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Comparative Effects of Some Botanical Extracts and Chemicals in Controlling the Red Spider Mite *Tetranychus evansi* Baker & Pritchard on Solanaceous Crops

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Abstract

The tomato red spider mite, *Tetranychus evansi*, is an invasive pest reported on solanaceous crops in Benin around 2008, causing heavy economic damage. The control of this mite by farmers is mainly done through intensive applications of chemical pesticides that are not always effective. In the present study, we evaluated in a laboratory, at IITA-Benin, the effects of two botanical insecticides: the Cashew Nut Shell Liquid (CNSL) and Neem oil. This is together with Acarius 18 EC, a chemical acaricide generally used by growers on eggs and adult females *T. evansi*. The half recommended dose (0.5 l/ha), the recommended dose (1 l/ha), and the double recommended dose (2 l/ha) of Acarius and Neem oil as well as solutions at 1%, 2 %, 3%, 4% and 5% of CNSL were tested. Mean egg hatching rates varied significantly among treatments, ranging from 0.00 ± 0.00% (Neem oil and CNSL) (respectively at half recommended dose and 4%) to 100% (Control). Mortality of adult female *T. evansi* also differed significantly among treatments ($P < 0.0001$), ranging from 22.00 ± 4.20% to 100%. The highest mortality rates were recorded with Neem oil at any doses and with CNSL at 4%, whereas the lowest rate was recorded with the control treatment. Fecundity of pesticide-treated females *T. evansi* and proportion of eggs that hatched revealed significant differences among all doses of products ($P < 0.0001$). It appears from this study that even the half recommended dose of Neem oil and the CNSL at 4% were very effective on suppressing *T. evansi* populations and should, therefore, be subject to further studies to test their compatibility with natural enemies, and to determine strategies for their efficient applications in greenhouse and under field conditions.

Keywords: Mite pests of tomato, Cashew Nut Shell Liquid (CNSL), Neem oil, *Solanum lycopersicon*, biopesticide

Introduction

The tomato red spider mite, *Tetranychus evansi* Baker and Pritchard (Acari: Tetranychidae), is an invasive pest of tomato and other solanaceous crops in several African, American, Asian, and European countries, with the potential of causing up to 90% yield reduction (Sarr *et al.*, 2002; Saunyama & Knapp, 2003; Navajas *et al.*, 2012). In the Republic of Benin (West Africa), *T. evansi* has become, since 2008, the key mite pest of first importance not only of tomato (*Solanum lycopersicon* L.), but also of other solanaceous crops such as the African eggplant (*Solanum macrocarpon* L.) (Azandémè-Hounmalon *et al.*, 2014, 2015). This mite is characterized by its high reproductive capacity, which leads to high population levels in a short time resulting in an important economic damage (Moraes & McMurtry, 1986). It could destroy a whole solanaceous field in less than one week if no adequate treatment is applied (Azandémè-Hounmalon *et al.*, 2014). Besides its invasive nature, recent reports indicate that *T. evansi* may be displacing native spider mite species, hence posing new pest management challenges (Ferragut *et al.,* 2013).

While there are efforts to control *T. evansi* using cultural practices (Saunyama & Knapp, 2003; Savi *et al.*, 2019ab; Djossou *et al.*, 2020; Savi *et al.,* 2021), application of chemical pesticides remains the method preferred by farmers (Toroitich *et al.,* 2014; Azandémè-Hounmalon *et al.*, 2015). However, previous studies have shown that chemical applications can entail the risk of resistance development among insect and mite populations because of long-term exposure to pesticides (Blair, 1989; Tsagkarakou *et al.*, 2002; Nyoni *et al.,* 2011). Thus, this result to the recrudescence of the pest as these pesticides had lost their efficacy (Copping & Menn, 2000; Marcié & Medo, 2014; Reddy, 2016). As a result, there is an urge to search for alternative methods that can efficiently control this mite pest without harming the environment. Fortunately, biopesticides such as plant extracts and essential oils have been acknowledged to be effective while being biodegradable, with no hazardous effects on the environment (Sanon *et al.*, 2005; Rochefort *et al.,* 2006; Salma & Jogen, 2011; Sarwar, 2015). As a consequence, several studies have evaluated the efficacy of plant extracts in the control of agricultural and crop pests including vegetable mite pests (Adango *et al.*, 2020) and insect pests (Gnago *et al.,* 2010; Fayalo *et al.,* 2014; Sane *et al.,* 2018), as well as other arthropod pests associated with bees and bee products (Gbedomon *et al.,* 2012).

