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Biological efficiency of *Cleome viscosa* L. (Capparidaceae) leaves hydroalcoholic formulations against *Helicoverpa armigera* Hübner (Lepidoptera: Noctuidae) of tomato and their effects on a ferruginous soil microorganisms, in Burkina Faso

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Abstract
Helicoverpa armigera is a major constraint which causes huge losses to tomatoes production up to 85 % of the yields, in Bukina Faso. A study has been done at Kou valley to control this pest and to reduce the damages. The experimentation was a randomized Fisher block design of five treatments (three doses of *Cleome viscosa* hydroalcoholic formulations, Lambda-chyalotrin + acetamipride 35g EC, with an untreated control) in four replications. The biological efficacy coefficients of the insecticides have been evaluated with the help of Afanasseva *et al*., formula.The soil microorganisms have been counted on different specific media. *C. viscosa* hydroalcoholic formulation at the high dose (260.42 L/ha) with a biological efficacy coefficient of 65.21 showed the lowest damage with 10.5% of attacked fruits. It was followed by the normal dose which gave 46.37 efficacity coefficient with 12.00% of attacked fruits. The effects of the high dose were generally comparable to those of Lambda-chyalotrin + acétamipride. The higher dose led to the highest yields (33.26 t/ha) which is a yield increase of 222.47% compared to the untreated control. In addition, the different doses of *C. viscosa* formulations, stimulated the development of microscopic fungi, celullolytic, ammonifying and nitrifying bacteria in the soil. The bioinsecticide formulation based on *C. viscosa* leaves, applied at the dose of 260.42 L/ha, effectively controls *H. armigera* of tomato. It can be recommended as a biopesticide in an integrated pest control programme against *H. armigera* in tomato production.

Keywords: *Helicoverpa armigera, Cleome viscosa*, tomato, Burkina Faso

Introduction

Horticultural crops plays a very important role in the world' food security. They are the most productive and constitute in West Africa, one of the main components of urban and peri-urban agriculture that supports the economic of cities development (FAO, 2012) [11]. They play a key role in most nutrition and poverty programs by significantly contributing to family incomes (James and *al.*, 2010, Yolou and *al.*, 2015) [15, 48]. Fruit and vegetable production is an activity of food sovereignty (FAO, 2012) [11]. It employs more than 40% of the world's workforce, including more than 52% in Africa and Asia (Momagri, 2016) [31]. In Burkina Faso, the vegetable market sector is dominated by solanaceous plants, which include tomatoes, aubergines, potatoes, peppers. (Mahrh, 2007) [27]. This sector remains the main source of some rural populations activity during long dry periods. The revenue from the tomatoes marketing represents 21% of the market gardening sector turnover, ie an added value of 17.47 billion CFA francs (Mah, 2011) [25]. Among the horticultural crops, tomatoes rank second after onions. They are a recurring means of reducing poverty and improving the living conditions of producers. Its production is more and more interesting in terms of yield and cultivated lands. The production varied from 50,158 tonnes in 2004/2005 to 289,572 tonnes in 2013/2014 (Marhasa, 2014) [30].

However, the tomato cultivation is subject to numerous constraints including parasite pressure due to pests such as *Bemisia tabaci* (Gennadius) and *Helicoverpa armigera* (Hübner) (Blancard and *al.*, 2009, Ouattara and *al.*, 2017a) [5, 37]. Tomato is the most processed speculation in this country. Most tomato varieties are susceptible to insect pest attacks according to Chougourou and *al.* (2012) [8] and Mondédji and *al.* (2015) [32]. This is a blow to production, which decreased from 289,572 tonnes in 11,766.39 ha in 2013-2014 (Marhasa, 2014) [30] to 200,518.93 tonnes in 23,054.45 hectares in 2016-2017 (Maah, 2017) [24] with a decline in production of nearly 89,000 tonnes, more than 30%. To overcome these pests and improve yields in order to meet the ever-increasing market demand, the use of synthetic pesticides by producers is almost systematic (Kanda and *al.*, 2013 and Mondédji and *al.*, 2015) [19, 32]. Indeed, to ensure economically viable production, chemical pesticides remain the most common method of control for producers who sometimes use non-recommended pesticides for certain crops such as cotton (Toé, 2010; Congo 2013 and Pafasp, 2014) [45, 9, 39]. In addition, the doses used and the frequency of spraying often exceed the recommendations (Pafasp, 2014) [39]. The use of synthetic chemicals in the protection of horticolturale gardening constitutes a hot topic for their chronic or acute toxicities. Their adverse effects have been demonstrated on humans and environment and then the resistance of bio-aggressors to these types of insecticides (Mondédji and *al.*, 2015 and Agboyi and *al.*, 2016) [32, 2]. Indeed, the intensive utilisation of pesticides leads to a high direct exposure of the producers and indirectly the consumers. As the pesticide residues are found in crops and foods. That increases the emergence of forms of insects resistance and the pollution of the components environment (Gnankiné and *al.*, 2013 and Son and *al*, 2018) [12, 42].

