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Are bioinsecticides able to effectively substitute chemicals in the control of insect pests of okra (*Abelmoschus esculentus* L. Moench) in Cote d'Ivoire?

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ABSTRACT

Objective: Okra (*Abelmoschus esculentus*, Malavaceae) production faces pest and disease attacks that leads to use of chemical pesticides. This study was performed to compare effectiveness of the bioinsecticide Levo 2.4 SL (Oxymatrin 2% and Prosular 0.4%) to the chemical pesticides Abalone 18 EC (Abamectin 18g/l) and Viper 46 EC (Acetamiprid 16g/l and Indoxacarb 30g/l) against okra insect pests in Cote d'Ivoire.

Methodology and Results: So a field experiment was carried out at Bonoua (05°16'17N; 03°35'40 W) in the South East of Cote d'Ivoire, in a Randomized Complete Block Design (RCBD) with four replications and four treatments; Levo 2.4 SL, Abalone 18 EC, Viper 46 EC and the Control. Insect communities, damages and yield profit rate were assessed and analyzed with Statistica 7.1 at 5%. The inventory of insect allowed the identification of 28 species distributed into 19 families and 10 orders. The main pest insects observed were Hemiptera; *Aphis gossypii* (41.59%), *Bemisia tabaci* (39.11%), *Jacobiasca* sp (1.26%) and *Dysdercus wolkerii* (1.44%), Coleoptera; *Podagrica decolorata* (9.03%) and caterpillars of Lepidoptera; *Syllepte derogate* (1.36%). Then control plots presented no healthy plants (0%), while the bioinsecticide (Levo 2.4 SL), and the chemical insecticides; Abalone 18 EC and Viper 46 EC presented respectively 60%, 77.5% and 90% of healthy plants (index 0). Overall, the effectiveness of the bioinsecticide to control insect pests appeared similar to those of the chemical pesticides. However, Levo 2.4 SL seems to be less effective against *Aphis gossypii* and *Dysdercus wolkerii* populations. Highest fruit yield of okra was recorded in treated plot with Viper 46 EC (12.55±0.98 t/ha), followed by Abalone 18 EC (12.2±0.8 t/ha) and Levo 2.4 SL (11.15±1.09 t/ha). Whereas, the lowest yield obtained from control plots was 6.84±0.15 t/ha. The yield profit rates were 62.82; 78.18 and 83.28% respectively for Levo 2.4 SL, Abalone 18 EC and Viper 46 EC when compared to the control. The control of insect pests by the bioinsecticide and the chemical insecticides increased significantly the okra yield.

Conclusion and application of Results: Therefore, the bioinsecticide can be eco-friendly alternative to control insect pest of okra in Cote d'Ivoire. Then, the bioinsecticide Levo 2.4 SL can be proposed to limit damages caused by chemicals on the environment and human health.

Keywords: Bioinsecticide, Levo 2.4 SL, *Abelmoschus esculentus*, insect pests, Cote d'Ivoire.

INTRODUCTION

Vegetables contribute to food security and the reduction of poverty of smallholder farmers in sub-Saharan Africa. They are very rich in vitamins, minerals and proteins. In Cote d'Ivoire, several vegetable crops are grown, but the most important are eggplant, pepper, tomato and okra (Soro *et al.,* 2007). Okra (*Abelmoschus esculentus* L.) is an important vegetable because all its parts (roots, stems, leaves, fruits, seeds) are valued in food, medicinal, artisanal and even industrial (Marius *et al*., 1997). The plant is rich in minerals, carbohydrates fibre, protein, fat and phenols (Huang *et al*., 2007). One of the major constraints in okra cultivation is its susceptibility to numerous insect pests and diseases during the various stages of its growth (Srinivasan & Krishnakumar, 1983; Asare-Bediako *et al*., 2014c). Okra is attacked by various serious economic pests like Coleoptera, Homoptera and Lepidoptera Orders (Gnago *et al*., 2010; Asare-Bediako *et al*., 2014c). Pests and diseases are major constraints to the quality and quantity of okra produced with total losses of about 35-40 % (Mohankumar *et al.,* 2016) or to 69% yield loss in okra (Rawat & Sahu, 1983). Farmers rely on chemical pesticides e.g. organophosphates, carbamates, organochlorine and pyrethroids for the control of pests in many countries (Mccaffery, 1998) thereby endangering environmental and public health (Mohankumar *et al.,* 2016). Extensive use of insecticides leads to the problems of pest resistance, resurgence, pesticides residues, destruction of beneficial fauna and environmental pollution (Adilakshmi *et al*., 2008; Sarkar *et al*., 2016). Otherwise, with okra being a vegetable crop harvested every alternate day, the residues of insecticides ought not to remain in the edible part (Priya & Misra, 2007). Therefore, the present study was undertaken to evaluate the efficacy of a bio-pesticide for eco-friendly management of okra pests and to preserve health.

MATERIAL AND METHODS

Field study: The study was carried out at Bonoua (05°16'17N; 03°35'40 W) in the South East of Côte d'Ivoire and characterized by four seasons (two dry seasons and two rainy seasons) throughout the year. The annual rainfall ranges between 1600 and 2000 mm, temperature of 26 °C to 32 °C and relative humidity of 65% to 90%. Vegetation was characterized by humid forest while soils are sandy-clay type (Guillaumet & Adjanohoun, 1971).

Material: Plant material consisted of okra hybrid variety seed named « Hiré ». It has very hardy plants and a very high germination rate. This seed is used by the majority of farmers of the region. Commercial formulation of a bio-insecticide; LEVO 2.4 SL (Oxymatrin 2% and Prosular 0.4%) and two chemical insecticides; ABALONE 18 EC (Abamectin 18g/l) and VIPER 46 EC (Acetamiprid 16g/l and Indoxacarb 30g/l) were tested. The control of nematodes and fungi for all the treatments was done using Vital 3G (30g/kg Oxamyl) and Banko plus (550 g/l Chlorothalonil and 100 g/l Carbendazime) (MINAGRI, 2015). Fertilization was performed using NPK 12-22-22 and the foliar fertilizer CALLIFERT, rich in trace elements.

