Biological efficiency of *Ocimum basilicum* L. hydroalcoholic formulations against whitefly, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) on tomatoes and their effects on a ferruginous soil microorganisms, in Burkina Faso.

OUEDRAOGO Bouraïma[1], MANO Elias[2], KAMBOU Georgeş*[3], SOMDA Irénée[4]

Abstract

A biological efficiency study of different doses of *Ocimum basilicum* L. hydroalcoholic formulations against whitefly, *Bemisia tabaci* which causes big damage to tomato has been done at the Kou Valley, in Burkina Faso. The experimentation was a randomized block design of five treatments: untreated control, K-optimal (Lambda-cyhalothrin (15 g/L) + Acetamiprid (20 g/L)) at 1 L/ha; *O. basilicum* at 78.12 L/ha; *O. basilicum* at 156.25 L/ha and *O. basilicum* at 260, 42 L/ha in four replications. The insect counting has been done using transparent cages to catch white flies on tomatoes in each useful plot. The soil microorganism's number was evaluated on agar media culture. Between the different rates of *O. basilicum* formulations, the rate of 260.42 L/ha resulted in a similar mortality to K-optimal at 1 L/ha. Its efficiency coefficients varied from 3.25 to 75.70 in comparison with the untreated control. The efficiency coefficients of 156.25 L/ha varied from 2. 36 to 69.76 and those of the 78.12 L/ha varied from 1.46 to 64.76. However, if the *O. basilicum* formulation at 260.42 L/ha inhibited the number of ammonifying bacteria by 78.80%, on the other hand it stimulated the nitrifying bacteria by 234.41% in comparison with the untreated control at this stage. All of these factors allowed to obtain for *O. basilicum* at 260.42 L/ha formulation a yield increase of 17.53% in comparison with the untreated control

Keywords: *Ocimum basilicum*, *Bemisia tabaci*, *tomato*, soil microorganisms, Burkina Faso.

Résumé

Efficacité biologique de formulations hydro-alcooliques *d'Ocimum basilicum* L. contre la mouche blanche, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) de la tomate et de leurs effets sur les microorganismes d'un sol ferrugineux, au Burkina Faso.

Une étude sur l'efficacité biologique de différentes doses de formulations hydro-alcooliques d'*Ocimum basilicum* L. contre la mouche blanche, *B. tabaci* qui cause des dégâts énormes sur la tomate a été conduite dans la Vallée du Kou, au Burkina Faso. Le dispositif expérimental a été un Bloc de Fisher à cinq (05) traitements répétés quatre (04) fois : Témoin non traité ; K-optimal (Lambda-cyhalothrine (15 g/L) + Acétamipride 20 g/L)) à 1 L/ha; *O. basilicum* à 78,12 L/ha ; *O. basilicum* à 156,25 L/ha et *O. basilicum* à 260, 42 L/ha. Le comptage des insectes a été effectué avec des cages cylindriques transparentes placées sur des plants de tomates dans chaque parcelle utile. Les microorganismes du sol ont été évalués sur des milieux de culture gélosés. Entre les différentes doses d'*O. basilicum*, la dose de 260,42 L/ha a entraîné une mortalité similaire au K-optimal à 1 L/ha. Ses coefficients d'efficacité ont varié de 3,25 à 75,70 par rapport au témoin non traité contre 2,36 à 69,76 pour la dose de 156,25 L/ha et de 1,46 à 64,76 pour la demi-dose de 78,12 L/ha. Cependant, si la formulation d'*O. basilicum* à 260,42 L/ha a inhibé le nombre de bactéries ammonifiantes de 78,80% elle a par contre stimulé les bactéries nitrifiantes de 234,41% par rapport au témoin non traité au stade maturation. L'ensemble de ces facteurs ont permis d'obtenir à la formulation *O. basilicum* 260, 42 L/ha un surplus de rendement de 17,53% par rapport au témoin non traité.

Mots clé : *Ocimum basilicum*, *Bemisia tabaci*, tomate, microorganismes du sol, Burkina Faso

1. Matourkou Multipurpose Agricultural Center, PO Box 130 Bobo Dioulasso, Burkina Faso Tel: (00226) 20970698/76198445. Email: bouraimaouedraogo@yahoo.fr
2. Institute of Science Apply Research and Technologies. PO Box; 2393 Bobo Dioulasso, Burkina Faso Tel: (00226) 71040291/75125110. Email: manoe2005@gamil.com
*3. Institute of Environmental and Agricultural Research, DRREAO, PO Box 910 Bobo-Dioulasso, Burkina Faso. Tel: (00226) 78009103/70390176. Email: kambougeorges2000@yahoo.fr.
4. Institute of Rural Development / Nazi Boni University. Bobo-Dioulasso, Tel: (00226)70286635. Email:ireneesomda@yahoo.fr.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most important vegetable crops in the world (Naika *and al.*, 2005). In 2017, it was the first vegetable crop in terms of production and was cultivated in 179 countries (FAOSTAT, 2019). In Burkina Faso, market gardening plays a vital role in agricultural policy as it helps to diversify population's diet but also to generate significant financial resources and to reduce seasonal unemployment in rural areas (Tourigny, 1993). The burkinabé market gardening generates more than sixty (60) billion CFA francs annually in added value (MAHRH, 2007) and among the most produced vegetable speculations, tomato ranks in the second place after the onion bulb (MAAH, 2017). Tomato plays a very important socio-economic and nutritional role and the total value of tomato sales was estimated at 17,469,073,587 FCFA or 21% of the market turnover gardening in 2008 (MAAH, 2011). In Burkina Faso, the importance of the crop is seen in the tremendous growth in its production, which increased from 50,158 tons in 2004 to 157,086 tons in 2008 (DGESS, 2014).