In Africa, several plant species are known and used for their biocidal activities (toxic, repellent, anti-appetite) against pests (Baidoo *et al.,* 2012). Neem (*Azadirachta indica* A. Juss) is one of such plant whose extracts (leaf, seed oil etc..) are being extensively used as an alternative to chemical pesticides in managing insect and mite pests (Fayalo *et al.,* 2014; Traoré *et al.,* 2019a; Adango *et al.*, 2020). The major active ingredient of Neem extracts is the azadirachtin that can cause, on arthropods, several negative effects such as feeding inhibition, repellency, fertility and fecundity reduction, behavioral changes, and increased mortality (Schmutterer, 1990; Dimetry *et al.,* 1993; Mordue & Nisbet, 2000; Musabyimana *et al.*, 2001). The main advantages of using neem extracts are their insecticidal and acaricidal activities, their low toxicity towards mammals and birds, and their fast degradation in the soil and animals (Isman, 2006; Normas, 2008).

The cashew tree (*Anacardium occidentale* L.) is a multipurpose tree. In Benin, cashew is the second largest export crop after cotton. In 2013, Benin was ranked 5th exporter of raw cashew nuts among the main world exporters with a production of 180.000 tons / year (FAO, 2013). However, in spite of such a high production, some of the products and by-products of cashew trees are often thrown away, although some of them could have biocidal properties that could be considered in the control of crop pests. In their study, Chabi *et al.* (2014) have shown that leaves and bark of cashew tree have fungicidal and bactericidal properties. Other studies have shown that Cashew Nut Shell Liquid (CNSL: the balm derived from shell) have interesting biocidal properties against pests (Cavalcante *et al.*, 2003; Chabi *et al.*, 2013; 2014).

To control mite and other insect pests, Acarius 18EC (Abamectin 18g / L, EC) is the chemical insecticide-acaricide widely used by farmers in major vegetable production in Benin (Azandémè-Hounmalon GY unpublished). The active ingredient of Acarius 18 EC is Abamectin that has been enriched with oil to facilitate its penetration into the plant tissue. It acts by ingestion and, to a lesser extent, by contact on mobile forms of mites and on biting-sucking insects.

Whereas Neem oil have been shown to cause deleterious effects on some mite species (Adango *et al.*, 2020; Azandémè-Hounmalon *et al.*, in press), no studies have yet been carried out to determine the acaricidal properties of the CNSL.

Therefore, this paper focuses on evaluating the efficacy of Neem oil and CNSL (two botanical insecticides) in comparison with Acarius 18 EC (chemical insecticide-acaricide) in controlling the tomato red spider mite *T. evansi*, a first step for their possible use as alternatives to chemical pesticides on vegetable farms.

2. Methods

2.1 Study Site

The study was conducted in a laboratory at the International Institute of Tropical Agriculture (IITA), Benin-Station, located at 12 km NW Cotonou (6°25’N; 2°19′E; 15 m asl). The experimental conditions were 25 ± 2 °C, 60–70% RH and 12:12 h (L: D).

2.2 Plants and Mites Rearing

The potted tomato plants used in the study were kept on metallic benches in a screenhouse for about 45 days until they bear at least four completely developed leaves. The leaves were subsequently picked, either for producing leaf discs or for rearing *T. evansi*.

The population of *T. evansi* used in this study was originally collected from a vegetable farm at Sèmè-Kpodji in the Southern-Benin (6°22’N; 2°37E) in March 2016 and maintained in a screenhouse at IITA-Benin (27 ± 1 °C, 70–80% RH and 12:12 h (L:D) photoperiod) on nightshade (*Solanum macrocarpon*) or tomato plants.