Methods

Experimental Design: Field experiment was laid out in Randomized Complete Block Design (RCBD) with four replications and four treatments: (1) the control plots; (2) the plots treated with the bioinsecticide Levo 2.4 at 1 l/ha; (3) the plots treated with the bioinsecticide Abalone 18 EC at 0.5 l/ha and (4) the plots treated with Viper EC at 1 1/ha considered as the reference treatment. Each plot covers an area of 16 m^2 (8 m x 2

m) and contain 40 plants (4 rows of 10 plants). The plants were cultivated with spacing of 0.60 m x 0.40 m. The plots were separated by 1 m and the blocks by 2 m.

Planting and field monitoring: The study was conducted on open-field. The plants were cultivated using local standard agronomic practices, such as fertilization and pesticide application. Two seeds were sown per hole and later thinned to one plant per stand. A maximum of 11 plants were maintained per row. A compound fertilizer of NPK 12-22-22 was applied at the rate of 50 kg/ha in two applications, first during growth, and secondly at flowering. Data were recorded on 10 mid plants per plot. Weeding, hoeing and hilling were realized on a regular basis from planting to harvesting (Eziah *et al*., 2016). Pesticides were applied using a compressed air sprayer (15 l). One sprayer was assigned to each of the treatments and applications are performed every two weeks. A first survey on insect populations and damages was carried out three days before insecticide application. Subsequently, one survey was carried out three days, after each application. The applications and survey of the infestation were carried out from 6 to 9 o'clock in the morning or 4 to 6 o'clock in the afternoon alternatively (Adja *et al*., 2014).

Insect sampling, pest infestation and okra yield evaluation: The field surveys were performed to identify insect communities and determine infestation rate of insect pests. Insect sampling and pest infestation evaluation started three days after insecticide application and pursued every week during eight weeks. The number of insect pests was recorded on ten plants randomly selected in each plot. Insect identification was based on different keys (Michel & Bournier, 1997; Bordat & Arvanitakis, 2004; Poutouli *et al*., 2011). Assessment of insect damages was performed by counting the attacked plants (plants with leaves, flowers, stems or fruits with perforations or traces of insects) using index scale of Reich, 2006 (Table 1). The percentage of healthy and attacked plants was calculated for each treatment. The number of damage fruits and okra yield in each plot were recorded twice a week (Sohail *et al*., 2015) and yield profit rates of treated plots calculated (Adja *et al*., 2014) as:

$$Healthy\ Yield\ Profit\ Rate = (HYTP - HYCP) * 100/HYCP$$

where, HYTP: Healthy Yield on Treated Plot; HYCP: Healthy Yield on Control Plot

Table 1: Scale of damage index caused by insects (Reich, 2006)

Index	Percentage of leaves attacked	Observations
0	Healthy plants	No visible attack
1	Weakly attacked plants	Weak attacks
2	Moderately attacked plants	Moderate attacks
3	Mean attacked plants	Average attacks
4	Strongly attacked plants	Strong attacks
5	Plants totally destroyed or dead	Destroyed plants

Data analysis: Data analyses were performed with STATISTICA 7.1 using one-way ANOVA for larvae populations and number of fruits and Duncan test for the multiple comparison of averages when significant difference at 5%.

RESULTS

Insect collected: Forty thousand and thirty-one (40031) individuals among twenty-eight insect species distributed into 19 families and 10 orders were collected (Table 2). According to their feeding, their damages and their number, some of them were considered as major pests. These are the flea beetles (*Podagrica decolorata*), white flies (*Bemisia tabaci*), aphids (*Aphis gossypii*), jassids (*Jacobiasca* sp), bugs (*Dysdercus wolkerii*) and caterpillars of Lepidoptera (*Syllepte derogata*) (Appendix 1) which represented respectively 9.03; 39.11; 44.59; 1.26; 1.44; 1.36% of the individuals observed. Several others pests were also recorded such as *Nisotra* sp. (Chrysomelidae), *Myzus Persicae* (Aphididae), *Nezara viridula* and *Asparvia armigera* (Pentatomidae), caterpillars of *Anomis flava, Earias sp.,* (Noctuidae) *Spodoptera littoralis* (Gelechiidae), *Zonocerus variegatus, Gryllus lucens, Anacridium sp* (Orthoptera). We also observed the red polyphagous mite *Tetranychus urticae* (Tetranichidae, Acari) which caused damage on okra plants. However, useful insects as predators *Cheilomenes sulphurea* (Coccinellidae), *Lasius niger, Formica rufa, Pachycondyla sylvestrii* (Formicidae), *Chrysoperla sp* (Chrysopidae), *Brachythemis sp, Hemistigma sp.* (Libelliludae), *Sphodromantis lineola, Mantis religiosa* (Mantidae), *Forficula senegalensis* (Forficulidae) and Pollinators *Apis melifera* (Apidae) had been found (Table 2).

Table 2: Inventory of Insect species

Orders	**Families**	**Species**	**Statutes**
Coleoptera	Chrysomelidae	*Podagrica decolorata*	Polyphagous
		Nisotra sp.	Polyphagous
	Coccinellidae	*Cheilomenes sulphurea*	Predators
Homoptera	Aleyrodidae	*Bemisia tabaci*	Phyllophagous and vectors of diseases
	Aphididae	*Myzus Persicae* *Aphis gossypii*	Phyllophagous Polyphagous
	Cicadellidae	*Jacobiasca lybica*	Phyllophagous and vectors of diseases
Heteroptera	Pyrrhocoridae	*Dysdercus wolkerii*	Polyphagous
	Pentatomidae	*Nezara viridula*	Polyphagous
		Asparvia armigera	Phyllophagous
Lepidoptera	Tortricidae	*Syllepte derogata*	Phyllophagous
	Noctuidae	*Anomis flava*	Phyllophagous
		Earias sp.	Fruitivores
	Gelechiidae	*Spodoptera littoralis*	Polyphagous
Hymenoptera	Formicidae	*Lasius niger* *Formica rufa* *Pachycondyla sylvestrii* *Camponotus olivieri*	Predators
	Apidae	*Apis melifera*	Pollinators
Orthoptera	Pyrgomorphidae Gryllidae Acrididae	*Zonocerus variegatus* *Gryllus lucens* *Anacridium sp*	Phyllophagous
Neuroptera	Chrysopidae	*Chrysoperla sp.*	Predators
Odonaptera	Libelliludae	*Brachythemis sp.* *Hemistigma sp.*	Predators
Dictyoptera	Mantidae	*Sphodromantis lineola* *Mantis religiosa*	Predators
Dermaptera	Forficulidae	*Forficula senegalensis*	Predators

Effectiveness of insecticides against the main pests

Podagrica deoclorata: This Coleoptera appeared at the raising (between 25.5±1.29 and 27.75±1.7 individuals per plot). No significant difference ($p>0.05$) was observed among the treatments before spraying (Appendix 1a). Its population started increasing during growth and flowering and decreased during fructification and maturation (Figure 1a). The density of flea beetles was significantly ($p<0.05$) reduced on Viper 46 EC plot (6.75±2.87 to 28±3.56) as compared to Abalone 18 EC (14.5±2.08 to 39±15.38) and Levo 2.4 SL (11.5±1.91 to 34±2.58), which presented lowest number than the control (26.25±6.29 to 65.25±15.65) at the different stages of the plant development (Appendix 2a).