However, many constraints hamper the development of tomato sector in Burkina Faso and we have witnessed in recent years, a drop in yields from 12.5 tons / ha in 2012 to 10.07 tons / ha in 2017 (FAOSTAT, 2019). Among constraint factors, damages are caused by weeds (*Cyperus* spp), insect pests and pathogens such as fungi, bacteria and viruses (Ouattara *et al.*, 2017). Among the diseases, bacterial wilt caused by *Ralstonia solonacearum* led to a lot of damage (Kambou *et al.*, 2018). As of harmful insects, we have *Tuta absoluta* which has wreaked havoc in recent years in Burkina Faso (Son *et al.*, 2017) and the whitefly, *Bemisia tabaci* which causes several damages on tomato crops especially by the introduction of viral infections (Hanafi, 2000; Gnankine, 2005).

Several control methods have been developed to reduce the harmful effects of *B. tabaci.*

Among these, there is the research for resistant or tolerant varieties (Channarayappa *et al.*, 1992) and the inoculation of bacteria like *Rhizobacteria* in tomato to increase its resistance (Shavit *et al*., 2013) or the use of chemical products such as synthetic pyrethroids (cypermethrin, bifenthrin), organophosphates (malathion, pyrimiphos), chloronicotinyls (imidacloprid, acetamiprid) and Thiadiazines (buprofezin) (https://www.bio-enligne.com/lte /216-aleurode-insecticide.html). Among all these methods, chemical control seems to be the short-term method most effective and the most commonly used. However, phenomena of resistance to chemicals such as pyrethroids, organochlorines and organophosphates have been observed on insects in West Africa (Houndété *et al*., 2010; Agboyi *et al*., 2016).

According to the phenomenon of resistance making chemical control sometimes ineffective, it is worth mentioning that chemicals are rarely selective, thereby resulting in the elimination of many natural enemies of pests such as predators and parasitoids (Amoabeng *et al*., 2014).

It is also necessary to emphasize the danger of chemical pesticides on users, consumers and the environment. The use of chemicals is a source of water and soil pollution. In Benin for example, endosulfan, DDT and endrin have been detected in different soil samples (Assogba-Komlan *et al.*, 2007).

The presence of residues of metamidophos, endosulfan and dimethoate in water in agricultural areas in Senegal was highlighted (Ngom *et al*., 2012) and according to Ashraf *et al*. (2010), the use of polluted water for irrigation not only degrades the quality of groundwater, but also poses serious dangers to human and animal health.

These harmful effects of chemical control are especially favored by the illiteracy of the majority of our agricultural producers and pesticides sellers. This is why, research on bio-pesticides is more than necessary nowadays, in order to preserve the environment as well as human and animal health. This research already carried out by some authors (Kambou *and* Guissou, 2011; Kambou and Nair, 2015; Yadave *and* Mendhulkar, 2015) have been concluded and attested that some plant extracts are good insecticides to control *B. tabaci*. Biological control is more and more developed. For example, Aslam *et al.* (2004) concluded in a study that essential oils of *O. basilicum* are potentials control agents against *B. tabaci* under greenhouse conditions. Bouchelta *et al.* (2005) in Morocco used alkaloids, saponins and flavonoids extracted from *Capsicum frutescens* L. to control *B. tabaci*. Their results were interesting because on eggs, the mortality ranges from 35% to 59% while on adults, it is between 29% to 86%. Song *et al.* (2010) and Dross (2012) introduced the association of aromatic plants with tomatoes to control the pest. The basil cultivars tested reduced he abundance of *B. tabaci* larva up to 1.8 meters away. Dossa (2018) in Benin republic showed that the aqueous extract of *O. basilicum* associated with *O. gratissimum* better controlled the density of *B. tabaci* on tomato production than the other insecticide treatment. Ouédraogo *et al*. (2019) explained the best insecticidal activity of the methanol extract of *O. basilicum* in comparison to the hexane extract of *P. biglobosa* against *B. tabaci* of tomato in laboratory conditions. This is why for the first time, the present study deals with the biological efficiency of hydro alcoholic extracts of *Ocimum basilicum* on whiteflies and its effects on the biological properties of a ferruginous soil were studied in Burkina Faso.

MATERIAL AND METHODS

Plant material

The plant material consisted of tomato, Petomech VF variety susceptible to whitefly. The leaves of *O. basilicum* were collected from the Farako-ba areas (11° 06' north, 4° 20' west).

Animal material

The animal material on which the study has been done was the white fly's *B. tabaci* (Gennadius) (Hemiptera: Aleyrodidae) which have infested tomato in the field. Transparent cages were used to catch whiteflies on 20 tomato plant in each useful plot.

Insecticide product

A chemical, K-Optimal (Lambda-cyhalothrin (15g/L) + Acetamiprid (20g/L)) was used as a control product. A sustained pressure backpack sprayer was used for the phytosanitary treatments and graduated cylinders for the dosages. Phytosanitary treatments took place three weeks after the appearance of whiteflies and were done every ten days.

