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SUSCEPTIBILITY OF COTTON LEAFHOPPER *Jacobiella facialis* (HEMIPTERA: CICADELLIDAE) TO PRINCIPAL CHEMICAL FAMILIES: IMPLICATIONS FOR COTTON PEST MANAGEMENT IN CÔTE D'IVOIRE

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ABSTRACT

Jacobiella facialis is a sucking insect pest of cotton in Côte d'Ivoire. Heavy infestations on cotton resulted in shedding of leaves, squares, young bolls and subsequently lead to significant yield losses. In recent years, attacks of the jassid remain persistent throughout the entire crop cycle despite insecticide treatments. Susceptibility tests of ten (10) active ingredients (chlorpyrifos-ethyl, profenofos, acetamiprid, imidacloprid, alpha-cypermethrin, lambdacyhalothrin, spinoteram, sulfoxaflor, spinosad and chlorantraniliprole) were performed against pest populations collected in Bouaké by leaf-dip method n° 15 proposed by Insecticide Resistance Action Commitee (IRAC 15, version 3). Lethal concentrations LC_{50} and LC_{90} were determined for all active ingredients. To compare susceptibility between different field strains, discriminate concentrations (LC_{90}) for the most toxic active ingredients were tested by the same method on jassid populations from five localities (Korhogo, Boundiali, Ferké, Ouangolo and Niakara). Five active ingredients, chlorpyrifos-ethyl, profenofos, acetamiprid, alpha-cypermethrin and imidacloprid, with respective lethal concentrations (LC_{50}) of 0.0012, 0.011, 0.024, 0.057, 0.070 mg/ml, were the most toxic to jassid, while spinosad and chlorantraniliprole were the least toxic as LC_{50} values were 1.616 mg/ml and 5.4 mg/ml respectively. Data collected on discriminate concentrations (LC_{90}) for four active ingredients did not revealed any significant difference between the susceptibility levels of jassid strains. However, it was noted that survival rates were consistently high in strain collected from Boundiali and Korhogo, indicating low heterogeneity within some field populations. The results have provided important information on active ingredients to consider when developing pest management programs.

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1 Introduction

Cotton is a major commercial crop grown in the Center and Northern areas of Côte d'Ivoire. It contributes to social and economic development of the populations living in these parts of the country (Koffi, 2013). Cotton crop is however subject to many constraints which deteriorate its production and fall of income for farmers. Cotton suffers from insect pest attacks throughout its growing season (Gangadhar et al., 2007). Indeed, cotton parasitism in Côte d'Ivoire is particularly diversified by comprising bollworm complex (*Helicoverpa armigera*, *Thaumatotibia leucotreta*, *Pectinophora gossypiella*) and sucking pests (*Aphis gossypii*, *Bemisia tabaci*, *Jacobiella facialis*) (Vaissayre et al., 1995; Ochou & Martin, 2002; Ochou, 2011).

Among the various strategies adopted by farmers to manage pest damage, insecticides are the first line of defense. The repeated use of chemical formulations for crop protection can however lead to several risks. Among many other risks, development of insecticides resistant in pest populations is most common one. For instance, in Côte d'Ivoire, the massive and repeated usage of pyrethroïds has led to the selection of resistant populations of *Helicoverpa armigera* against this family of insecticides (Martin et al., 2000). Consequently, a strategy of management and prevention of resistance against pyrethroïd has been developed since 1998 to deal with this major pest (Ochou & Martin, 2002; Djihinto et al., 2016). It aims to reduce the use of pyrethroïd by selecting their chemical alternatives (benzoylurea, diamides, organophosphorus, avermectines, etc.) to ensure part of the foliar treatments.

Despite the successful adoption of this strategy of protection, a number of previously minor pests caused increasing damage to cotton plants over the past 5 years, thus becoming more important pest. A large number of cotton growers are complaining about the persistence of severe infestations of leafhoppers *J. facialis* causing shedding of squares, young bolls, and leading subsequently to significant yield losses. In fact, jassid outbreaks occur throughout the crop production cycle. Damages are increasingly noticeable years after years (Koné et al., 2017).

With regard to the recent pest status, regular monitoring of its susceptibility to commonly used insecticides is necessary. The present study aimed to determine the susceptibility of jassid (*J. facialis*) against major active insecticides family in order to ensure judicious selection of insecticides for intensive management of jassid (*J. facialis*) in Côte d'Ivoire.