***Bemisia tabaci*:** This Homoptera appeared at the raising (37.75±8, 73 to 41.5±12, individuals a plant per plot). There was no significant difference ($p>0.05$)

among the treatments before spraying (Appendix 1b). Then, this pest population increased slowly in the subsequent plant development stages (growth and flowering) and became important at the following stages (fructification and maturation) (Figure 1b). After the spray, highest mean population of whitefly was observed on control plot (185.25±7.5 to 416±50.67) compared to treated plots during all the stages of plant development (Figure 1b). There were significant differences ($p<0.05$) between the treatments (Appendix 2b). In fact, during growth and flowering, Viper 46 EC (23.5±2.64 to 49.5±5.32) presented lowest number of whitefly compared to Abalone 18 EC (75±10.42 to 75.26±7.08) and Levo 2.4 SL (48±3.91 to 75±3.55). But, during fructification and maturation, no significant difference had been recorded among plots treated with Viper 46 EC (171.25±36.94 to 215.25±14.81), Levo 2.4 SL (215.25±14.81 to 182.25±43.79) and Abalone 18 EC (176±18.63 to 190.75±41.09).

***Aphis gossipii*:** This Homoptera appeared at the raising (68.25±35.08 to 79.75±25.94 individuals a plant per plot), but there was no significant difference among the treatments, before spraying ($p>0.05$) (Appendix 1c). Then, this pest population increased slowly in the subsequent plant development stages (growth and flowering) and became important at the following stages (fructification and maturation) (Figure 1c). After the spray, highest mean population of Aphids was observed on control plot (147±2.45 to 560±34.09) compared to treated plots during all the stages of plant development (Figure 1c). There were significant differences among the treatments ($p<0.05$) (Appendix 2c). In fact, during growth and flowering, Viper 46 EC (11.25±3.86 to 45.25±11.92) presented lowest number than Abalone 18 EC (41.75±5.91 to 93±21.49), and Levo 2.4 SL (46.5±9.46 to 96.75±15.08). But, during fructification and maturation, Viper 46 EC (139.5±25.64 to 167.25±26.01), Abalone 18 EC (190.25±31.65 to 224±23.11) and Levo 2.4 SL (147.25±12.65 to 181±28.77) presented close populations (Appendix 1c).

***Jacobisca lybica*:** This Homoptera appeared at the raising (3±0.81 to 3.75±1.25 individuals a plant per plot), but there was no significant difference among the treatments, before spraying ($p>0.05$) (Appendix 1d). Then, this pest population increased slowly in the subsequent plant development stages (growth and flowering) and became increased rapidly at the following stages (fructification and maturation) (Figure 1d). After the spray, highest mean population of jassids was observed on control plot (5.5±1.29 to 16.75±2.75) compared to treated plots during all the stages of plant development (Figure 1d). There were significant differences between the treated plots and control plots ($p<0.05$) (Appendix 2d). However, the number of jassids on Levo 2.4 SL plots (0.5±1 to 6.25±2.62), Abalone 18 EC plots (2.5±1.29 to 9.5±1.29) and Viper 46 EC plots (0.5±1 to 8±1.63) were closed during growth, flowering, fructification and maturation.

Dysdercus wolkerii: This Heteroptera was absent at raising (before spraying). It appeared at the end of the growth (less than 2.5±1.29 individuals a plants per plot). This pest population increased and at the subsequent plant development stages (growth, flowering, fructification and maturation) (Figure 1e). After the spray, highest mean population of bugs was observed on control plot (2.5±1.9 to 25±3.55) compared to treated plots during all the stages of plant development (Figure 1e). There were significant differences between the treated plots and control plots ($p<0.05$) (Appendix 2e). However, the number of bugs on Levo 2.4 SL plots (0.75±0.95 to 7.75±3.86), Abalone 18 EC plots (3.5±0.57 to 6±2.94) and Viper 46 EC plots (less than 2.25±0.95) were pretty close during growth, flowering, fructification and maturation.

***Syllepte derogata*:** This Lepidoptera was absent at raising (before spraying) (Figure 2f). It appeared at the growth (0.5±1 to 2.25±1.7 a plant per plot). This pest population fluctuated at the subsequent plant development stages (growth, flowering, fructification and maturation) (Figure 1f). After the spray, highest mean population of caterpillars were observed on control plot (3.5±1.29 to 36±2.16) compared to treated plots during all the stages of plant development (Figure 2f). During flowering, there were significant differences ($p<0.05$) between the treated plots (Appendix 1f). Viper 46 EC plot (0.75±0.95 to 1±1.41) presented lowest number of caterpillars than Abalone 18 EC (2±1.15 to 3.25±1.25) and Levo (6.25±2.63 to 7.5±2.38). But, during the fructification and maturation, plots treated with Viper 46 EC (1±0.81), Abalone 18 EC (1.25±0.95 to 1.75±1.25) and Levo 2.4 SL (2±0.81 to 2.5±1.29) presented close populations.