Methods

Experimental Design

The test was conducted on a site on the rice plain in the Kou Valley, located about thirty (30) kilometers from Bobo-Dioulasso. This site presents a ferruginous soil with clayey-silty texture, characterized, in general, by their low content of organic matter with a pH between 5.5 and 6.5 and a high concentration of exchangeable bases (Wellens *and al*., 2008). The experimental was a Fisher Block design of five (05) treatments in four (04) replications (untreated control; Lambda-cyhalothrin (15 g/L) + Acetamiprid (20 g/L) at 1 L/ha; *O. basilicum* hydro-alcoholic formulation at 78.12 L/ha; *O. basilicum* hydro-alcoholic formulation at 156.25 L/ha and *O. basilicum* hydro-alcoholic formulation at 260, 42 L/ha). The elementary plot was 8 m x 4 m or 32 m^2. The cultivation technics were those applied in the area. To prepare the seedbed, plowing followed by all motorized harrowing was carried out. A manual leveling was accompanied to level the ground well before the staking which was done manually with a spacing of 40 cm between the plants and 80 cm between the lines. Two manual weeding were carried out to control weeds. Organic fertilization has consisted to an application of organic matter at the rate of 20 tons/ha as background manure and mineral fertilization has consisted to the NPK fertilizer (15-15-15) application, at the rate of 300 kg/ha at the 15^{th} day after transplanting (DAT) and 200 kg/ha of urea (46 N) in two fractions (at the 30^{th} DAT and 45^{th} DAT).

Preparation of *O. basilicum* hydro-alcoholic formulations

On the basis of the results obtained in the laboratory against *B. tabaci*, a hydro - alcoholic formulation has been developed: one kilogram of *O. basilicum* leaf powder is macerated in ten (10) liters of ethanol 96 ° for 48 hours, and 3.25 g of CITEC soap powder were added to the filtrate as an adjuvant per liter of porridge.

Biological efficiency and coefficients of *O. basilicum* hydro-alcoholic formulations against tomato *B. tabaci.*

The whiteflies were caught in transparent plastic cages on twenty (20) tomato plants at the rate of five (05) plants per row, diagonally. The efficiency coefficients of the extracts were determined by the formula of Afanasseva *et al*. (1983):

C= 100 * ((A-B) / A- (a-b) / a))

With: C: efficiency coefficient

A: number of whiteflies before application on the treated plot.

B: number of whiteflies after application on the treated plot.

a: number of whiteflies before application on the untreated control plot.

b: number of whiteflies after application on the untreated control plot.

Effects of *O. basilicum* hydro-alcoholic formulations on soil microorganisms

Soil samples were taken with the auger on two blocks at the depth of 0-20 cm before tomatoes transplanting, and by tomato phenological stages. The microorganisms were evaluated on agar media cultura (Starch-Ammonia-Agar for nitrifying bacteria; Meat-Pepton-Agar for ammonifying bacteria; Czapek-Dox for microscopic fungi; Getchinson (G) for cellulolytic bacteria) according to the method of Tepper *et al*. (1987).

Effects of *O. basilicum* hydro-alcoholic formulations on tomato yield

The yield was evaluated by counting the number of tomato fruits and by weighing tomatoes expressed in kilograms per hectare (kg/ha).

Statistical analysis of the data

The data on the average number of whiteflies per plant was transformed by the formula √x + 1. Two software programs have been used for processing these data and others: Genstat Discovery edition 3 for descriptive and then variance analysis (ANOVA) following by the Student-Newman-Keuls test at the 5% threshold.

RESULTS

Biological efficiency of *O. basilicum* hydro-alcoholic formulations at different doses on *B. tabaci* population density

Before applying the different insecticides, there was no significant difference between the different treatments on *B. tabaci* population density (Table 1).

Table 1: Effects of different doses of *O. basilicum* hydro-alcoholic formulations on *B. tabaci* populations (average number of white flies / plant).

Treatments	Days after treatment (DAT)									
	0		1		21		31		41	
	without transf.	after $\sqrt{x+1}$	without transf.	after $\sqrt{x+1}$	without transf.	after $\sqrt{x+1}$	without transf.	after $\sqrt{x+1}$	without transf.	after $\sqrt{x+1}$
Untreated control	224.40	**15.01 a**	195.55	**14.01 a**	41.11	**6.49 a**	17.35	**4.28 a**	11.53	**3.54 a**
Lambda +Aceta. 1.00 L/ha	193.80	**13.96 a**	20.79	**4.67 d**	14.53	**3.94 d**	5.55	**2.56 cd**	2.66	**1.91 d**
O. basilicum 78.13 L/ha	204.40	**14.33 a**	45.74	**6.83 c**	31.46	**5.70 b**	10.01	**3.32 b**	7.51	**2.92 b**
O. basilicum 156.25 L/ha	207.00	**14.42 a**	36.00	**6.08 b**	23.30	**4.93 d**	6.98	**2.83 c**	5.75	**2.60 c**
O. basilicum 260.42 L/ha	192.40	**13.90 a**	22.47	**4.84 d**	15.14	**4.01 d**	4.83	**2.42 d**	3.63	**2.15 d**
Mean		**14.33**		**7.28**		**5.01**		**3.08**		**2.62**
CV (%)		**5.10**		**4.20**		**5.20**		**6.90**		**5.10**
ETR (ddl=12)		**0.82**		**0.20**		**0.17**		**0.10**		**0.08**
ETM (Sẍ)		**0.41**		**0.10**		**0.09**		**0.05**		**0.04**

N. B: The means of the same column assigned to the same letter are not significantly different from each other at by the STUDENT NEWMAN-KEULS test at the 5% threshold.

At the first day after insecticides application, the average effect of the insecticides (5.61 whiteflies/plant) is a reduction of 56.96% in comparison with the untreated control. Between the different doses of *O. basilicum*, the high dose (260.42 L/ha), which is not different from Lambda-cyhalothrin + Acetamiprid, shows a reduction of 65.45% in comparison with the untreated control. The dose of 156.25 L/ha and the half-rate of 78.12 L/ha, resulted in respective reductions of 56.60% and 51.25% in comparison with the untreated control.