In addition, the substances extracted from plants often have interesting insecticidal properties. Their uses are less dangerous for the environment, the producer and the consumer. Recent studies have shown the beneficial effect of the application of moringa leaf extracts on aphids (Mahmood and *al.*, 2017) [26] and *Balanites aegyptiaca* on *Callobruchus maculatus* (Koubala and *al.*, 2013) [22]. Other more recent studies conducted by Mano and *al.* (2019) [29] on *H. armigera* have shown that the methanolic extracts of *Cleome viscosa* and *Parkia biglobosa* leaf powders cause considerable larval mortality rates of 42.65% and 21.65%, respectively, during methanolic extracts of powdered powders. leaves of *Mytragina inermis* caused significant larval dwarfism rates of 68.20%. These last mentioned revealed that *C. viscosa* and *P. biglobosa* contain chemical compounds with insecticidal properties such as steroids, triterpenes, tannins, flavonoids, saponosides, anthocyanins and anthraquinones (Mano and *al*, 2019) [29].

In addition, there are dozens of parasitoid species of *H. armigera* in Africa (Van den Berg and *al.*, 1988, Streito and Nibouche, 1997) [46, 43]. The most important of which is *Meteorus laphygmarum* (Hymenoptera: Braconidae) (Streito and Nibouche, 1997) [43]. The use of plant extracts as a bioinsecticide favors the development of natural enemies (Mano and *al.*, 2018 and Son and *al.* 2018) [28, 42] and reduces farmers' dependence on pesticides. Thus the alternatives to the use of synthetic insecticides need to be promoted.

Material and Methods

Plant material

The experimental trial was conducted at the research station of Kou valley, 30 km north of Bobo-Dioulasso (11° 22 North and 4 ° 22 East). The plant material was consisted of *Cleome viscosa* leaf powder. After identification, the leaves were collected in 2016 in western Burkina Faso (11 ° 06 'N, 4 ° 20' W) for their insecticide property against *H. armigera* observed in the laboratory (Mano and *al.*, 2019) [29]. They were dried on racks, ventilated in the shade, at room temperature (about 30 ° C) and then reduced to powder using an electric grinder (BLG-450). The tomato variety petomech VF served as a host plant sensitive to *Helicoverpa armigera*.

Preparation of bioinsecticide products

On the basis of laboratory results against *H. armigera*, a soluble concentrate was developed. This soluble concentrate (SL) was obtained by percolation of 500 g of powder in ethanol at 96% at room temperature (30 ± 2 ° C) to which water and 3.25 g of soap powder were added. CITEC brand as adjuvant per liter of porridge. This hydroalcoholic formulation is called Kambouhelicoverpacide1.

Experimental apparatus

The experimental device was a randomized Fisher block with five treatments (untreated control, K - optimal (Acetamipride + Lambda cyhalothrin), *C. viscosa* 78.12L/ha, *C. viscosa* 156.25 L/ha, *C. viscosa* 260.42 L / ha hydroalcoholic formulations in four replications. The elementary plot had 32 m² (8m x 4m), and that of the useful plot 24.32 m² containing six lines of tomatoes. Insecticide products were applied to tomato plants using pressurized sprays at once every 10 days from the 20th day after transplanting (DAT) to 100th DAT, at least 15 days before the first harvest of the fruits.