2.3. Pesticides Tested

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The pesticides used in this study included the Cashew Nut Shell Liquid (CNSL) and Neem oil, two biopesticides, and Acarius 18 EC, which is a chemical acaricide (Abamectin 18g/L, EC) commonly used by growers on vegetable farms to control arthropod pests.

Neem oil is obtained from *Azadirachta indica* A. Juss. (Meliaceae) seeds and is used as an insecticide whose active ingredient is Azadirachtin. It is a 100% natural oil that is non-toxic to humans and animals. It does not act by contact but prevents insects from feeding thereby disturbing their development and their ability to oviposit (Karnavar, 1987; Belanger & Musabyimanan, 2005). The Neem oil used in this study was purchased from Biophyto at Allada in the Republic of Benin.

The chemical pesticide Acarius 18 EC (Abamectin 18g/L, EC), miticide-insecticide, is manufactured by Savana Www.Savanna-France.Com. The application dose recommended is 0.5 l/ha. Abamectin acts by ingestion and, to a lesser extent, by contact on biting-sucking mites and insects (RECA, 2013; http://terra.mg/agricom/agriculture/fr/produit/acarius-018-ec/, June 2022).

The CNSL was obtained from the Nutrition Department at the Faculté des Sciences Agronomiques (FSA) of the Université d'Abomey-Calavi (UAC) in Benin. The different concentrations of CNSL tested in this study were based on the method reported by Kerala Agricultural University (2009).

2.4 Experimental Design

The experiment consists of the application of the two botanical insecticides (i.e., Neem oil and CNSL), the chemical acaricide-insecticide (i.e., Acarius 18EC), and the control treatment (application of tap water alone). Three different doses of Neem oil and Acarius including half of recommended dose (D1), the recommended dose (D2), and the double of the recommended dose (D3) were tested.

According to the recommendations by RECA (2013), 25 ml of Acarius should be mixed with 15 liters of water while 80ml of Neem oil are requested for 16 liters of water (https://www.biophyto-benin.com). For CNSL, five solutions of the respective concentrations of 1%, 2%, 3%, 4%, and 5% were prepared in distilled water with vegetable soap (palmida) added as emulsifier. To achieve it, 50g of the soap were dissolved in 670 ml of water. Then, 330 ml of CNSL was added to the mixture which was vigorously stirred to obtain 1l of a good emulsion (i.e., the stock solution). Series of dilutions were carried out using the stock solution to obtain the different concentrations of CNSL tested (1%, 2%, 3%, 4% and 5%).

For each pesticide, the solution used in the experiments was prepared as presented in Table 1.

Table 1. Different doses used for acaricide treatment

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Doses (ml/l) of water

Treatments	D1	D2	D3	1%	2%	3%	4%	5%
Acarius	0.83	1.66	3.34	-	-	-	-	-
Neem oil	2.5	5	10	-	-	-	-	-
CNSL	-	-	-	10	20	30	40	50

D1 = Half recommended dose; D2 = Recommended dose; D3 = Double recommended dose
1%, 2% 3% 4% and 5% = concentrations of CNSL

2. 5 Data Collection

2.5.1 Effects on Adult Females *T. evansi*

Per treatment, 5 leaf discs cut from fresh *S. lycopersicum* leaves were dipped for 5 seconds into the pesticide solution tested. The leaf discs (2 cm diameter) were then placed on the lower side up on water-soaked cotton wool in Petri dishes (9 cm diameter), and it was allowed to dry for 30 minutes (Toroitich *et al*., 2014). Thereafter, 10 adult females *T. evansi* (24 to 48h-old) were transferred from the rearing unit to each leaf disc. The monitoring started 24 h later for six consecutive days during which the daily mortality of females, the number of eggs laid, and those that hatched were recorded. Escaped mites were excluded from the analysis.