At the 21st day, the average effect of insecticides (4.65 whiteflies/plant) is a reduction of 28.35% in comparison with the untreated control. The high dose of *O. basilicum* (260.42 L/ha) and the average dose (156.25 L/ha) which are not different from each other and with Lambda-cyhalothrin + Acetamiprid showed a reduction at least 39.40% in comparison with the untreated control. The half-dose (78.12 L/ha) resulted in a reduction of 12.17% in comparison with the untreated control.

At the 31st day, after insecticides application, the average effect of the insecticides (2.78 whiteflies/plant) is a reduction in the population density of the whiteflies by 35.05% in comparison with the untreated control. The lowest densities are found in *O. basilicum* (260.42 L/ha and 156.25 L/ha) which are not different from Lambda-cyhalothrin + Acetamiprid applied at 1.00 L/ha.

At the 41st day, after the 4th application, the average effect of the insecticides (3.28 whiteflies/plant) is a reduction of 7.34% in comparison with the untreated control. Between the doses of *O. basilicum*, only the high dose of 260.42 L/ha which is not significantly different from the control product Lambda-cyhalothrin + Acetamiprid at 1 L / ha resulted in a reduction of 39.27% in comparison with the untreated control. *O. basilicum* at 156.25 L/ha and 78.13 L/ha show reductions of 26.55% and 17.51% respectively in comparison with the untreated control.

Biological efficiency coefficients of the different doses of *O. basilicum* hydro-alcoholic formulations

The efficiency coefficients of the different formulations doses varied from 1.46% to 76.42% during the different observation periods (Table 2). Between the different doses of *O. basilicum*, the efficiency coefficients of the high dose varied from 3.25 to 75.70 with an average of 24.22 in comparison with the untreated control. The plots treated with 156.25 L/ha dose showed efficiency coefficients from 2.36 to 69.76 with an average 21.12 in comparison with the untreated control. As for the half-dose, efficiency coefficients ranging from 1.46 to 64.76 were recorded with an average of 18.23 in comparison with the untreated control. The efficiency coefficients of the Lambda-cyhalothrin + Acetamiprid at 1 L/ha varied from 3.76 to 76.42 with an average of 23.97 in comparison with the untreated control.

Table 2: Biological efficiency coefficients of *O. basilicum* hydro-alcoholic formulations doses.

Treatments		Days after treatment (DAT)				
		1	21	31	41	Mean
Untreated control	_	_	_	_	_	
Lambda +Aceta. 1.00 L/ha	_	76.42	10.82	4.87	3.76	23.97
***O. basilicum* 78.12 L/ha**	_	64.76	3.60	3.10	1.46	18.23
***O. basilicum* 156.25 L/ha**	_	69.76	7.74	4.62	2.36	21.12
***O. basilicum* 260.42 L/ha**	_	75.70	11.13	6.80	3.25	24.22

Effects of *O. basilicum* formulations rates on ferruginous soil microorganisms

According to cellulolytic bacteria, before application, the average number of cellulolytic bacteria in plots to be treated with insecticides (48.43 10^3 bacteria/ 1 g dry soil) is a reduction of 34.55% in comparison with the untreated control (Table 3). The plot to be treated with Lambda-cyhalothrin + Acetamiprid showed a decrease of 35.01% in comparison with the untreated control. Between the doses of *O. basilicum* formulations, the lowest dose is in the plots to be treated with the high dose of formulation 260.42 L/ha and is 56.81%. When compared to the period before application, a general increase is noted at maturation in the treatments based on *O. basilicum* formulations, i.e. from 29.54% at 78.12 L/ha to 61.70% at the high dose of 260.42 L/ha. The increase is only 10.74% for the untreated control. The chemical causes an 8.10% drop.

According to microscopic fungi, the average number of fungi in the plots to be treated (2.59 10^3 fungi / 1g dry soil) is an increase of 202.34% in comparison with the untreated control. The largest number is for control product treatments and the high dose of *O. basilicum*. After application, the average effect of insecticides (49.52 10^3 fungi / 1g dry soil) is an increase of 18.78% in comparison with the untreated control. Among the doses of *O. basilicum*, the dose of 260.42 L / ha stimulated these microorganisms by 150.06% in comparison with the untreated control. It is followed by the control product. The other doses of *O. basilicum* were indistinguishable from the untreated control. The number of fungi at this stage is higher than with the period before insecticides application.

Table 3: Effects of *O. basilicum* hydro-alcoholic formulations different doses on soil microorganisms.

Treatments	cellulolytic bacteria (10^3 bacteria/ 1g of dry soil)		microscopic fungi (10^3 fungi/1g of dry soil)		ammonifying bacteria (10^3 bacteria/ 1g of dry soil)		nitrifying bacteria (10^3 bacteria /1g of dry soil)	
	Before application	Complete maturation	Before application	Complete maturation	Before application	Complete maturation	Before application	Complete maturation
Untreated control	74.00 a	81.95 a	1.28 c	41.69 c	1651.00 c	644.20 c	2815.00 b	824.20 c
Lambda +Aceta. 1.00L/ha	48.09 c	44.19 b	2.43 b	52.45 b	3007.00 b	903.20 b	1317.00 d	893.50 c
***O. basilicum* 78.12 L/ha**	59.30 b	76.82 a	2.54 b	40.19 c	1711.00 c	1107.60 a	2567.00 c	669.90 d
***O. basilicum* 156.25 L/ha**	54.35 bc	54.62 b	1.65 c	42.89 c	1655.00 c	966.10 b	3360.00 a	1065.40 a
***O. basilicum* 260.42 L/ha**	31.96 d	51.68 b	3.74 a	62.56 a	3288.00 a	272.00 d	963.00 e	942.90 b
Mean	53.54	61.90	2.33	47.95	2262.00	779.00	2204.00	879.00
CV (%)	8.50	8.00	8.90	7.70	3.70	6.00	2.10	6.60
ETR (ddl = 8)	4.53	4.95	0.21	3.71	83.80	46.40	46.50	57.60
ETM (Sẍ)	2.61	2.86	0.12	2.14	48.38	26.79	26.85	33.26

N. B: The means of the same column assigned to the same letter are not significantly different from each other at by the STUDENT NEWMAN-KEULS test at the 5% threshold.

