV = covariance*

Table V : averages of *P. truncatus* dead and emerged on the maize in husk treated with *P. guajava* essential oil

Essential oil doses (mL)	curative method		preventive method		persistente method	
	died	emerged	died	emerged	died	emerged
0.0	0.33±0.33(0.88)a	143.33±4.48(11.99)a	0.67±0.67(0.99)a	103.00±14.42(10.12)a	2.33±0.67(1.65)a	122.00±6.11(11.06)a
0.1	0.33±0.33(0.88)a	39.00±19.21(5.50)b	1.00±0.00(1.22)a	12.67±12.67(2.54)b	2.00±1.00(1.48)a	19.33±19.33(3.02)b
0.15	0±0(0.71)a	0.67±0.33(1.05)c	1.67±0.33(1.46)a	6.00±3.46(2.26)b	1.00±1.00(1.09)a	7.67±5.69(2.50)b
0.2	0.33±0.33(0.88)a	0.33±0.33(0.88)c	2.00±1.15(1.47)a	1.00±1.00(1.09)b	3.00±0.00(1.87)a	6.67±6.67(1.98)b
Probability	0.802ns	< 0.0003***	0.552ns	0.0014**	0.3571ns	< 0.0056**
CV (%)	30.94	38.73	34.83	47.05	33.44	52.77

*ns = not significant at 5%; *** = very highly significant difference (0.1%); ** = very highly significant difference (1%). The averages enter brackets arise raw data. The averages followed by the same letter were not significantly different at the beginning of 5% (Newman and Keuls test. CV = covariance*

Table VI : averages of *P. truncatus* death and emerged on the maize without husk treated with *P. guajava* essential oil

Essential oil doses (mL)	curative method		preventive method		persistent method	
	died	emerged	died	emerged	died	emerged
0.0	0.67±0.67(0.99)a	98.67±10.33(9.93)a	0±0(0.71)a	130.33±17.33(11.39)a	0.67±0.67(0.99)a	100.00±11.93(9.99)a
0.1	0±0(0.71)a	6.00±3.46(2.26)b	0.33±0.33(0.88)a	13.33±4.70(3.57)b	1.00±0.58(1.17)a	5.33±3.38(2.21)b
0.15	0.33±0.33(0.88)a	23.67±13.57(4.18)b	1.33±0.88(1.27)a	3.00±2.08(1.67)b	0.33±0.33(0.88)a	12.33±6.49(3.13)b
0.2	0.33±0.33(0.88)a	31.00±15.87(4.93)b	2.67±1.76(1.61)a	9.00±6.24(2.63)b	1.67±0.88(1.38)a	4.67±2.40(2.06)b
Probability	0.758ns	< 0.025*	0.2773ns	0.0001***	0.6080ns	< 0.0004***
CV (%)	37.99	45.65	50.63	29.78	42.87	33.51

*ns = not significant at 5%; *** = very highly significant difference (0.1%); * = very highly significant difference (5%). The averages enter brackets arise raw data. The averages followed by the same letter were not significantly different at the beginning of 5% (Newman and Keuls test. CV = covariance*

Table VII : averages of *P. truncatus* death and emerged on the shelled maize treated with *P. guajava* essential oil

Essential oil doses (mL)	curative method		preventive method		persistente method	
	died	emerged	died	emerged	died	emerged
0.0	0±0(0.71)a	113.67±9.74(10.67)a	0.67±0.67(0.99)a	97.67±5.04(9.90)a	0±0(0.71)a	104.67±17.89(10.17)a
0.1	0±0(0.71)a	6.33±4.84(0.29)b	0±0(0.71)a	4.00±2.08(2.00)c	0.67±0.67(0.99)a	0.67±0.67(0.99)b
0.15	0.33±0.33(0.88)a	14.67±6.89(3.53)b	1.33±0.67(1.29)a	11.67±2.33(3.46)b	0.67±0.33(1.05)a	3.00±2.52(1.62)b
0.2	0±0(0.71)a	5.33±3.93(2.08)b	1.00±0.00(1.22)a	2.67±2.18(1.56)c	2.00±1.00(1.48)a	2.00±1.23(1.43)b
Probability	0.44ns	< 0.0004***	0.2568ns	0.0001***	0.2764ns	< 0.0001***
CV (%)	19.92	32.74	33.82	18.21	42.06	30.92

*ns = not significant at 5%; *** = very highly significant difference (0.1%). The averages enter brackets arise raw data. The averages followed by the same letter were not significantly different at the beginning of 5% (Newman and Keuls test. CV = covariance*

Conclusion

The control of maize pests, namely *P. truncatus*, was confronted, in recent years, for a resistance to synthetic insecticides (non-biodegradable and harmful to humans) of the devastating. Considering the prohibitive cost of these insecticides, their toxicity and their degrading action on the environment, the current trend aimed at the use of the phyto-bioactive extracts, little toxic, biodegradable, less expensive and proven effectiveness. It was about the essential oils of certain aromatic plants containing highly active molecules and having insecticidal, larvicidal and ovicidal properties. In the case of the current work, the chemical composition study of the essential oils showed, mainly, the presence of β-caryophyllene in the *L. camara* leaves and epi-β-bisabolol in those of *P. guajava.* The emergence averages high enough at the level of control substratum were probably due to the strong fertility of *P. truncatus*, the good fertility of its eggs and larvae efficient penetration in grains.maize. *L. camara* and *P. guajava* essential oils very rich in hydrogenated terpenes accompanied by low rates of oxygenated compounds affected the *P. truncatus* eggs hatching and the development of its newly formed larvae. These volatile extracts have shown ovicidal and larvicidal properties in all the forms of maize conservation.

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