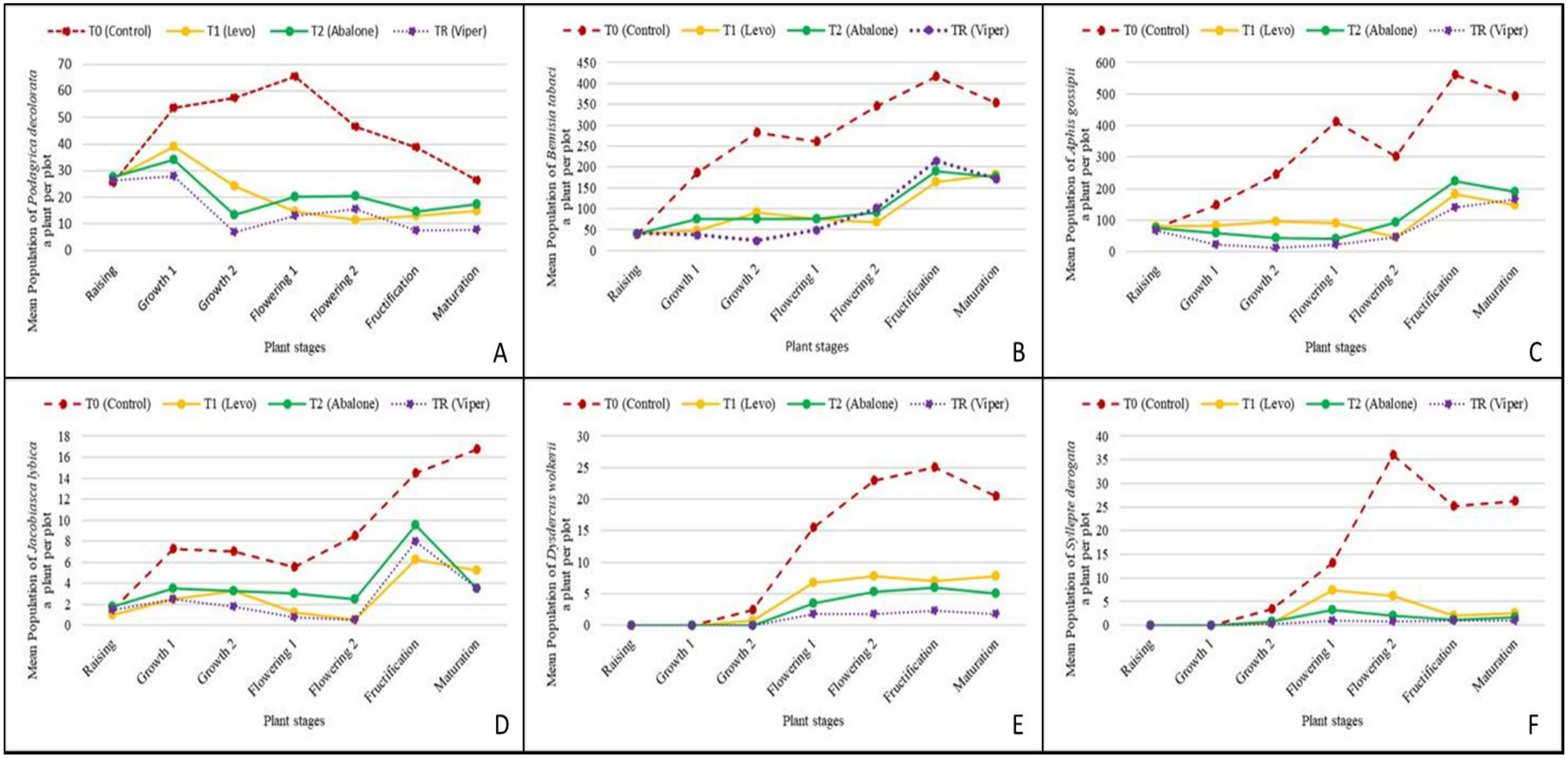

Figure 1: Evolution of mean insect number on okra plants: (A) *Podagrica deoclorata*; (B) *Bemisia tabaci*; (C) *Aphis gossipii*; (D) *Jacobisca lybica*; (E) *Dysdercus wolkerii* and (F) *Syllepte derogata*.

Infestation and damage caused by the main pests on okra: Before the spray (raising), the majority of okra plants (88%) were healthy (index 0) compared to 12% of attacked plants (index 1). The infestation level was low on all the plots. After the spray, all the plants on untreated plots presented high infestation. In fact, on control plots, 100% of plants were attacked (index 2 to 4) at subsequent plant development stages (growth, flowering, fructification and maturation). However, on the treated plots with the bioinsecticide (Levo 2.4 SL), 60% of plants were healthy (index 0). Then attacked plants on those plots (40%) presented index 1 to 3. On plots treated with the chemical insecticides; Abalone 18 EC and Viper 46 EC, 77.5% to 90% of plants were healthy while 10 to 22.5% attacked plants had index 1 to 2. Regarding to the damages, flea beetles (Coleoptera) chew small holes in the leaves since while aphids, white fly and jassids (Homoptera) and bugs (Heteroptera) suck the sap from okra since rising to maturation. Then, earworms (Lepidoptera) eat the fruit and leaves since flowering to maturation.

Effect of the treatments on okra yield: Yield of okra were varied significantly in different treatment (Table 3). Highest fruit yield of okra was recorded in treated plot with Viper 46 EC (12.55±0.98 t/ha), followed by Abalone 18 EC (12.2±0.8 t/ha) and Levo 2.4 SL (11.15±1.09 t/ha). Whereas, the lowest yield obtained from control plots was 6.84±0.15 t/ha (Table 3). Yield on Viper 46 EC plot and Abalone 18 EC plot were similar, but higher than yield on Levo 2.4 SL plot. The total number of fruits harvested were significantly higher on treated plot (895.25±74.62 to 969.75±91.91) compared to control plots (543±20.78) (Table 3). In addition, the rate of healthy fruits on treated plots (74.91±3.18 to 80.31±7.09%) were significantly higher ($p<0.05$) than these on control plots (41.26±5.11%), However, the rate of attacked fruits on treated plots (19.68±7.09 to 25.73±5.11%) were significantly lower ($p<0.05$) than the control one (58.73±5.11%). Then, yield profit rate due to insecticide spray on plots treated with Levo 2.4 SL, Abalone 18 EC and Viper 46 EC were respectively 62.82; 78.18 and 83.28%.