According to ammonifying bacteria, before application, the average number of bacteria in the plots to be treated (2415.10^3 bacteria / 1 g dry soil) is an increase of 146.29% in comparison with the untreated control. The greatest number is located in the plot treated with *O. basilicum* 260.42 L/ha. At the full maturity, the average effect of insecticides (812.23. 10^3 bacteria / 1 g dry soil) is an increase of 126.08% in comparison with the untreated control. However, strong inhibition of bacteria of 57.78% appeared at *O. basilicum* high dose of 260.42 L/ha. The number of bacteria at this stage is less than during the period before treatment.

According to nitrifying bacteria, before insecticides application, the average number of nitrifying bacteria in the treated plots (2,051.75 .10^3 bacteria/ 1 g dry soil) is a reduction of 27.11% in comparison with the untreated control. Only the plot of *O. basilicum* 156.25 L/ha shows a surplus of nitrifying bacteria (+ 19.36%) in comparison with the untreated control. After the application of insecticides, the average effect of insecticides (892.93.10^3 bacteria / 1 g dry soil) is an increase of 108.34% in comparison with the untreated control. At this stage there is a reduction in the number of nitrifying bacteria in comparison with the period before application. However, the *O. basilicum* formulations at doses of 156.25 L/ha and 260.42 L/ha stimulated the nitrifying bacteria by 129.26% and 114.40% respectively, in comparison with the untreated control.

Table 4: Effects of *O. basilicum* hydro-alcoholic formulations different doses on tomato yield

Untreated control	949528.00 b	-	33212.00b	-
K-Optimal 1,00 L/ha	1026419.00 c	108.10	36418.00ba	109.65
***O. basilicum* 78,12 L/ha**	969058.00bc	102.06	34675.00b	104.41
***O. basilicum* 156,25 L/ha**	1004215.00 bc	105.76	35897.00ba	108.08
***O. basilicum* 260,42 L/ha**	1197678.00 a	126.13	39035.00 a	117.53
Mean	1029380.00		35834.00	
CV (%)	3.40		5.00	
ETR (ddl=12)	36641.80		1267.70	
ETM (Sẍ)	18320.90		633.85	

N. B: The means of the same column assigned to the same letter are not significantly different from each other at by the STUDENT NEWMAN-KEULS test at the 5% threshold.

Effects of different doses of *O. basilicum* formulations on the components of tomato yield.

According to the number of fruits, the average effect of insecticides (1,049,342.5 fruits /ha) represents an increase of 10.51% in comparison with the untreated control (Table 4). Between the different doses of *O. basilicum* formulations, only the high dose of 260.42 L/ha showed a net increase of 26.13% in comparison with the untreated control and 16.69% in comparison with Lambda-cyhalothrin + Acetamiprid at 1 L/ha. The dose of 156.25 l / ha was not different from the control product and resulted in an increase of 5.76% of tomatoes in comparison with the untreated control.

For the yield criteria, the average effect of insecticides (36,506.25 kg/ha) represents an increase in yield of 109.92% in comparison with the untreated control. Between the doses of *O. basilicum* formulations, only the high dose of 260.42 L/ha shows a net increase of 17.53% in comparison with the untreated control.

Correlations between some studied factors

The regression line indicates a strong negative correlation between the numbers of *B. tabaci* at the 42nd day after treatment and the tomato yield (figure 1). An infestation of 50 white flies per plant for example will lead to a tomato' yield loss of 10 948.98 kg per ha.

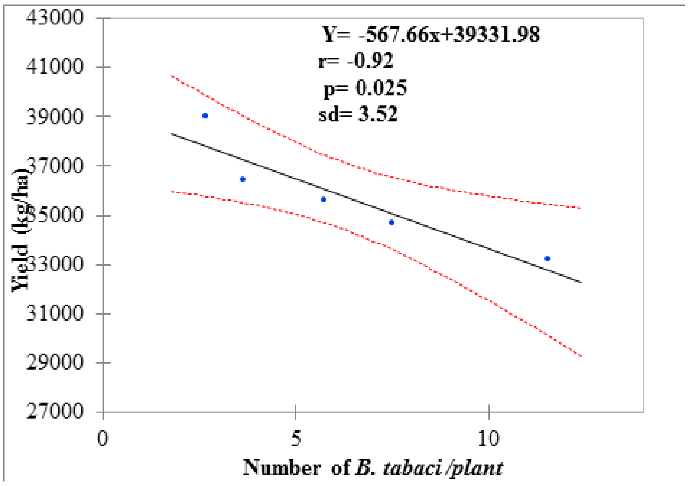

Figure 1: Correlation between the numbers of *B. tabaci* at the 42nd day after treatment and the tomato yield

DISCUSSION

The dynamics evolution of *Bemisia tabaci* population density was characterized by a continuous decrease over time during tomato development. Nzi *et al.* (2010) in Ivory Coast pointed out that the decline in the number of insects at the end of the cycle was linked to the senescence of the plants which are no longer palatable by insects. In this study, in addition to the senescence of the plants, this decrease is likely mainly related to the influence of the climate because insects are very sensitive to high temperature (Ohnesorge *et al*., 1981) because while the plant was getting older, we moved towards the warm period which is not favorable for the development of *B. tabaci*.