2 Materials and Methods

2.1 Study area

The study on susceptibility of *J. facialis* to various insecticides was carried out at the Cotton Entomology laboratory located in Bouaké (7°67'N, -5° 09'W). The response of *J. facialis* after exposing to discriminate concentrations was undertaken in five localities within the cotton growing area (Figure 1), precisely in Korhogo (9°27'N, -5°37'W), Boundiali (9°52'N, -6°47'W), Ferké (9°6'N, -5°2'W), Ouangolo (9°97'N, -5,15'W) and Niakara (8°67'N, -5° 28'W).

2.2 Materials

2.2.1 Target pest insect

This study was performed on adults *Jacobiella facialis* Jacobi, 1912 (Cicadellidae), a sap sucking pest of cotton which lives underside of leaves. These are small in size, ranging in colour from green, through yellow-green to brown. Severe infestation may cause plants to shed squares and small bolls although this rarely happens. Larger bolls may turn soft and spongy and fail to mature (Godfrey et al., 2008; Madar & Katti, 2010; Selvaraj et al., 2011).

2.2.2 Jassid collections

The jassid collection was performed on cotton plants in farmers' field and all stages of insect were collected. The captured insects were collected in a cage having young cotton plant and covered with muslin clothes in order to bring them back to laboratory according to the method of Ahmad et al. (1999).

2.2.3 Insecticidal formulations

Ten (10) active ingredients of commercial formulations which were used for the bioassays are presented in Table 1. They belong to different chemical families and are from various sources.

2.3 Methods

Bioassays were performed on *J. facialis* adults, collected from field and reared under laboratory conditions up to the 1st generation, using leaf-dip method n°15 proposed by Insecticide Resistance Action Committee (IRAC 15, version 3). Several insecticidal concentrations were prepared by diluting these formulations in distilled water. Cotton leaf disc (55 mm diameter) were cut and dipped with gentle agitation into test solution for 20 seconds or in distilled water to serve as a control. These leaf discs allowed to surface-dry on an absorbent paper. Then, these were positioned on agarose gel (6 g/l) cast at the bottom of petri dish with upper surface of the leaf against gel. Ten (10) adults of