Effects of hydroalcoholic formulations of *C. viscosa* on *H. armigera* larvae

The evaluation of *H. armigera* larvae has been done by direct observation every ten days on the leaves and fruits of 20 plants of the useful plot at each tomato phenological stage (Table 2). A record was taken seven days before the start of treatment (14th DAT). Then the insects were counted two hours before each treatment. At each survey, the direction of the plants choice to be observed has been changed.

C. viscosa hydroalcoholic formulations efficiency coefficients on *H. armigera* larvae

The efficiency coefficient (C) of the formulations was determined by the formula of Afanaseva and *al.* (1983) [1]:

$$C = 100 * (\frac{A-B}{A} - \frac{a-b}{a})$$; with :

A: Number of larvae before treatment application
B: Number of larvae after application on the treated plot
a: Number of larvae before application on the control plot
b: Number of larvae after application on the control plot

Effects of *C. viscosa* hydroalcoholic formulations on damage caused by *H. armigera* on tomato.

The number of attacked fruits was evaluated by direct observations on tomatoes fruits of the useful plot. The observations were made every ten days during the morning freshness.

Effects of *C. viscosa* hydroalcoholic formulations on soil micoorganisms.

The effects of *C. viscosa* hydroalcoholic formulations on soil micoorganisms were evaluated by counting cellulolytic bacteria, microscopic fungi, ammonifying bacteria and nitrifying bacteria on agar culture media (Tepper and *al.*, 1987) [44].

Data analysis

The data was processed using two software packages: Genstat Discovery ed 3 for the descriptive analysis then of variance (ANOVA) according to the Student-Newman-Keuls test at the significance level α = 5% and XLStat version 2015 under Windows 10 for linear correlations. Percentage data of attack symptoms were transformed by the square root anglarcsinus formula of variable P (percentage of symptoms per treatment): anglarcsin (√P). Those of average number of larvae per plant were transformed by the formula √x + 1, with x the average number of larvae per plant. These transformations were applied to the data to ensure normality of distributions and equality of variances.

Results

Biological efficacy of *C. viscosa* hydroalcoholic formulations on the population density of *H. armigera*.

As evidenced by the analysis of variance (Table I), a significant difference was noted between larval population dynamics of treated and untreated *H. armigera* ($p < 0.001$, d.f.: 12). Like the reference (K-optimal) control, the high dose 260.42 L / ha recorded the lowest larval populations

(0.03 to 0.06 larva / plant) with a reduction of 90% to 92.31. % monitoring the normal dose (0.08 to 0.22 larvae / plant) with 63.33 to 79.49% reduction of larvae away from the untreated control (0.26 to 0.60 larvae / plant). Half the dose of 78.12 L / ha was less influential (0.09 and 0.24 larvae / plant).

Table 1: Effects of *C. viscosa* hydroalcoholic formulations on *H. armigera* larval dynamics' infestations (average / plant)

Traitments	Before application		Fructification		Early maturation		Maturity	
	Without Transf.	After √x+1	Without Transf.	After √x+1	Without Transf.	After √x+1	Without Transf.	After √x+1
Untreated control	0.54	1.24 a	0.60	1.26a	0.39	1.18a	0.26	1.12a
Lambda-cyhalotrin + acetamipride 1L/ha	0.54	1.24 a	0.13	1.03d	0.08	1.04b	0.06	1.03c
C. viscosa formulation 78.12L/ha	0.50	1.23 a	0.24	1.11b	0.09	1.04b	0.18	1.08b
C.viscosa formulation156.25/ha	0.50	1.23 a	0.22	1.10 b	0.08	1.04b	0.16	1.08b
C. viscosa formulation 260.42L/ha	0.54	1.24 a	0.06	1.06 c	0.03	1.01b	0.04	1.02c
Means		1.23		1.11		1.06		1.07
Cv (%)		4.70		1.06		2.40		2.20
S.e.d (d.f.=12)		0.01		0.01		0.03		0.02
S.e.s (Sx)		0.01		0.01		0.02		0.01
Probability		0.99		< 0.001		< 0.001		< 0.001
Meaning		*		****		****		****

NB: The averages of the same column affected by the same letter do not differ significantly at the threshold of 5% (NEWMAN-KEULS test).*: No significant, ****: Very highly significant

Biological efficiency of the different rates of *C.viscosa* hydroalcoholic formulations on *H. armigera*.