The application of the different insecticides resulted in a decrease in the number of *B. tabaci* in comparison with the untreated control. This efficiency is related not only to the active ingredients contained in it, but also to their mode of action, their persistence, the mode of application (doses, frequency, etc.). The control product consists of the use of lambda-cyhalothrin that fights against tomato moth (*Helicoverpa armigera*) and acetamiprid against sucking biting insects including whitefly *B. tabaci*. Acetamiprid, which belongs to the neonicotinoid family, acts by contact and ingestion against whiteflies and has systemic properties. It acts on the central nervous system of insects by disrupting the transmission of nerve impulses at the synapse level (Acta, 2014). During this experimentation, this efficiency was highlighted as evidenced by its efficiency coefficients and its persistence, of which the number of applications made it possible to cover the tomato phenological stages. The efficiency of *O. basilicum* extracts, shown by Ouédraogo *and al*. (2019), is linked to the presence of several chemical constituents in this plant species. These authors have demonstrated the presence of chemical compounds (anthraquinones, sterols / triterpenes, flavonoids) which are responsible for this insecticidal property. Other authors, such as Ntonga *and al.* (2012) have also already shown that *O. basilicum* had insecticidal properties against *Anopheles funestus*, the vector of malaria. These authors pointed out that *O. basilicum* contain hydrocarbon monoterpenes (56.20%) and that oxygenated monoterpenes and / or the combination of phenolic compounds with terpene are responsible for this efficiency. The number of whiteflies decreased when the rates were higher but also the number decreased when the plant got older. This indicates that high rates would therefore have more insecticidal effects on whiteflies and this may be linked to the high content of active ingredient in it. Nadio *et al*. (2015) achieved the same results with increasing rates of the essential oil extracted from *Ocimum sanctum* against the insect *Dysdercus volkeri*. This is why during this experimentation, the formulation of *O. basilicum* at 260.42 L/ha exhibited the best efficiency and also induced the best yield. The higher the number of whiteflies on the plant is, the higher their devastating effect is, and vice versa. This finding is similar to that of Hanafi (2000) who found that the damage associated with whiteflies on tomatoes (and therefore on yields) is linked to the level of infestation.

Nadio *et al.* (2015) have already pointed out that some insecticides inhibit the development of bacteria or have a repellent or bactericidal effect. The increase in the number of cellulolytic bacteria at maturation in the other treatments of the trial may be linked to the good presence of organic matter (because of the old tomato leaves fallen on the ground and also from the burying of herbs through weeding), a food source for cellulolytic bacteria (Jones and Wild, 1975). The increase in the number of microscopic fungi in the treatments of *O. basilicum* in comparison with the period before application shows that the formulations of *O. basilicum* behaves like a nutritious diet which can stimulate the development of these fungi especially when the applied dose is high. The large number of microscopic fungi at maturation could be explained by manual weeding which incorporates carbonaceous substances for the fungi (Kambou and Millogo, 2018) or by the good soil cover by the tomato plants which created favorable conditions to their multiplication. The very low number at the start of cultivation may be linked to plowing, which has led to the destruction of soil aggregates (Caesar-Ton That *et al*., 2007) as well as fungal hyphae (Six *et al*., 2000). Bunemann *et al*. (2006) underlined for this purpose that chemical fertilizers, by stimulating plant growth, stimulate root exudation or the return of plant residues thus promoting microbial activity. Bacteria all require special conditions (neutral pH, average humidity, cool temperature). Thus the decrease in the number of ammonifying and nitrifying bacteria at maturation in comparison to the period before application is probably linked to the inhibition of cellulolytic bacteria by the toxicity of insecticides, except for the half-dose (78.12 L/ha) of *O. basilicum* formulation which seems less toxic. However, this did not prevent the stimulation of nitrifying bacteria in comparison with the untreated control at maturation, at the dose of 156.25 L / ha and the high dose of 260.42 L / ha of *O. basilicum* thus reflecting a good absorption of nitrogen in its ammoniac and nitrate form, increase the best yield of tomatoes obtained at the rate of 260.42 L/ha.

CONCLUSION

The application of hydro-alcoholic formulations of *O. basilicum* at the dose of 260.42 L/ha resulted in an efficiency coefficients against the whitefly, *B. tabaci* which varied from 3.25% to 75.70% equivalent or superior to lambda-cyhalothrin associated with acetamiprid applied at 1 L/ha. Hydro-alcoholic formulations of *O. basilicum* did not affect the dynamics evolution of soil microorganisms, promoting good absorption of soil nutrients. This rate led to a tomato' fruits increase of 26.13% and a yield increase of 17.53% in comparison with the untreated control. In tomato production, hydro-alcoholic formulation of *O. basilicum* applied at 260.42 L/ha could be included in an integrated control program against whitefly, *B. tabaci* preserving consumers' health and the environment.

REFERENCES

Acta., 2014. Index phytosanitaire. Mrne.Tous. 956p**.**

Afanasseva A.I., Gruzdiev G.C., Dmitriev L.B., Zinchenko V.A., Kalinin V.A., Slotsev R.I., 1983. Practical guide to plant protection chemistry.Kolos, Moscow.**,** 272 P.

Agboyi L.K., Ketoh G.K., Martin T., Glitho I.A., Tamò M., 2016. Pesticide resistance in *Plutella xylostella* (Lepidoptera: Plutellidae) populations from Togo and Benin. International Journal of Tropical Insect Science, 36(4), 204-210.