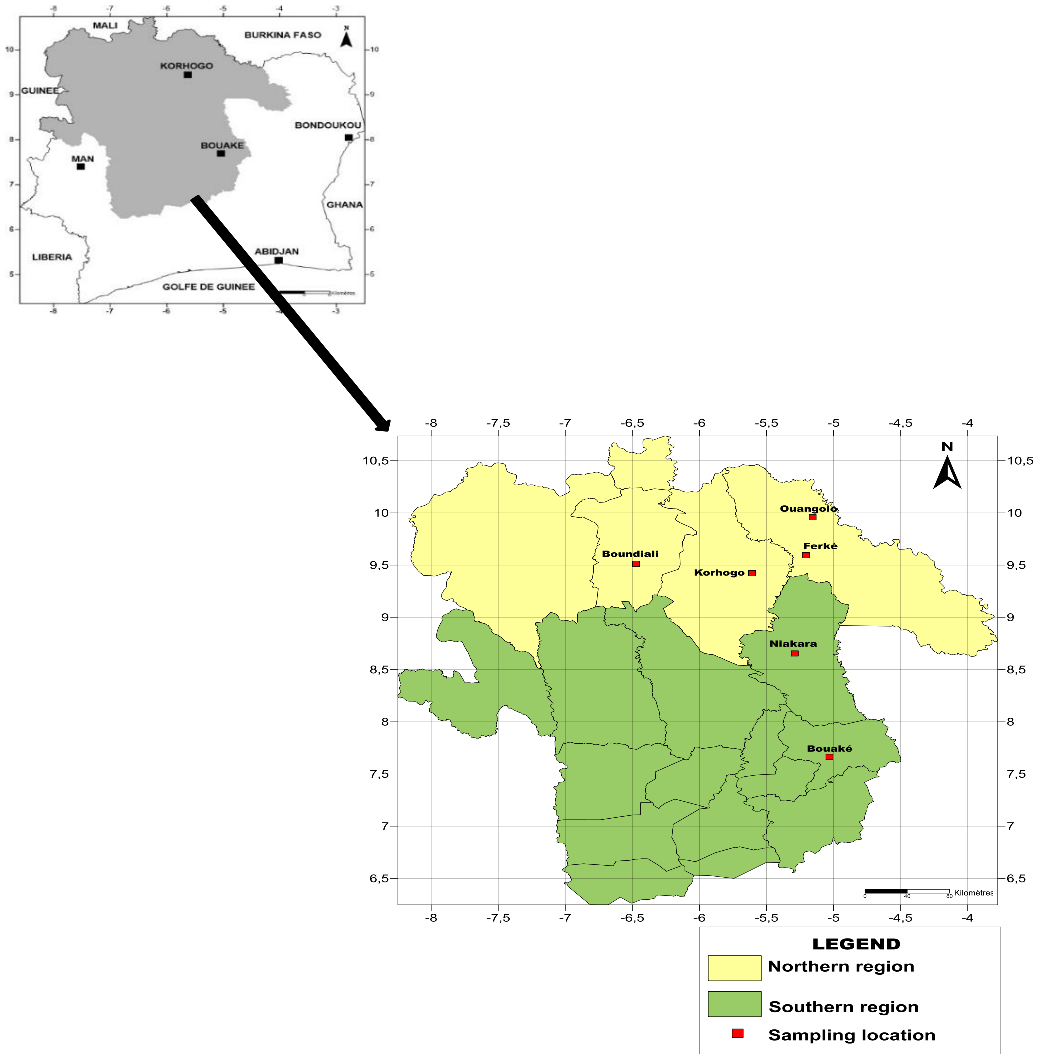

Figure 1 Area of study showing sample locations of *Jacobiella facialis*

jassids were removed from the rearing cage and were anesthetized with carbon dioxide (CO_2) for a short time. Then they are placed on underside of the treated leaf and petri dish was closed with an airy (ventilated) lid. After jassids were recovered from anesthesia, each petri dish was turned over so that the lid was down. Three repetitions were performed for each concentration and petri dishes were stored at 26 ± 2°C temperature, 55.2 ± 13% relative humidity and 24 h for photoperiod (12h of light and 12 h of darkness). Jassid mortality in each dish was recorded after 48 h exposure to determine LC_{50} and LC_{90} values. Moribund individuals, unable to promptly make a movement, were considered dead.

The LC_{90} concentration of 4 active ingredients (chlorpyrifos-ethyl, profenofos, alpha-cypermethrin and acetamiprid) was used as a discriminate concentration to diagnose susceptibility of 5 strains of jassid from Korhogo, Boundiali, Ferké, Ouangolo and Niakara. Distilled water served as control for all toxicology tests.

2.4 Data analysis

The mortality data were corrected by the formula of Abbott (1925) and analyzed by probit analysis (Finney, 1971) using the software Win DL version 2.0 from CIRAD to determine lethal concentration (LC) values. Data on the susceptibility of different strains of jassid were expressed as percent survivors. The error bars on the histograms were represented from the standard deviation values attached to each of these rates. The analysis of variance (ANOVA) was calculated with SPSS software version 20. Differences among treatment means were tested with Duncan multiple range test at 5% significant level.

Table 1 Insecticidal formulations tested for bioassays

Chemical family	Active ingredient	Trade name	Content	Dose of usage	Manufacturer
Neonicotinoïds	Acetamiprid	Assail 30 SG	16 g/l	1 l/ha	Dow AgroSciences
	Imidacloprid	Caotop 30 SC	30 g/l	1 l/ha	Ningbo Sega Chemical Company / N.S.G.M.C
Organophosphorus	Chlorpyrifos-ethyl	Pyriforce 480 EC	480 g/l	1 à 2 l/ha	STEPC / LDC
	Profenofos	Curacron 720 EC	720 g/l	1 l/ha	Syngenta / RMG
Pyrethroids	Lambda-cyhalothrin	Karate zeon	100 g/l	_	Dow AgroSciences
	Alpha-cypermethrin	Fastac SC	100 g/l	_	Dow AgroSciences
Spinosyns	Spinosad	GF-976 SC	480 g/l	_	Dow AgroSciences
	Spinetoram	GF-1567 SC	480 g/l	_	Dow AgroSciences
Sulfoximines	Sulfoxaflor	GF-2032 SC	240 g/l	_	Dow AgroSciences
Diamides	Chlorantraniliprole	Coragen SC	200 g/l	_	Dupont

Table 2 Susceptibility of *Jacobiella facialis* population from Bouaké to ten active ingredients