The coefficient efficiencies of the contol product (Lambda-cyhalotrin + acetamipride 1 L/ha) varied from 36.04 o 98.10 with an average coefficient of 64.01. The one of *C. viscosa* formulation applied at the rate of 78.12 L/ha varied from 14.39 to 63.43 and those of *C. viscosa* formulation 156.25 L/ha, *C. viscosa* formulation 260.42 L/ha varied respectively from 14.39 to 67.81 and from39.86 to 86.42. At the end the average coefficient efficient of *C. viscosa* formulation at 260.42 L/ha is at the same level of the one of Lambda-cyhalotrin associated to acétamipride 1 L/ha (Table II).

Table 2: Efficacy rate of *C. viscosa* formulations different doses on *H. armigera* larvae (%)

Treatment	Phenological stage				
	Before application	Fructification	Early maturation	Maturity	Average
Untreated control	-	-	-	-	-
Lambda-cyhalotrin + acetamipride 1 L/ha	-	98.10	57.89	36.04	64.01
C. viscosa formulation 78.12 L/ha	-	63.43	56.91	14.39	44.91
C.viscosa formulation 156.25 L/ha	-	67.81	56.91	14.39	46.37
C. viscosa formulation 260.42 L/ha	-	86.42	69.34	39.86	65.21

Influence of *C. viscosa* hydroalcoholic formulations on cumulative *H. armigera* larval infestations.

The average effects of the insectides (1.16 larva/plant) is reduction of 22.15 % the numbe of larvae per plant in comparison with the untreated control. Between e ormulations of C. viscosa only hydroalcoholic formulation at the rate of 260.42 L/ha which is not significantly different with the control product (A cetamipride + lambda cyhalotrin) led to a reduction of 26.85 in comparison with the untreated control.

Table 3: Effects on *H. armigera* cumulative larval infestation (number / plant)

Traitements	Without transf.	After % to √x+1 control
Untreated control	1.23	1.49 a -
Lambda-cyhalotrin + acetamipride 1 L/ha	0.20	1.10 c 73.83
C. viscosa formulation 78.12 L/ha	0.48	1.22 b 81.88
C.viscosa formulation 156.25 L/ha	0.46	1.21 b 81.21
C. viscosa formulation 260.42 L/ha	0.18	1.09 c 73.15
Mean		1.22
Cv (%)		2.8
S.e.d (d.f.=12)		0.03
S.e.s (Sx)		0.02
Probability		< 0.001

hydroalcoholic formulations on tomato fruits infestation by *H. armigera*.

A highly significant difference ($p < 0.001$) was observed between the doses and the untreated control (Table IV). On average, the attacked fruit rate decreased as the application rates increased (23.6% to 10.5% attack). The highest larval incidence was noted on untreated plots (21.31% at the fruiting stage, 35.84% at the beginning of maturation and 48.85% at maturity). The lowest rates were observed in the high dose, 260.42 L / ha with 3.06% fructification stage attack, 4.21% early maturation attack and 2.66% attack. at maturity. On average the fruits were more attacked at the early-maturing stage (19.96%) than in the other phenological stages of the tomato.

Table 4: Effects of *C. viscosa* hydroalcoholic formulations on tomato fruits infestations by *H. armigera* (% of fruits attacked)

Traitments	Fructification		Early maturation		Maturity		Average incidence	
	No transf.	AnglArc Sin√P	No transf	AnglArc Sin√P	No transf	AnglArcSin√P	No transf.	AnglArcSin√P
Untreated control	21.31	27.5 a	35.84	36.8 a	48.85	44.4 a	35.33	36.5 a
Lambda-cyhalotrin + acetamipride 1 L/ha	2.89	9.8 c	4.44	12.1 d	1.23	6.3 d	2.85	9.8 d
C. viscosa formulation 78.12 L/ha	15.13	22.9 b	17.44	24.6 b	15.48	23.2 9 b	16.02	23.6 b
C.viscosa formulation 156.25 L/ha	3.09	10.1 c	6.28	14.5 c	3.41	10.6 c	4.26	12.0 c
C. viscosa formulation 260.42 L/ha	3.06	10.1 c	4.21	11.8 d	2.66	9.5 c	3.31	10.5 cd
Means		16.08		19.96		18.8		18.48
Cv (%)		5.00		7.10		6.20		5.50
S.e. (d.f = 12)		0.80		1.41		1.16		1.01
S.e.s (Sx)		0.40		0.70		0.58		0.50
Probability		< 0.001		< 0.001		< 0.001		< 0.001
Significance		****		****		****		****

Effect of *C. viscosa* hydroalcoholic formulations on ferruginous soil microorganisms.