2.5.2 Effects on *T. evansi* Eggs

Per treatment, 5 leaf discs (25 mm diameter) were cut from fresh *S. lycopersicum* leaves and on each of them, 10 newly laid *T. evansi* eggs (24 h-old) were deposited. The 5 leaf discs for each treatment were then placed, lower side up, on water-soaked cotton wool in a Petri dish (9 cm diameter) and sprayed with the pesticide solution at its appropriate dose for 5 seconds. The leaf discs were then dried out at ambient air for 1h. The leaf discs contained in a Petri dish represent the 5 replicates for each treatment. The leaves were monitored daily for five consecutive days to record the number of eggs that hatched per treatment and per dose.

2.5.3 Data Analysis

The mortality data on ovicidal tests were corrected in relation to the control (water) using the Abbott's formula (Abbott, 1925), while actual uncorrected figures were used for adult mortality. Data on egg and adult mortality rates were arcsine square root-transformed (Arcsine$\sqrt{(X)}$), which is then subjected to a one-way analysis of variance (Proc GLM). In case of significant differences, treatments means were separated using the Student-Newman-Keuls test (SAS 9.1, 2009).

3. Results

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3.1 Effect on Mortality of Adult Female *T. evansi*

The temporal evolution of different product effect on the mortality of adult female *T. evansi* is shown in Figure 1 and Table 2. The mean mortality rate of adult female *T. evansi* varied between 22.00 ± 4.20% (Control) to 100% (CNSL 4%, 5% and Neem oil). At day 1 (i.e., 24 hours) after application, the highest mortality rate of *T. evansi* females (100%) reached half recommended dose (D1) of Neem oil, 4% and 5% of CNSL. Also, 3 days after application of Acarius, this rate reached the double recommended dose (D3). At the end of the observation period, the analysis of variance showed significant differences in the effects of treatments on the mortality of adult female *T. evansi* (df = 11; F = 39.82; P < 0.0001; Table 2). The Student-Newman Keul test revealed that all the doses of Neem oil as well as the 4% and 5% of CNSL solutions had statistically similar effects by inducing the highest mortality of adult female *T. evansi* (Table 2).

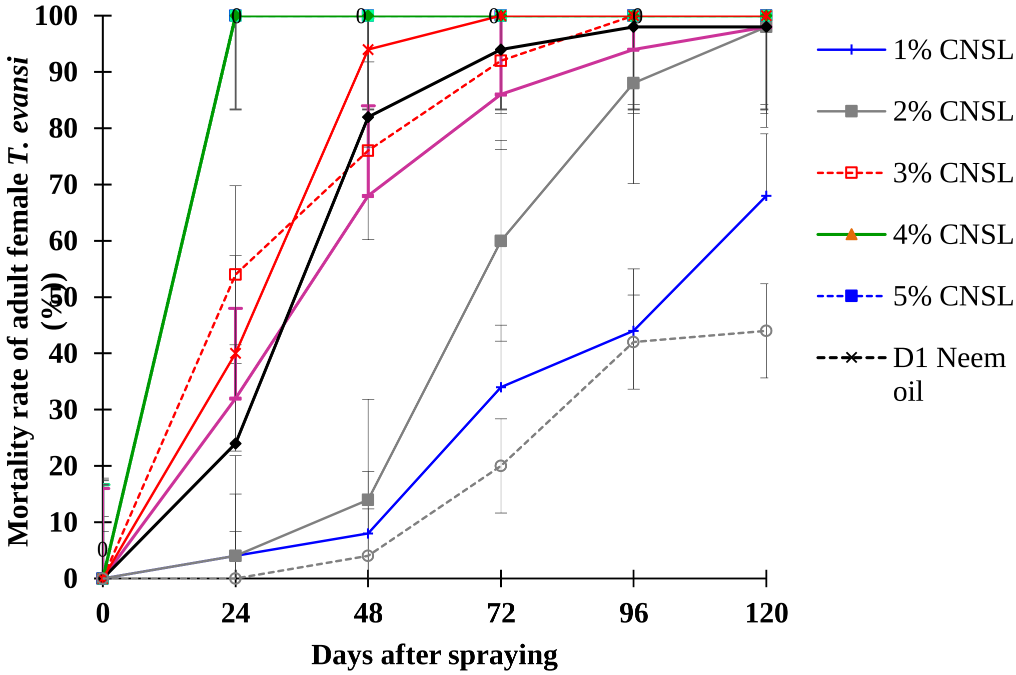

Figure 1. Adult mortality of *T. evansi* at 1%, 2%, 3%, 4%, 5% of CNSL, at half recommended dose D1, recommended dose D2 and double recommended dose D3 of different pesticide products