Chemical family	Active ingredient	n	$LC_{50} \pm SD$	95% CL	χ^2	df	Slope	$LC_{90} \pm SD$
Organophosphorus	Chlorpyrifos-ethyl	270	0.0012±0.0002	0.0003-0.003	5.99	7	0.686	0.090±0.003
	Profenofos	150	0.011±0.0038	0.0005-0.42	1.722	3	0.801	0.47±0.025
Neonicotinoïds	Acetamiprid	300	0.024±0.0030	0.0029-0.07	1.286	8	0.668	1.98±0.032
	Imidacloprid	300	0.070±0.0022	0.00501-0.04	6.321	7	0.649	1.66±0.029
Pyrethroïds	Alpha-cypermethrin	300	0.057±0.0044	0.0018-0.26	8.429	8	0.491	23.09±0.41
	Lambda-cyhalothrin	210	0.132±0.024	0.021-0.343	3.365	5	0.746	6.93±0.36
Sulfoximines	Spinoteram	240	0.119±0.033	0.012-0.391	6.056	5	0.673	9.59±0.30
	Sulfoxaflor	180	0.157±0.019	0.049-0.3328	3.364	4	0.964	3.35±0.26
Spinosyns	Spinosad	240	1.616±0.023	0.332-3.923	8.415	5	0.790	67.66±0.30
Diamides	Chlorantraniliprole	180	5.4±0.020	0.761-10.97	0.589	4	1.268	55.34±0.23

n: number of tested insect 95% CL: 95% Confidence limits χ^2: Chi2 df: degree of freedom SD: standard deviation

3 Results

3.1 Susceptibility of *J. facialis* against used active ingredients

Efficacy of selected insecticides (10) was evaluated on the basis of jassids mortality. It was reported that all selected insecticides have significant effect on jassids mortality as compared to the control. LC_{50} value (mg/ml) of insecticides for jassids from Bouaké varied with the types of tested actives ingredients as shown in table 2. Among the chemical bioassay, chlorpyrifos-ethyl (0.0012 mg/ml) and profenofos (0.011 mg/ml) registered less LC_{50} values while this value was reported highest for the spinosad (1.616 mg/ml) and chlorantraniliprole (5.4 mg/ml). LC_{50} values of acetamiprid, alpha-cypermethrin, imidacloprid, spinetoram, lambda-cyhalothrin and sulfoxaflor against jassids populations were reported 0.024, 0.057, 0.070, 0.119, 0.132 and 0.157 mg/ml respectively.

3.2 Susceptibility of different *J. facialis* strains against used insecticides

In order to assess their susceptibility level to four active ingredients, six strains of *J. facialis* were tested using discriminate concentrations. Survival rates of the tested jassid batches varied according to active ingredients and localities. Susceptibility of various *J. facialis* strains against used active ingredients has been shown in Figure 2.

At 1.98 mg/ml acetamiprid, survival rates varied from 3.33% (Bouaké, Ouangolo, Niakara) to 13.33% (Boundiali) while at the same concentration Korhogo and Ferké strains strain have 6.67% survival (Figure 2a). Further, it was reported that the survival rate for Boundiali strain is 4 fold higher than those of Bouaké, Ouangolo and Niakara strains.

Survival rates against profenofos insecticides at 0.47 mg/ml varied between 10% (Bouaké, Ferké, Ouangolo, Niakara) to 26.67% (Boundiali). For Korhogo this rate was 23.33% (Figure 2b). However, survival rates for Boundiali and Korhogo strains were 2 fold higher than those obtained for other strains.

In case of chlorpyrifos-ethyl, survival rates were reported between 6.67% (Bouaké) to 33.33% (Korhogo) at 0.09 mg/ml concentration. For Niakara, Ferké, Boundiali and Ouangolo strains, the rate of surviving jassids were 10, 16.67, 26.67 and 30 percent respectively. Further, survival rates for Korhogo and Ouangolo strains were more than 4 fold higher than the Bouaké strain (Figure 2c).