Before insecticides application, there is no significant difference between the objects according to the number of cellulolytic soil bacteria was observed (Table V). At the maturation, the average effect of insecticides ($2.46.10^4$ bacteria/ 1g dry soil) is a bacteria reduction of 0.40% in comparison wih the untreated control. Ho wever the most important quantity of bacteria is situated at the midle rate and higher rate of *C. viscosa* formulation. The number of cellulolytic bacteria is higher than the period before application.

According to microscopic fungi, there is no significant difference between the objects. At the maturation, the average effects of insecticides at ($10.43.\ 10^4$ fungi/ 1g dry soil) is a reduction of 19.40 % in comparison with the untreated control. The inhibitions are situated on the control product and the higher rate of C. viscosa formulation. *C. viscosa* formulation 78.12 L/ha and *C. viscosa* formulation 156.24 L/ha are not different with the untreated control. However, the number of microscopic fungi at this stage became more important than the period before insecticides application, at the different rates of *C. viscosa* formulations.

According to soil ammonifying bacteria, there is no significant difference between the treatments. The average effectsof the insecticides ($0.74\ 10^6$ /1 g dry soil) is an increase of 29.82% the number of ammonifying bacreia in comparison with the untreated control. All the insecticides stimulated the number of ammonifying bacteria. But in comparison with the period before application they led to a reduction.

According to nitrifying bacteria, there is no significant difference between the treatments before insecticides application. The average effect of the insecticides ($2.24\ 10^6$/ 1g dry soil) is decree se of 71.96% in comparison with the untreated control. The most important decrease on the control product, C. viscosa formulation at the rate of 78.12 L/ha and *C. viscosa* formulation at the rate of 260.42 L/ha. The number of this bacteria are weak in comparison with the period before application. But the number of nitrying bacteria is important than the number of ammonifying bacteria which shows that the process of soil nitrification is going normaly.

Table 5: Effects of *C. viscosa* hydroalcoholic formulations on ferruginous soil microorganisms

Traitments	Cellulolytic bacteria (10^4 / 1g dry soil)		Microscopic fungi (10^4 / 1g dry soil)		Ammonifying bacteria (10^6 / 1g dry soil)		Nitrifying bacteria (10^6 / 1g dry soil)	
	Before application	Completed maturation	Before application	Completed maturation	Before application	Completed maturation	Before application	Completed maturation
Untreated control	0.14a	2.47c	6.52a	12.94a	1.12a	0.57c	1.79a	7.99a
Lambda-cyha + acetamipride 1 L/ha	0.12a	2.16d	6.53a	8.85b	1.08a	0.70b	1.79a	1.59c
C. viscosa formulation 78.12 L/ha	0.13a	1.95e	6.54a	12.03a	1.10a	0.73b	1.75a	1.74c
C.viscosa formulation 156.25 L/ha	0.13a	2.63b	6.55a	11.63a	1.08a	0.85a	1.78a	3.91b
C. viscosa formulation 260.42 L/ha	0.14a	3.08a	6.56a	9.21b	1.11a	0.68b	1.76a	1.73c
Means	0.13	2.46	6.54	10.93	1.10	0.71	1.78	3.40
CV (%)	56.9	2.2	16.1	6.7	27.0	7.1	33.8	10.0
S.e.d (d.f. = 8)	0.08	0.06	1.05	0.73	0.30	0.05	0.60	0.339
S. e. s (Sx)	0.04	0.03	0.53	0.37	0.15	0.02	0.30	0.17
Probability	0.10	<0.00	0.10	< 0.001	0.10	0.00	0.10	<0.001
Meaning	*	***	*	****	*	***	*	****

NB: The averages of the same column affected by the same letter do not differ significantly at the threshold of 5% (NEWMAN-KEULS test) ;*: No significant ; ****: Very highly significant

Effect of the different doses of *C.viscosa* hydroalcoholic formulations on tomato yield components and the yield.