Amoabeng B.W., Gurr G.M., Gitau C.W. & Stevenson P.C., 2014. Cost:benefit analysis of botanical insecticide use in cabbage: implications for smallholder farmers in developing countries. Crop Protection, 57, 71-76.

Ashraf M. A., Maah M. J., Yusoff I and Mehmood K., 2010. Effects of Polluted Water Irrigation on Environment and health of people in Jamber, district Kasur, Pakistan. International Journal of Basic & Applied Sciences, 10. (3) 37-57.

Aslan I., Ozbek H., Çalman O., Sahin F., 2004. Toxicity of essential oil vapours to two greenhouse pests, *Tetranychus urticae* Koch and *Bemisia tabaci* Genn. Industrial crops and products. 19. (2): 167-173

Assogba-Komlan F., Anihouvi P.t, Achigan E., Sikirou R., Boko A., Adje C., Ahle V., Vodouhe R., Assa A., 2007. Pratiques culturales et teneur en éléments anti nutritionnels (nitrates et pesticides) du *Solanum macrocarpum* au sud du Bénin. *African Journal of Food, Agriculture, Nutrition and Development*, 7(4), 1-21.

Bouchelta A., Boughdad A. et Blenzar A., 2005. Effets biocides des alcaloïdes, des saponines et des flavonoïdes extraits de *Capsicum frutescens* L. (Solanaceae) sur *Bemisia tabaci* (Gennadius) (Homoptera :Aleyrodidae). Biotechnology, Agronomy, Society and Environment 9(4). **9** (4), 259–269.

Bünemann E.K., Schwenke G.D., van Zwieten L., 2006. Impact of agricultural inputs on soil organisms – A review. Soil Research. 44: 379 – 406.

Caesar-TonThat T.C., Busscher W.J., Novak J.M., Gaskin J.F., Kim Y., 2007. Effects of polyacrylamide and organic matter on microbes associated to soil aggregation of Norfolk loamy sand.

Channarayappa S.G., Ivan S., Muniyappa V, Frist R.H., 1992. Resistance of *Lycopersicon* species to *Bemisia tabaci*, a tomato leaf curl virus vector. Canadian Journal of Botany. 70. 2184-2192.

Direction Générale des Etudes et des Statistiques Sectorielles., 2014. Annuaire des statistiques agricoles 2012. 163-168.

Dossa S. H.., 2018. Valorisation des plantes aromatiques dans la gestion intégrée des principaux insectes ravageurs de la grande morelle au sud du Bénin : cas de *Ocimum gratissimum* et *O. basilicum.* Mémoire de fin d'études en master de spécialisation en protection intégrée et préservation des ressources naturelles en milieu urbain et péri-urbain. Université de Liège. Gembloux Agro-bio Tech. Belgique. 69p.

Dross C., 2012. Impact de plantes aromatiques associées à la tomate sur les populations d'aleurodes *Bemisia tabaci*. Mémoire. Master Sciences et Technologies du Vivant et de l'environnement. Mention ERM. Spécialité «De L'Agronomie à l'Agro écologie » soutenu le 28 juin 2012. 45p.

FAOSTAT, 2019. Production de la tomate dans le monde, en Afrique et au Burkina Faso. http://www.fao.org/faostat/fr/#data/QC, (15/07/2018).

Gnankine O., 2005. Etude de la bioécologie de *Bemisia tabaci* (Gennadius) (Homoptera : Aleyrodidae) et de son ennemi naturel, Encarsiasp. (Hymenotera : Aphelinidae) en culture cotonnière dans l'Ouest du Burkina Faso. Thèse de doctorat. Université de Ouagadougou, 133p.

Hanafi A., 2000. La mouche blanche et le virus des feuilles en cuillère (TYLCV). *In :* bulletin mensuel d'information et de liaison du PNTTA, Institut Agronomique et Vétérinaire Hassane II- Maroc.73.1-4.

Houndété T. A., Kétoh G. K., Héma O. S., Brévault T., Glitho I. A., Martin T., 2010. Insecticide resistance in field populations of *Bemisia tabaci* (Hemiptera: Aleyrodidae) in West Africa. Pest Management Science. 66. 1181–1185.

Jones M.J. and Wild A., 1975. Soils of the West African Savannah. Technical Communications, Vol. 55. Commonwealth Agricultural Bureaux, Farnham Royal, 246 p.

Kambou G., Guissou I.P., 2011. Composition phytochimique et effets insecticides d'extraits aqueux de substances épicées sur les insectes ravageurs du haricot vert (*Phaseolus vulgaris*) au Burkina Faso. Tropicultura. 29. (4) : 212-217.

Kambou G., Nair G. M., 2015. Savon CITEC: un nouvel additif pour les extraits aqueux de *Cassia nigricans* et de *Capsicum annum* afin de lutter contre les mouches blanches (*Bemisia tabaci*, Homoptera, Aleyrodidae) et *Helicoverpa armigera* (Lépidoptères, Noctuidae) sur des tomates au Burkina Faso. Revue internationale des innovations et de la recherche agricoles. Vol. 3.(4): 1807-1813.

Kambou G., Hema S.A., Boro F., Ouedraogo L, 2018. Biological efficiency of polyethylene plastics and Idefix (Cupric hydoxid 65.60%) in injection against tomatoes bacterial wilt (*Ralstonia solancearum* (Smith, 1896) and their effects on soil microorganisms, in Burkina Faso. International journal of Agriculture Innovations and Research. Vol.6. (4): 31-38.