Survival rates to alpha-cypermethrin at 23.09 mg/ml were reported 6.67% for Boundiali, Bouaké and Ferké. While in case of Niakara and Korhogo, the survival rates were 13.33%. Further, in case of Korhogo and Niakara strains, survival rate were nearly two fold higher than the survival rates of Bouaké, Boundiali and Ferké strains and this difference was significantly differ (Figure 2d). Data collected on discriminate concentrations (LC_{90}) for four (4) active ingredients did not reveal any significant difference

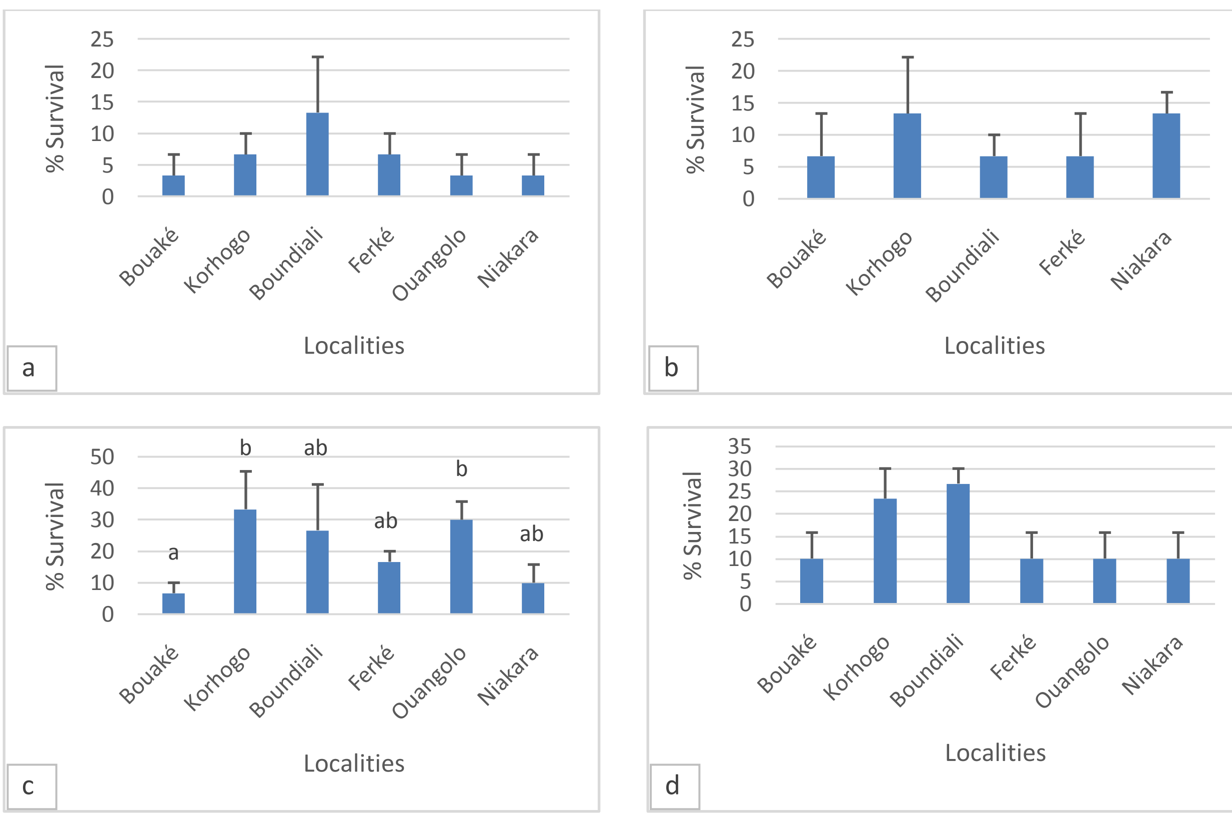

Figure 2 *Jacobiella facialis* strains survival percentage once exposed to active ingredients
a) Acetamiprid b) Alpha-cypermethrin c) Chlorpyrifos-ethyl d) Profenofos

between the susceptibility levels of jassid strains, except for chlorpyrifos-ethyl

4 Discussion

Jassid is a sap sucking insect of many crops throughout the world. Recently, it became most important and emergent pest of cotton in Côte d'Ivoire (Koné et al., 2017). However, there are little information on the susceptibility of this pest against used insecticides for crop protection because studies on *J. facialis* are limited in Côte d'Ivoire and in West Africa region. So, regular monitoring of pest susceptibility to commonly used pesticides is necessary to take decision for ensure prudent selection of insecticides for effective pest management programs. In the present study, some insecticides such as pyrethroïds, organophosphorus, neonicotinoids which are widely used in Côte d'Ivoire for the management of various cotton pests including sucking pests over the years (Ochou & Martin, 2002) and some new insecticides which belong to new chemical families of insecticides (spinosynes, sulfoximines, diamides and oxadiazines) have been assessed as an alternatives of the commonly used pesticides.