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Table 2. Effects of treatments on mortality of adult female *T. evansi*

Treatments	N	Mean ± SE	Df	F	P
CNSL 1%	25	31.60 ± 5.67a			
CNSL 2%	25	52.80 ± 8.13b			
CNSL 3%	25	84.40 ± 4.69cd			
CNSL 4%	25	100.00 ± 0.00d			
CNSL 5%	25	100.00 ± 0.00d	11	39.82	<0.0001
Acarius D1	25	75.60 ± 5.41c			
Acarius D2	25	79.20 ± 5.91c			
Acarius D3	25	86.80 ± 5.43cd			
Neem oil D1	25	100.00 ± 0.00d			
Neem oil D2	25	100.00 ± 0.00d			
Neem oil D3	25	100.00 ± 0.00d			
Control	25	22.00 ± 4.20a			

Values represent Means ± SE. Means followed by the same letter in a column are not significantly different for the performance measurement (SNK test, $P < 0.05$); D1 = Half recommended dose; D2 = Recommended dose; D3 = Double recommended dose; 1%, 2%, 3%, 4% and 5% = concentrations of CNSL
N= Number of observations

3.2 Effects on Viability of *T. evansi* Eggs

Among all the three pesticides tested (all doses pooled together), the average hatching rates of *T. evansi* eggs ranged from 0% (Neem oil, CNSL 4% and 5%) to 100% (Control) (Figure 2). Results of the analysis of variance showed significant differences in the viability of *T. evansi* eggs among all the treatments (df = 11; F = 46.7; $P < 0.0001$). However, no eggs hatching was recorded with Neem oil and CNSL (4% and 5%) applications (Table 3).

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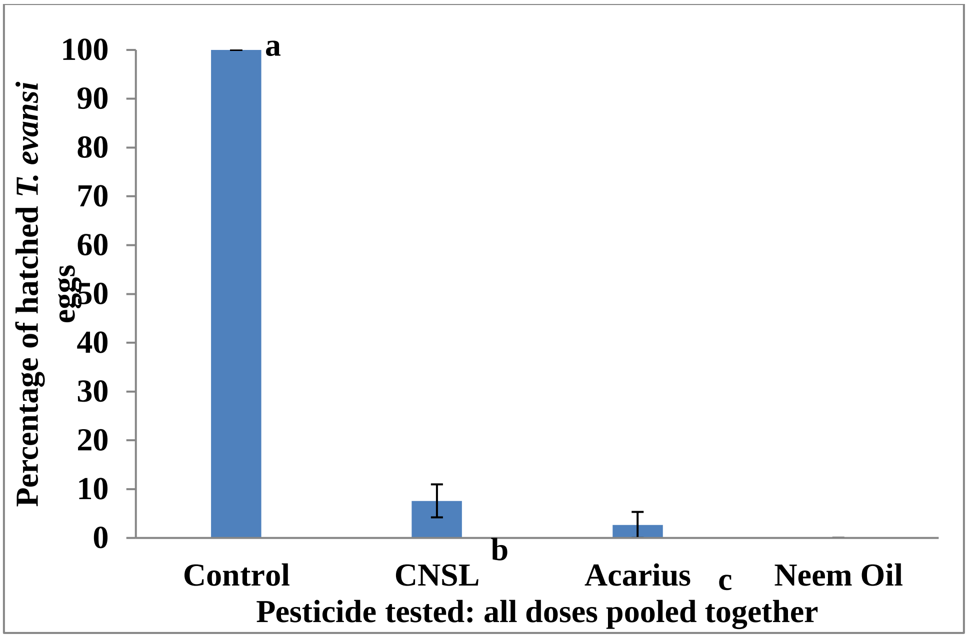