Kambou G., Millogo A.M., 2018. Efficacité biologique d'extraits aqueux de substances naturelles (*Cassia nigricans* Vahl., *Parkia biglobosa* (Jacq.) R. Br ex G. Don., *Capsicum annum* L., *Cleome viscosa* L.) sur la chenille légionnaire (*Spodoptera frugiperda* J.E Smith) en culture du maïs et de leurs effets sur les microorganismes d'un sol ferrugineux, au Burkina Faso**.** Journal of Environmental Science, Computer Science and Engineering & Technology. Sec. A; Vol.8. (1): 36-51.

Ministère de l'Agriculture et des Aménagements Hydro-agricoles, 2017. Situation de référence du programme de développement des cultures fruitières et légumières (PDCFL), Phase 2018-2022, Ministère de l'Agriculture et des Aménagements Hydrauliques, Ouagadougou, Burkina Faso, 61p.

Ministère de l'Agriculture et de l'Hydraulique, 2011. Rapport général du module maraîchage. Ministère de l'Agriculture et de l'Hydraulique, Ouagadougou, Burkina Faso, 318 p.

Ministère de l'Agriculture, de l'Hydraulique, des Aménagements et des Ressources Halieutiques, 2007. Analyse de la filière maraichage au Burkina Faso. 127p

Nadio N. A., Poutouli W. P., Akantetou P., Laba B., Tozoou P., Bokobana M. E., Koba K.., Raynaud C., Sanda K., 2015. Propriétés insecticides et répulsives de l'huile essentielle d'*Ocimum sanctum* L. envers *Dysdercus voelkeri* schmidt (heteroptera; pyrrhocoridae)

Naika S., De Jeude J.V.L., De Goffau M., Hilmi M. Van D.B., 2005. La culture des tomates: production, transformation et commercialisation, Agromisa et CTA, Wageningen, Pays-Bas, 105 p.

Ngom S., Traore S., Thiam M.B. & Anastasie M., 2012. Contamination des produits agricoles et de la nappe phréatique par les pesticides dans la zone des Niayes au Sénégal. Synthèse *Revue des Sciences et de la Technologie*, *25*(1), 119-130.

Ntonga A. P., Belong P., Tchoumbougnang F., Barkwo Fils E-M., Fankem H., 2012. Composition chimique et effet insecticides des huiles essentielles des feuilles fraîches d'*Ocimum cancun* sims et d'*Ocimum basilicum* L. sur les adultes d'*Anopheles funestus*, Vecteur du paludisme au Cameroun. Journal of applied Biosciences. Vol. 59. 4340-4348.

Nzi J.C., Kouamé C., N'Guetta A.S.P., Fondio L., Djidji A.H., Sangaré A., 2010. Evolution des populations de *Bemisia tabaci* Genn. Selon les variétés de tomates au Centre de la Côte d'Ivoire. Sciences & Nature Vol.7. (1): 31 - 40.

Ohnesorge B., Sharaf N. & Allawi T., 1981. Population studies on the tobacco whitefly *Bemisia tabaci* Genn. (Homoptera: Aleyrodidae) during the winter season. Part 1. J. Appl. Entomol. 92. (2): 127-136.

Ouattara A., Tiendrebeogo F., Lefeuvre P., Claverie S., Hoareau M., Traore E.V., Barro N., Traore O., Lett J-M., 2017. Tomato leaf curl Burkina Faso virus: a novel tomato-infecting monopartite begomovirus from Burkina Faso. Archives of Virology, 162.(5) : 1427-1429.

Ouedraogo B., Kambou G., Yaro B and Nacro H. B., 2019. phytochemical composition and biological efficiency of *Ocimum basilicum* L. leaves, *Parkia biglobosa* (jacq.) R. Br ex G. Don, pods powders organic extracts against *Bemisia tabaci* biotype B (gennadius) (hemiptera: aleyrodidae) of tomato (*Lycopersicum esculentum* miller) (solanales: solanaceae), in Burkina Faso. World journal of pharmaceutical research, vol 9, 1074-1088

Shavit R., Ofek-Lalzar M., Burdman S and Morin S., 2013. Inoculation of tomato plantes with rhizobacteria enhances the performance of the phloem-feeding insect Bemisia tabaci. Frontiers in Plants Sciences. 4:306

Six J., Paustian K., Elliott E.T., Combrink C., 2000. Soil structure and organic matter: Distribution of aggregate-size classes and aggregate-associated carbon. Soil Science Society of America Journal. 64. (2):681-689.

Son D., Bonzi S., Somda I., Bawin T., Boukraa S., Verheggen F., Francis F., Legreve A. & Schiffers B., 2017a. First Record of *Tuta absoluta* (Meyrick, 1917) (Lepidoptera: Gelechiidae) in Burkina Faso. *African Entomology.*25. (1): 259–263.

Song B. Z., Wu H. Y. Kong Y., Zhang J., Du Y. L and Yao Y. C., 2010. Effects of intercropping with aromatic plants on the diversity and structure of an arthropod community in a pear orchard. Biocontrol. 55. (6) : 741-751.

Tepper E.Z., Chilnikova V.K., Prievierzeva G.I., 1987. Guide pratique de microbiologie. M. Agropromizdat. 239p.

Tourigny G., 1993. Gestion phytosanitaire des pépinières de tomates, Ouagadougou, Burkina Faso, 50p.

Wellens J., Traoré F., Diallo M., Dakoure D. et Compaore N. F., 2008. Renforcement structurel de la capacité de gestion des ressources en eau pour l'agriculture dans le bassin du Kou. Rapport Technique 2. APEFE-DRI/CGRI. Bobo-Dioulasso, Burkina Faso.150 p

Yadave A and Mendhulkar V.D., 2015. Repellency AND toxicity of *Couroupita guianenis* leaf extract against silverleaf whitefly (*Bemisia tabaci*). International Journal of Scientific and Research Publications. Vol 5. (4): 1- 4.