Table 3: Yield of on Okra

	Treatments				
	T0 (Control)	**T1 (Levo)**	**T2 (Abalone)**	**T3 (Viper)**	**P**
Total number of fruits	543±20.78 a	895.25±74.62 b	947.5±111.85 b	969.75±91.91 b	0.00002
Number of healthy fruits	223.42±20.81 a	671.91±80.86 b	738.12±50.82 bc	774±97.43 c	0.00001
Number of attacked fruits	319.57±38.39 b	225.02±18.33 a	209.37±68.78 a	195.74±86.6 a	0.047
Healthy fruits Rate (%)	41.26±5.11 a	74.91±3.18 b	78.28±4.7 b	80.31±7.09 b	0.00001
Attacked fruits Rate (%)	58.73±5.11 b	25.73±5.11 a	21.71±4.7 a	19.68±7.09 a	0.00001
Productions (kg/plot)	10.95±0.24 c	17.84±1.74 b	19.52±1.43 bc	20.08±1.57 c	0.00001
Yield (t/ha)	6,84±0,15 a	11.15±1.09 b	12.2±0.8 bc	12.55±0.98 c	0.00001

DISCUSSION

Twenty-eight (28) insect species among 19 families and 10 orders were recorded. The main insect pests of okra observed were flea beetles (*Podagrica decolorata*), white flies (*Bemisia tabaci*), jassids (*Jacobiasca* sp), aphids (*Aphis gossypii*) and caterpillars of Lepidoptera (*Syllepte derogata*). Those insects had been reported in Cote d'Ivoire (Gnago *et al*., 2010), Ghana (Asare-Bediako, 2014a; Asare-Bediako, 2014b), Nigeria (Adewusi & Oshipitan, 2013), India (Bhatt *et al*., 2018) and Pakistan (Shabozoi1 *et al*., 2011; Bhutto *et al*., 2017). We also observed the red polyphagous mite, *Tetranychus urticae* (Tetranichidae, Acari). This mite is a serious pest of vegetables, fruits and field crops in Ghana but hardly noticed by farmers (Eziah *et al*., 2016). In addition to the main pests, several pests among the families of Chrysomelidae, Aphididae, Pentatomidae, Noctuidae, Gelechiidae, Orthoptera had been recorded in the field as reported in Cote d'Ivoire (Gnago *et al*., 2010), Nigeria (Adewusi & Oshipitan, 2013) and Pakistan (Solangi & Lohar, 2007).

Otherwise, the inventory revealed useful insects. The predators were Coccinellidae, Formicidae, Chrysopidae, Libelliludae, Mantidae and Forficulidae. Several authors reported the same families of predators in Pakistan (Solangi & Lohar, 2007), Sudan (Satti & Bilal, 2012) and India (Bhatt *et al.,* 2018). The pollinator was *Apis*. Connolly (2013), Kumar *et al*. (2018) and Nandhini *et al*. (2018) reported bees (Apidae) as the main pollinators ok okra. The studies showed that the chemical insecticides Viper and Abalone reduced pest population compared to bio-insecticide (Levo) which reduced significantly the pest populations than the control. The efficiency of these insecticides on the pests could be attributed to the action of the chemical, the formulation or to the diet of the pests. Viper contained Acetamiprid (Neonicotinoids) and Indoxacarb (Oxadiazins). Acetamiprid is a systemic ingredient that acts by contact and ingestion on Hemiptera, Thysanoptera and Coleoptera. Indoxacarb (Oxadiazines) is neurotoxic and also acts by contact and ingestion on Lepidoptera caterpillars (Zekeya *et al*., 2017). So, affected insects stop feeding, are paralyzed and die (Zekeya *et al*., 2017). Levo contained Oxymatrin (Quinolizidine) and Prosular (Alcaloïds). Levo SL exerts its function mainly by direct contact and as stomach insecticide and has additional anti-feeding and repelling effects. The natural active ingredient of Levo is extracted and derived directly from the seeds of *Sophora flavescens*. Insects treated with Levo display breath inhibition and motion imbalance symptoms related to the Central Nervous System (Sineria. 2019). It controls white flies, jassids, aphids and flea beetles. Its effectiveness against Homoptera and flea beetles may also be due to anti-appetizing and repellent substances. On caterpillars, its effect is average compared to Viper which presents high effect on Lepidoptera because of indoxacabe, compared to control. In Ghana Aetiba & Osekre, (2016) and Eziah *et al.* (2016) reported effectiveness of Levo respectively on okra insect pest and on spider mites. On plots tested with Abalone, white flies, aphids, jassids, caterpillars and flea beetles are moderately controlled. Abamectin (Avermectins) is an insecticide-acaricide which acts by contact with stomach action and has translaminar activity. Abamectin penetrates into the leaf on which it has been applied. It remains stored in the leaf and protects it against all the pests (Novelli *et al*., 2012). It's therefore a broad-spectrum insecticide which shown average efficacy on pests of Malvaceae including cotton (N'guessan, 2008). The treatments allowed to reduce the damage caused by insects. There is therefore a close relationship between the infestation level of the plots and the damage caused by the insects on okra plants. In fact, treated plots harbor few pests and have low, moderate and average infestations and damages to the various organs. Thus, the increase of the number of insects on the plots causes the evolution of the damages and increases the numbers of attacked plants on treated plots (severity damages ranging from 1 to 4). The Integrated Pest Management (IPM) approach significantly reduce populations of aphids, whiteflies, leafhoppers, leaf miners, fruit borer damage and incidence of virus and mildew, coupled with an increase in shoot and root growth and natural enemy populations as compared to the farmer's practice which consisted of the use of conventional pesticides (Mohankumar *et al*., 2016). Indigenous plant extracts could be possible alternate option in insect pest management program. There also showed minimum fruit damage and increase yield (Gnago *et al*., 2010; Asare-Bediako *at al.,* 2014a; Asare-Bediako *at al*., 2014b; Ali *et al*., 2015). Shabozoi1 *et al*. (2011) showed that there was negative correlation between insect pests and natural enemies' population. It was concluded that biopesticides are safe to natural enemies and integration of biopesticides with natural enemies have good impact on crop yield parameters. Total number of fruits, yield, attacked and healthy fruits are used to compare treatments. The spray of the insecticides improve production. Treated plots have significantly higher yields than untreated plots. There is also a close relationship between plot infestation level, insect damage and yield. In fact, plots treated with Levo, Abalone and Viper harbouring few insect pests, record little damage on the various organs. Consequently, yield on these treatments is greater than untreated plots. Mohankumar *et al*. (2016) reported that the yield increase in the IPM plots was 12.43 to 45.54% above the farmers practice. Otherwise, the adoption of poor agronomic practices by the farmers was the major contributing factor for the high incidences and severities of diseases and pests damage in their farms (Asare-Bediako et al., 2014c).