Figure 2. Eggs hatching of *T. evansi* after application of pesticide products
Columns followed by the different letters indicate significant differences (SNK test, P<0.05)

Table 3. Within-treatments effects of doses on hatchability of *T. evansi* eggs

Treatments	N	Mean ± SE	Df	F	P
CNSL1%	5	32.00 ± 11.57b			
CNSL2%	5	2.00 ± 1.99aa			
CNSL3%	5	4.00 ± 4.02a			
CNSL4%	5	0.00 ± 0.00a			
CNSL5%	5	0.00 ± 0.00a			
Acarius D1	5	8.00 ± 7.99a			
Acarius D2	5	0.00 ± 0.00a	11	46.7	<0.0001
Acarius D3	5	0.00 ± 0.00a			
Neem oil D1	5	0.00 ± 0.00a			
Neem oil D2	5	0.00 ± 0.00a			
Neem oil D3	5	0.00 ± 0.00a			
Control	5	100 ± 0.00c			

Values represent Means ± SE. Means followed by the same letter in a column are not significantly different for the performance measurement (SNK test, P < 0.05); D1 = Half recommended dose; D2 = Recommended dose; D3 = Double recommended dose; 1%, 2%, 3%, 4% and 5% = concentrations of CNSL N= Number of observations

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3.3 Fecundity of Adult Females *T. evansi* that Survived Pesticide Applications

The mean number of eggs laid by an adult female *T. evansi* that survived the pesticide applications ranged between 1.33 ± 0.32 (Acarius) and 24.68 ± 3.78 (Control). The results of the analysis of variance showed significant differences among treatments (df = 6; F = 9.28; P < 0.0001) (Table 4). However, there were no surviving *T. evansi* females with 4%, 5% of CNSL, and the Neem oil applications. For all the products, the lowest fecundity rate for the surviving *T. evansi* females was recorded with Acarius (1.33 ± 0.32).

Table 4. Fecundity of adult females *T. evansi* after application of pesticide products

Treatments	N	Mean ± SE	Df	F	P
CNSL 1%	25	8.16 ± 0.67ac			
CNSL 2%	16	9.68 ± 1.76c			
CNSL 3%	8	2.50 ± 0.88b			
CNSL 4%	-	-			
CNSL 5%	-	-			
Acarius D1	6	3.00 ± 0.68ab	6	9.28	<0.0001
Acarius D2	8	4.25 ± 1.55bc			
Acarius D3	3	1.33 ± 0.32ab			
Neem oil D1	-	-			
Neem oil D2	-	-			
Neem oil D3	-	-			
Control	25	24.68 ± 3.77d			

Values represent Means ± SE. Means followed by the same letter in a column are not significantly different for the performance measurement (SNK test, P < 0.05); D1 = Half recommended dose; D2 = Recommended dose; D3 = Double recommended dose; 1%, 2%, 3%, 4% and 5% = concentrations of CNSL
N= Number of observations

3.4 Viability of Eggs laid by Pesticide-treated Adult Females *T. evansi*

The hatching rate of eggs laid by pesticide-treated female *T. evansi* was significantly the lowest on CNSL 2% (0.40 ± 0.40) compared to the Control (20.00 ± 8.16). The results of the analysis of variance revealed significant differences among the different doses of products (df = 11; F = 5; P <0.0001) (Table 5). However, irrespective of the products and doses tested, none of those eggs were able to hatch.