The analysis showed a highly significant increase in the yield, number and weight of processed tomato fruits compared to untreated tomatoes ($p < 0.001$, d.f.: 12) (Table VI). The high dose of 260.42 L / ha provided the highest values in yields, weight / fruit, and number of fruits per plant (33.26 t / ha, 58.12 g / fruit and 18.36 fruits / plant) with a surplus of 122.47% of the untreated control yield (14.95 t / ha). Half the dose and the normal dose also had satisfactory yield surpluses of 82.54% and 100.80% respectively compared to the untreated control yield (14.95 t / ha).

Table 6: Effect of *C. viscosa* formulaions on tomato yield components and the yield

Treatment	Fruit weight average (g)	Number of fruits / plant	Yield (t / ha)	% to untreated control
Untreated control	32.55 c	7.29 d	14.95 d	-
Lambda-cyha + acetamipride 1 L/ha	53.90 b	14.62 b	29.17 b	195.12
C. viscosa formulation 78.12 L/ha	52.20 b	10.95 c	27.29 c	182.54
C.viscosa formulation 156.25 L/ha	52.90 b	14.44 b	30.02 b	200.80
C. viscosa formulation 260.42 L/ha	58.12 a	18.36 a	33.26 a	222.47
Mean	49.93	13.13	26.94	
Cv (%)	2.2	4.2	3.00	
S.e.d (d.f.=12)	1.10	0.55	0.80	
S.e.s (Sx)	0.55	0.28	0.40	
Probability	<0.001	<0.001	<0.001	
Meaning	****	****	****	

Correlations between studied factors

Correlation analysis (Figure 1; 2 and 3) reveals that yield, average fruit / plant and average fruit weight are strongly correlated with abundance of *H. armigera* larval population (r = - 0.98, p = 0.002) (r = -0.99, p <0.001) (r = -0.86, p = 0.058).

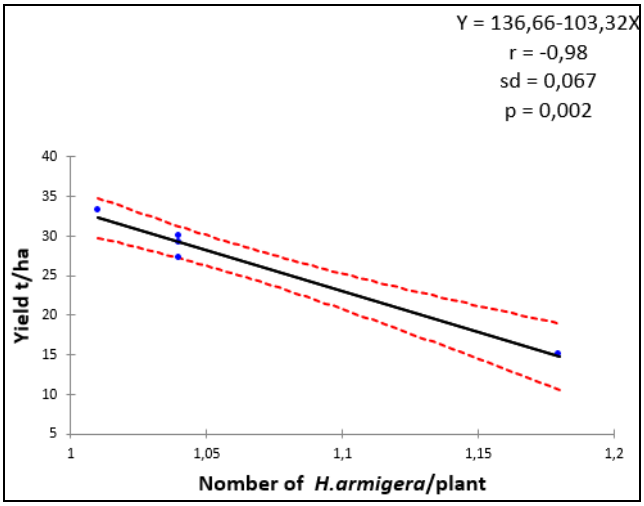

Fig 1: Correlation between yield and number of *H. armigera* per plant

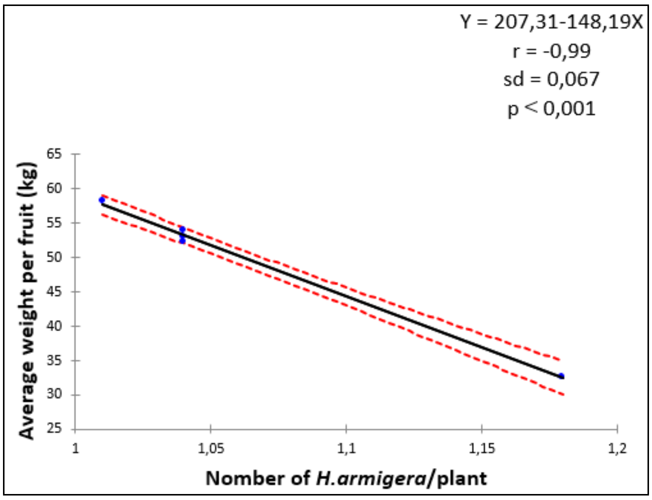

Fig 2: Correlation between the weight per fruit and the number of *H. armigera* per plant