CONCLUSION AND PROSPECTS

The present study on evaluation of the efficacy of a bio-pesticide for eco-friendly management of okra pests revealed that the bio-pesticide Levo 2.4 SL (Oxymatrin 2% and Prosular 0.4%) presents average effective against the pests compared to chemical insecticides; Abalone 18 EC (Abamectin 18g/l) and Viper 46 EC (Acetamiprid 16g/l and Indoxacarb 30g/l) which had high efficiency. Application of insecticides allowed to control the populations of okra pests, reduced their damage, and then, improved yield compared to control plots. Therefore, Levo 2.4 SL can be an alternative eco-friendly management option against okra pests in field.

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REFERENCES

Adewusi, O. F. & Oshipitan A. A., 2013. Effects of Chemical Constituents on Insect Pest Population in West African Okra, Abelmoschus. *Journal of Agriculture and Veterinary Science*. 5(1):23-29.

Adilakshmi A., Korat D.M. & Vaishnav P.R., 2008. Bio-efficacy of some botanical insecticides against pests of Okra. *Karnataka Journal of Agricultural Sciences*; 21(2):290-292.

Adja N. A., Danho M., Alabi T. A. F., Gnago A. J., Zimmer J-Y, Francis F., Kouassi K. P., Baudoin J-P & Zoro Bi I. A., 2014. Entomofaune associée à la culture de cucurbites oléagineuses africaines (*Lagenaria siceraria* Molina (Standl. 1930) et *Citrullus lanatus* Thumb (Matsum & Nakai 1916)) et impact des ravageurs sur la production. *Annales de la Société Entomologique de France (N.S.): International Journal of Entomology*, 50: 3-4, 301-310.

Aetiba J. P. N & Osekre E. A., 2016. Management of Insect Pests of Okra (*Abelmoschus esculentus* L. Moench) Using Oxymatrine-based Insecticide. *Advances in research, SCIENCEDOMAIN International*. 6(1):1-7.

Ali H., Iqbal J., Hassan M. W. & Jami M., 2015. Evaluation of indigenous plant extracts against sucking insect pests of okra crop. *Pakistan Entomologist*. 37(1):39-44.

Iqbal, J., H. Ali, M.W. Hassan and M. Jamil, 2015. Evaluation of indigenous plant extracts against sucking insect pests of okra crop. Pak.
Entomol., 37(1):39-44.

Asare-Bediako, E., Addo-Quaye, A.A. & Bi-Kusi, A., 2014a. Comparative efficacy of phytopesticides in the management of Podagrica spp and mosaic disease on okra (Abelmoschus esculentus L.). *American Journal of Experimental Agriculture*. 4(8), 879-889.

Asare-Bediako, E., Addo-Quaye, A. A. & Bi-Kusi, A., 2014b. Comparative efficacy of plant extracts in managing whitefly (Bemisia tabaci Gen) and leaf curl disease in okra (Abelmoschus esculentus L). *American Journal of Agricultural Science and Technology*, 2(1), 31-41.

Asare-Bediako E., Van Der Puije G.C., Taah K. J., Abole E.A. & Baidoo A., 2014c. Prevalence of Okra Mosaic and Leaf Curl Diseases and Podagrica spp. Damage of Okra (*Albelmoschus esculentus*) Plants. *International Journal of Current Research and Academic Review*. 2 (6): 260-271.

Bhatt B., Joshi S. & Karnatak A.K., 2018. Biodiversity of insect pests and their predators on okra agroecosystem. *Journal of Pharmacognosy and Phytochemistry*. 7(4): 84-86.

Bhutto Z. A., Magsi F. H., Soomro A. A., Chandio M. A., Channa N. A., Lashari S. H., Mangi S. & Junejo A. A. 2017. Integrated pest management of Okra insect pests. *International Journal of Fauna and Biological Studies*; 4(3): 39-42.

Connolly C. N. 2013. The risk of insecticides to pollinating insects. *Communicative & Integrative Biology*. 1: 6(5), e25074.

Eziah V. Y., Buba R. B. & Afreh-Nuamah K., 2016. Susceptibility of two spotted spider mite *Tetranychus urticae* KOCH (Acari; Tetranychidae) to some selected miticides in the Greater Accra Region of Ghana. *International Journal of Biology and Chemical Sciences*. 10(4): 1473-1483.

Gnago J. A., Danho M., Agnéroh. A. T, Fofana. I. K. & Kohou A. G., 2010. Efficacité des extraits de neem (*Azadirachta indica*) et de papayer

(*Carica papaya*) dans la lutte contre les insectes ravageurs du gombo (*Abelmoschus esculentus*) et du chou (*Brassica oleracea*) en Côte d'Ivoire. *International Journal of Biology and Chemical sciences*, 4(4): 953-966.

Guillaumet J. L. & Adjanohoun E., 1971. La Végétation de la Côte d'Ivoire; *In* Le Milieu naturel de Côte d'Ivoire. O.R.S.T.OM., Paris. 157-266.

Huang Z., Wang B., Eaves D.H., Shikany J. M. & Pace R. D., 2007. Phenolic compound profile of selected vegetables frequently consumed by African Americans in the southeast United States. *Food Chemistry*, 103:13951402.

Kumar S., Joshi P. C., Nath P. & Singh V. K., 2018. Impacts of Insecticides on Pollinators of Different Food Plants. *Entomol Ornithol Herpetol*. 7 (2). 7 p. 2161-0983.1000211.

Mccaffery A.R., 1998. Resistance to insecticides in Heliothine Lepidoptera: a global view. Philos. Trans. R. Soc. London; 353:1735-1750.

MINAGRI, 2015. Index Phytosanitaire. Ministère de l'Agriculture (MINAGRI / DPVCQ), FIRCA, WAAPP / PPAAO. Côte d'Ivoire, 47ème édition, 536 P.

Mohankumar S., Karthikeyan G., Durairaj C., Ramakrishnan S., Preetha B. & Sambathkumar S., 2016. Integrated Pest Management of Okra in India. *In* Integrated Pest Management of tropical vegetables crops: 167-177.