Variable susceptibility levels were detected among populations of *J. facialis* to different insecticides. The reduction in the size of jassid population indicated that all tested active ingredients were effective against jassid. Among these tested insecticides, chlorpyrifos-ethyl had highest toxic effect and this was followed by profenofos, acetamiprid, alpha-cypermethrin, imidacloprid, spinoteram, lambda-cyhalothrin, sulfoxaflor, spinosad and chlorantraniliprole.

Furthermore, among the tested insecticides, lowest LC_{50} values were reported from the chlorpyrifos-ethyl and profenofos and these two belongs to the organophosphorus family which act as non-systemic insecticide and work with contact, stomach and respiratory action. This family of insecticides inhibited acetylcholine esterase, an enzyme responsible of acetylcholine degradation involved in the excitatory neurotransmition. The residence time of acetylcholine at synapses is so prolonged by acetylcholine esterase inhibition, resulting in hyper-excitation and eventual death (Elersek & Filipic, 2011; Kostic et al., 2015). The concentrations of organophosphorous could be used as a choice of jassids control. Concerning chlorpyrifos-ethyl, the differences observed in survival rates between jassid strains showed a high sensitivity of the strain from Bouaké compared to those from Korhogo and Ouangolo, while strains from Boundiali, Ferké and Niakara showed an intermediate susceptibility level.

Acetamiprid and imidacloprid performed appreciable activity on jassid populations. These molecules belongs to the family of neonicotinoids which strongly bind to nicotinic acetylcholine receptors in the central nervous system of insects and causing nervous stimulation at low concentrations, but receptor blockage, paralysis and death at higher concentrations (Tomizawa & Casida, 2005; Kundoo et al., 2018). Similar result was also observed by Gopal & Tarikul (2014) those who reported that plants treated with imidacloprid have significantly less jassid populations.

Chlorantraniliprole was found to be the least toxic pesticide to the leafhopper with a higher LC_{50} value. This can be due to the fact that chlorantraniliprole is a molecule whose effectiveness is mainly proven on Lepidopteran (Lamotte & Fleury, 2012).

All concentrations tested under laboratory conditions should be tested for farm-based studies to confirm their effectiveness because in farm conditions, the environment is different from natural environment. As indicated by Koffi et al. (1998) bioassays under field conditions make it possible to judge the operational effectiveness of the tested insecticide, thus allowing a more realistic approach of the effectiveness of an insecticide in the field.

With respect to different dilutions of active ingredients, jassid strains from Bouaké, Korhogo, Boundiali, Ferké, Ouangolo and Niakara did not revealed any statistical differences in the survival rates, except for chlorpyrifos-ethyl. These results revealed that different locations leafhopper populations did not affect significantly from the used insecticides and showed at part susceptibility against acetamiprid, alpha-cypermethrin and profenofos. In fact, cotton growers in all these region seriously used the recommendation of protection program established since 1998. Cotton protection follows calendar treatments which recommend restricted use of pyrethroïds (Ochou & Martin 2002; Martin et al., 2005).

Although pooled data analysis suggested that the six jassid strains have a overall similar susceptibility against the used insecticides. After this also a general trend comes out which suggested that strains from Boundiali and Korhogo had higher survival rates as compared to the rest four strains (Bouaké, Niakara, Ferké and Ouangolo). The present findings are similar to that of Wei et al. (2015), those who reported that all four strains of *Empoasca vitis* has similar susceptibility against acetamiprid, imidacloprid, bifenthrin and chlorfenapyr, but there was a trend that two strains differed in their susceptibility level. This observation may be due to several factors, among which, one factor might be a relatively higher tolerance of both strains to active ingredients associated to agricultural practices. Another factor could be a possible heterogeneity within the population of both strains. However one should note that the number of populations evaluated in this study was very limited. Future studies with a much wider coverage are required to depict general trends.

Conclusion

The results of present study not only provide potency information of individual insecticides against this economically important insect but also provide some background information for further evaluation related to the susceptibility development in leafhopper in the cotton growing area of Côte d'Ivoire. The analysis of LC_{50} values has revealed different susceptibility levels of the tested insecticides. These results could serve as a useful guide for developing *J. facialis* IPM programs to ease the pressure of insecticide resistance. Future studies in field conditions with much wider coverage are required to depict general trends. The susceptibility level of acetamiprid, profenofos and alpha-cypermethrin is found approximately same for all jassid strains but detail field study required to established obtained facts.

Conflict of interest

All the authors declare that there is no conflict of interest.

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