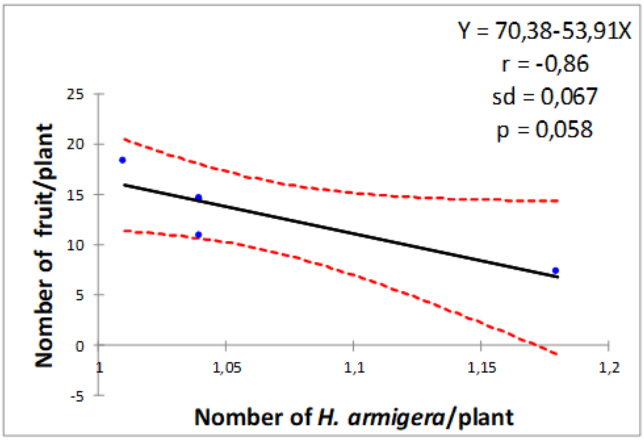

Fig 3: Correlation between the number of fruits per plant and the number of *H. armigera* per plant

Discussion

An insecticidal activity of three doses of hydroethanolic extract of *C. viscosa* against *H. armigera* was obtained in this study. The three doses had considerable control against the moth, *H. armigera* with a biological efficacy of 44.91% to 65.21%. Several reports implied insecticidal / repellent activities on stock insects (Ndungu and *al.*, 1995 and 1999, Belmain and *al.*, 2001, Dabire and *al.*, 2008) [33, 34, 4, 10]. These studies focused on the insecticidal properties of the plant on storage insects without mentioning the mode of action or taking into account possible interactions with host plants. The three doses tested resulted in a very significant reduction in *H. armigera* larval infestations. These results corroborate those of Mano and *al.* (2019) [29] who obtained 42.65% larval mortality of *H. armigera* treated with the methanolic extract of *C. viscosa* leaf powder under laboratory conditions. On the other hand, Islam and *al.* (2014) [14] showed higher mortalities (LD50 0.170 and 0.248 mg / cm2) against adults of *Tribolium castaneum* with chloroform and methanolic extracts of the aerial part of *C. viscosa* respectively, a higher cytotoxicity with the extracts of Root and chloroformic petroleum ether from *C. viscosa* fruits at CL 21.905 and 26.675 ppm against A. salina brine shrimp after 30 h exposure; a higher larvicidal effect of chloroformic extracts of fruit and *C. viscosa* roots at 185.390 and 272.910 ppm LC against *Culex* sp. after 30 hours of exposure. Indeed, the phytochemical analysis performed by Mano and *al.* (2019) [29] showed that methanolic extracts of *C. viscosa* leaves contained compounds including steroids, triterpenes, tannins, flavonoids, saponosides, anthocyanosides and anthraquinones that are known to possess insecticidal properties. On the other hand, Sivaraman and al (2014) [41] showed the presence in *C. viscosa* seeds of alkaloids, quinones and tannins. The decrease in larval infestations in the treated plots is probably due to the insecticidal effect of these chemical compounds. Correlations showed that the three doses were the basis of the low level of attacked fruit (3.31% - 16.02% attack) on the plots; which explains the maximum yield gain of 33.26 t / ha.

The effectiveness of *C. viscosa* extracts on the first stage of the larva of *H. armigera* was explained by the lethal effect of the extract on their stomach. In fact, ingestion toxicity was already observed by Mano *et al* 2019 [29] on L1 larvae of *H. armigera* fed on contaminated diets where the methanolic extract of *C. viscosa* had been shown to be more toxic. Ba and *al.*, 2009 [3] also obtained the same toxicity on the cowpea pod *Clavigralla tomentosicollis* where *C. viscosa* was the most effective with 37.5% mortality. These results corroborate those of Simdé at *al.*, 2019 [40] who observed an insecticidal activity of the same plant against the mango maggot, *Ceratitis cosyra* (WALKER).