Nandhini E., Padmini K., Venugopalan R., Anjanappa M. & Lingaiah H. B., 2018. Flower - visiting insect pollinators of okra [Abelmoschus esculentus (L.) Moench] in Bengaluru region. *Journal of Pharmacognosy and Phytochemistry*. 7(2): 1406-1408.

Novelli A., Vieira B. H., Vasconcelos A. M., Peret A. C. & Espindola E.L.G., 2012. Field and laboratory studies to assess the effects of Vertimec® 18EC on *Daphnia similis. Ecotoxicology and Environmental Safety*: 75: 87-93.

N'guessan W. P., 2008. Etude de l'efficacité de l'Emamectine (Avermectine) et du Spinoteram (Spinozine) sur les principaux ravageurs du cotonnier en Côte d'Ivoire: nouvelles approches de la gestion de la résistance de *Helicoverpa armigera* (Lepidoptera, Noctuidae, Hûbner, 1908) aux Pyrethrinoïdes, Mémoire de Diplôme d'Agronomie Approfondie, option Défense des Cultures, INP-HB/ESA Yamoussoukro, 95 p

Priya B. S. & Misra H. P., 2007. Biopesticides for the management of okra fruit borer, *Earias vitella* (Fabricius). Pest Management in Horticultural Ecosystems, short note 13(2):176-179.

Rawat R. R. & Shau H. R. (1983). Estimation of loss in growth and yield of okra due to Earias spp. *Indian Entomology*, 35 (3): 252-254.

Sardana R., Arora S., Singh D. K. & Kadu L.K., 2004. Development and validation of adaptable IPM in egg plant, *Solanum melongena* L. in a farmer's participatory approach. *Indian Journal of Plant Protection*; 32:123-125.

Sarkar S., Patra S. & Samanta A., 2016. Efficacy of different bio-pesticides against sucking pests of okra (Abelmoschus esculentus L. Moench). *Journal of Applied and Natural Science*. 8 (1): 333 - 339

Satti A. A. & Bilal. N. A. A., 2012. The major predators and their seasonal abundance in okra fields at elgorair scheme, northern sudan. The Experiment, December. 4 (4), 271-276.

Shabozoi1 N. U. K., Abro G. H., Syed T. S. & Awan M. S., 2011. Economic Appraisal of Pest Management Options in Okra. *Pakistan Journal of Zoology*. 43(5): 869-878.

Silva G. A., Picanço M. C., Bacci L., Crespo A. L. B., Rosado J. F. & Guedes R. N. C., 2011. Control failure likelihood and spatial dependence of insecticide resistance in the tomato pinworm, *Tuta absoluta*. *Pest Management Science*. 67(8): 913-920.

Sineria., 2019. Levo SL TW; Sophora flavescens plant extract Biological Insecticide. SINERIA. Randwycksingel 20-A015, 6229 EE Maastricht, The Netherlands info@sineria.com / www.sineria.com. 4 p.

Sohail K., Jan S., Usman A., Shah S. F., Usman M., Shah M., Mashwani M. A. & Mehmood A., 2015. Evaluation of some botanical and chemical insecticides against the insect pests of okra. *Journal of Entomology and Zoology Studies* 3 (2): 20-24

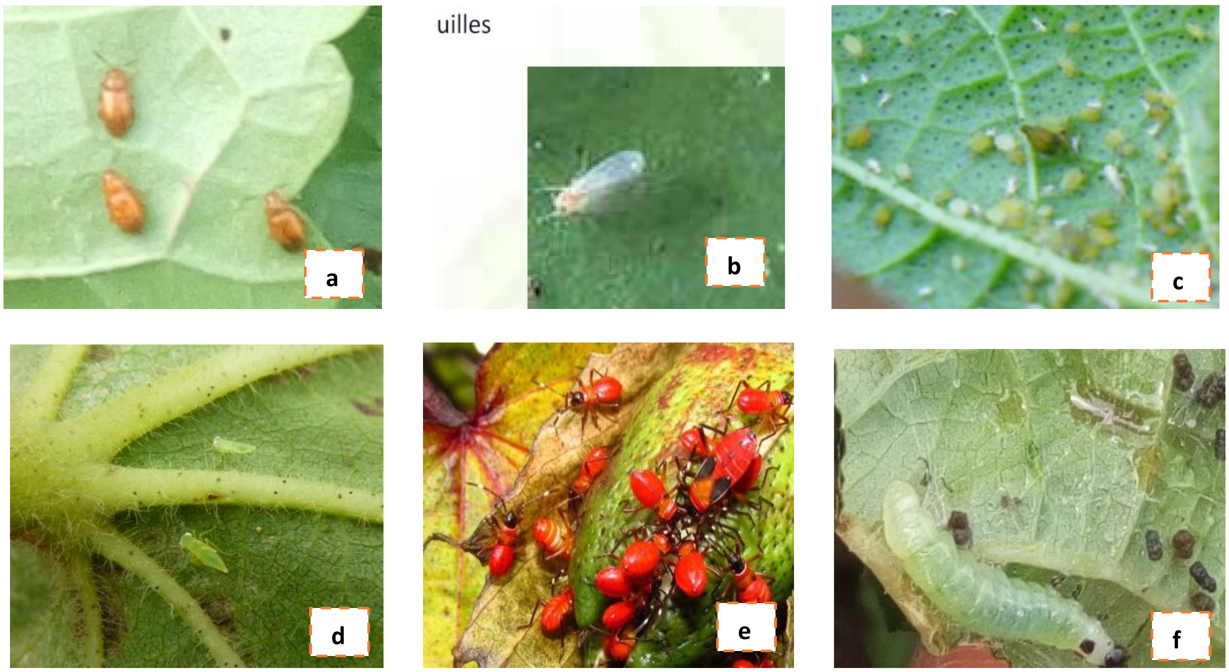
Solangi B. K. & Lohar M. K., 2007. Effect of some Insecticides on the population of insects Pests and Predators on Okra. *Asian journal of Plant Sciences*. 6: 920-926.

Tisler T. & Erzen N. K., 2006. Abamectin in the aquatic environment. *Ecotoxicology.* 15, 495-502.

Zekeya N., Ndakidemi P. A., Chacha M. & Mbega E., 2017. Tomato Leafminer, *Tuta absoluta* (Meyrick 1917), an emerging agricultural pest in Sub-Saharan Africa: Current and prospective management strategies. *African Journal of Agricultural Research*. Academic Journals. 12(6): 389-396.