The effectiveness of *C. viscosa* could also be due to contact toxicity. Indeed, according to studies by Ba and *al.*, 2009 [3], direct contact of *C. viscosa* extracts killed 100% of first-instar *C. tomentosicollis* larvae. Williams and *al.* (2003) [47] demonstrated pyrethroid contact toxicity of the same plant on the adult *Cylas formicarius elegantulus* S. (Coleoptera: Curculionidae). The same pyrethroids have been demonstrated by Mano and *al.*, 2019 [29] in the methanolic extracts of leaves of the plant. Antifeedant activities of *Cassia nigricans* chemical extracts have also been reported on larvae of *Heliothis zea* and *H. virescens* (Kambou and *al.*, 2008). While we used an ethanolic extract, the choice of solvants for extraction might have contributed to improved insecticide concentration and efficacy (Williams and *al.*, 2003 and Kambou and *al.*, 2008) [47, 17]. Contact toxicity also depends on the nature of the substances extracted. Kemassi and *al.* (2011) [20] showed 100% mortality of Schistocerca gregaria L5 adults and larvae treated with Cleome essential oil by direct spraying.

The low rates of fruit perforation observed in our study result from the inhibitory properties of larval growth of *H. armigera* caused by *C. viscosa* extract. Mano and *al.* (2019) [29] observed a rate of dwarfism of more than 10% of organic extracts of *C. viscosa*. Ngamo and Hance (2007) [35] also showed that the mono-terpenes contained in essential oils are reproductive inhibitors in *Acanthoscelides obtlectus* (Coleoptera: Bruchidae). Other authors have observed in *Schistocerca gregaria* L5 larvae treated with the cleome genus acetone extract, 16.66% of the emerged images present difficulties during moulting (Kemassi and *al.*, 2011) [20].

It is not excluded that a repulsive activity has increased the efficiency observed on treated tomato plots. This mode of action has been reported for several insect pests in hermetic storage conditions (Belmain and *al.*, 2001; Ketoh and *al.*, 2005 and Dabire and *al.* 2008) [4, 21, 10]. The effectiveness of *C. viscosa* comes from its repellent effects according to the results of Islam and *al.* (2014) [14] where the methanolic extract of *C. viscosa* exhibited the highest repulsions against adults of *Tribolium castaneum* (Coleoptera). Moreover Ba and *al.* (2009) [3] observed 100% mortality of *C. tomentosicollis* larvae after inhaling vapors from crushed *C. viscosa*, *Cassia nigricans* and *Cymbopogon Schoenanthus*. Cleome-type repellent activity is also reported on spider mites (Nyalala and Grout 2007) [36].

It is also noted that the different doses of *C. viscosa* extracts stimulated the development of microorganisms (microscopic fungi, celullolytic) of the soil and favored. Indeed, Ouattara (2017b) [38] and Lepinay (2013) [23] have shown that plant-microorganism trophic interactions can increase the density of these organisms and their activity. These results are consistent with those of Huber and Schaub (2011) [13] according to which organic inputs favor the life of microbes that incorporate carbonaceous substances (main source of nutrients). Bünemann and *al*. (2006) [6] noted that chemical fertilizers that stimulate plant growth and root exudation promote microbial activity. On the other hand, Chaussod (1996) [7] gives average values per gram of dry soil between 10^8 - 10^9 for bacteria and 10^4 to 10^6 for fongi. Our results are below these values due to the chemical fertilizers applications (acidification), manual weeding (increasing porosity, disruption of fungal structures) and weed abondunce. That, leads to the change of the physicochemical and biological properties of the soil; stimulate and sometimes inhibite microbial activity (Huber and Schaub, 2011, Kambou and Millogo, 2018) [13, 16].

Conclusion

The three doses of hydroethanolic extract of *C. viscosa* have a considerable control against the moth, *H. armigera* with a biological efficacy of 44.91% to 65.21% and contributed to the increase in tomato yield of order from 82.54% to 122.47%. The high dose of 260.42 L / ha of the formulation is the best in terms of efficacy against the larval populations of the moth (65, 21% efficiency) and their impact on tomato fruits (10.05% of fruits attacked). It obtain the best yield of more than 33 t / ha, higher than the average yield of 20 t / ha in Burkina Faso. All three doses are favorable for the development of microorganisms (microscopic fungi, celullogic, ammonifying and nitrifying bacteria) of the soil. With the hight dose of the bioinsecticide formulation made from *Cleome viscosa* leaf powder, the horticultural producers could effectively control *H. armigera*, the swamp pest of tomato in tropical Africa. Additional safety tests with crop beneficial insects are needed to prove the ecological importance of the formulation.

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