APPENDIX

Appendix 1 : Main insect pests founded on okra plants



Appendix 1 : Main insect pests founded on okra plants
Podagrica deoclorata (a); *Bemisia tabaci* (b); *Aphis gossipii* (c); *Jacobiasca* sp. (d); Larvae of *Dysdercus wolkerii* (e) and *Syllepte derogata* (f)

Appendix 2 : ANOVA of Mean population of the majors insect pests on okra plants

Appendix 2a: ANOVA of Mean number of *Podagrica deoclorata* on Okra plants

	Raising	Growth1	Growth 2	Flowering 1	Flowering 2	Fructification	Maturation
To (Control)	25.5±1.29 a	53.75±3.86 c	57.25±14.63 c	65.25±15.65 c	46.5±7.37 b	38.75±6.29 c	26.25±6.29 c
T1 (Levo)	27±5.35 a	39±15.38 b	24.25±3.86 b	14.5±3.31 b	11.5±1.91 a	13±1.82 b	15±4.08 b
T2 (Abalone)	27.75±1.7 a	34±2.58 ab	13.25±2.21 ab	20.25±4.35 b	20.5±7.37 a	14.5±2.08 b	17.5±4.2 b
TR (Viper)	26.5±1.73 a	28±3.56 a	6.75±2.87 a	13±3.74 a	15.5±3 a	17.5±1.29 a	7.75±2.21 a
P	0.7602	0.0052	0.00001	0.00001	0.00001	0.00001	0.0006

Appendix 2b: ANOVA of Mean number of *Bemisia tabaci* on Okra plants

	Raising	Growth1	Growth 2	Flowering 1	Flowering 2	Fructification	Maturation
To (Control)	37.75±8.73 a	185.25±7.5 c	283.25±32.77 c	260.25±19.5 c	346±61.31 b	416±50.67 b	352.75±13.5 b
T1 (Levo)	39.25±4.57 a	48±3.91 a	91±13.44 b	75±3.55 b	68.25±17.5 a	165±26.45 a	182.25±43.79 a
T2 (Abalone)	40.75±2.06 a	75±10.42 b	75±4.08 b	75.26±7.08 b	91.5±14.66 a	190.75±41.09 a	176±18.63 a
TR (Viper)	41.5±12.01 a	37.5±6.24 a	23.5±2.64 a	49.5±5.32 a	101.5±13.91 a	215.25±14.81 a	171.25±36.94 b
P	0.907	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001

Appendix 2c: ANOVA of Mean number of *Aphis gossipii* on Okra plants

	Raising	Growth1	Growth 2	Flowering 1	Flowering 2	Fructification	Maturation
To (Control)	75±30.73 a	147±2.45 d	246±44.09 c	411.5±36.44 c	302.5±34.33 b	560±34.09 c	493.5±41.9 b
T1 (Levo)	79.75±25.94 a	83.75±4.11 c	96.75±15,08 b	90.75±8.65 b	46.5±9.46 a	181±28.77 ab	147.25±12.65 a
T2 (Abalone)	74±27.27 a	58.75±4.64 b	42.5±8.22 ab	41.75±5.91 a	93±21.49 a	224±23.11 ab	190.25±31.65 a
TR (Viper)	68.25±35.08 a	23.75±4.78 a	11.25±3.86 a	21.75±7.23 a	45.25±11.92 a	139.5±25.64 a	167.25±26.01 a
P	0.958	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001

Appendix 2d: ANOVA of Mean number of *Jacobiasca lybica* on Okra plants

	Raising	Growth1	Growth 2	Flowering 1	Flowering 2	Fructification	Maturation
To (Control)	1.5±0.57 a	7.25±1.7 b	7±0.81 b	5.5±1.29 b	8.5±3.87 b	14.5±3.31 b	16.75±2.75 b
T1 (Levo)	1±0.81 a	2.5±1.29 a	3.25±1.25 a	1.25±1.25 a	0.5±1 a	6.25±2.62 a	5.25±1.7 a
T2 (Abalone)	1.75±0.95 a	3.5±1.29 a	3.25±1.5 a	3±1.41 a	2.5±1.29 a	9.5±1.29 a	3.5±1.29 a
TR (Viper)	1.5±1.29 a	2.5±1 a	1.75±0.95 a	0.75±0.95 a	0.5±1 a	8±1.63 a	3.5±1.29 a
P	0.727	0.0008	0.00024	0.00064	0.00057	0.00207	0.00001

Appendix 2e: ANOVA of Mean number of *Dysdercus wolkerii* on Okra plants

	Raising	Growth1	Growth 2	Flowering 1	Flowering 2	Fructification	Maturation
To (Control)	0±0	0±0	2.5±1.9 b	15.5±2.64 c	23±4.69 b	25±3.55 c	20.5±3.31 c
T1 (Levo)	0±0	0±0	0.75±0.95 a	6.75±2.36 b	7.75±4.19 a	7±2.58 b	7.75±3.86 b
T2 (Abalone)	0±0	0±0	0±0 a	3.5±0.57 a	5.25±3.86 a	6±2.94 a	5±3.36 ab
TR (Viper)	0±0	0±0	0±0 a	1.75±1.71 a	1.75±0.95 a	2.25±0.95 a	1.75±0.95 a
P			0.0025	0.00001	0.00001	0.00001	0,00001

Appendix 2f: ANOVA of Mean number of *Syllepte derogata* on Okra plants

	Raising	Growth1	Growth 2	Flowering 1	Flowering 2	Fructification	Maturation
To (Control)	0±0	0±0	3.5±1.29 b	13.25±3.77 c	36±2.16 c	25.25±4.11 b	26.25±5.56 b
T1 (Levo)	0±0	0±0	0.5±1 a	7.5±2.38 b	6.25±2.63 b	2±0.81 a	2.5±1.29 a
T2 (Abalone)	0±0	0±0	0.75±0.95 a	3.25±1.25 ab	2±1.15 ab	1.25±0.95 a	1.75±1.25 a
TR (Viper)	0±0	0±0	0.25±0.5 a	1±1,41 a	0.75±0.95 a	1±0,81 a	1±0.81 a
P			0,0016	0,00004	0,00001	0,00001	0,00001