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Table 5. Viability of *T. evansi* eggs after application of pesticide products

Treatments	N	Mean ± SE	Df	F	P
CNSL 1%	25	6.40 ± 3.36b			
CNSL 2%	25	0.40 ± 0.40a			
CNSL 3%	25	0.8 0± 0.80a			
CNSL 4%	25	-			
CNSL 5%	25	-			
Acarius D1	25	1.60 ± 1.60ab	11	5.0	<0.0001
Acarius D2	25	-			
Acarius D3	25	-			
Neem oil D1	25	-			
Neem oil D2	25	-			
Neem oil D3	25	-			
Control	25	20.00 ± 8.16c			

Values represent Means ± SE. Means followed by the same letter in a column are not significantly different for the performance measurement (SNK test, $P < 0.05$); D1 = Half recommended dose; D2 = Recommended dose; D3 = Double recommended dose; 1%, 2%, 3%, 4% and 5% = concentrations of CNSL N= Number of observations

Discussion

The use of pesticide plants extracts is now emerging as one of the important tools in crop protection, which preserve the environment. Many of such plants are known and used for their biocidal activities (toxic, repellent, anti-appetizing) against a wide range of pest (Yarou, 2017).

The results accrued from this study showed that the biopesticides Neem oil (half recommended dose) and CNSL (4% and 5% of concentration) exerted the most significant effects against *T. evansi* by inducing higher mortality (100%) and by reducing or neutralizing the fecundity and viability of their eggs compared with Acarius. It appears that Neem oil and CNSL have had ovicidal effects on *T. evansi*, and this could be explained by *T. evansi* egg having a slender chorion with airfoils (small holes related to embryonic respiration), which certainly facilitate its penetration by the toxic compounds (Bruce *et al.*, 2004). Similar results were reported by Asogwa *et al.* (2007), who showed that various concentrations of CNSL solutions (i.e., 6%, 8% and 10%) caused 100% mortality in termite populations. Kpoviessi *et al.* (2017a) reported that the CNSL can significantly reduce aphids, thrips, and *Maruca vitrata* Fabricius populations in cowpea fields. As reported by Araujo and Xavier (2009), the CNSL mainly contains anacardic acid, cardanol, cardol, 2-methylcardol in varying proportions and they are known to exhibit strong larvicidal activity against mosquitoes (Mukhopadhyay *et al.*, 2010; Oliveira *et al.*, 2011; Raraswati *et al.*, 2014; Paiva *et al.*, 2017). Similarly, 100% mortality of adults of *Sitophilus oryzae* L. (Coleoptera: Curculionidae) exposed to CNSL effects during five times (24h, 48h, 72h 96h, and 120h) was reported by Buxton *et al.* (2017). Moreover, Chinniah *et al.* (2020) reported that CNSL solution at 3% reduced 52% of the citrus leaf mite population, *Panonychus citri* McGregor.

As for the Neem oil, its effects of mite and insect pests have been reported by several authors (Fazil & Ansari, 2011; Oliveira *et al.*, 2013; Traoré *et al.*, 2019ab; Adango *et al.*, 2020; Savi *et al.*, 2021b; Azandémè-Hounmalon *et al.*, 2022, in press). Furthermore, the Neem oil, *Azadirachta indica*, has insecticide and ovicidal potentials against insects and mites (Zongo *et al.*, 1993; Ventura & Ito, 2000; Tedeschi *et al.*, 2001; Schukla & Kumar, 2002; Viana & Prates, 2003; Bruce *et al.*, 2004; Souza & Vendramim, 2005; Kumar *et al.*, 2005; Haq, 2006; Venzon *et al.*, 2007; Singha *et al.*, 2007; Prabhat Kumar, 2007; Charbonneau *et al.*, 2007; Yasmin *et al.*, 2008; Faye, 2010; Fazil & Ansari, 2011; Oliveira *et al.*, 2013; Traoré *et al.*, 2019ab; Adango *et al.*, 2020). The main compound of the Neem oil, Azadirachtin, widely admitted having fungicidal, insecticidal, and/or acaricidal properties (Karnavar, 1987; Bélanger & Musabyimana, 2005; Musabyimanan, 2005; Yarou *et al.*, 2017; Traoré *et al.*, 2019; Adango *et al.*, 2020). Azadirachtin can be found in the leaves and the fruits; its toxicity is higher by ingestion than by contact, which allows its selective use against some phytophagous pests (Akol *et al.*, 2002; Gaspari *et al.*, 2007). Azadirachtin has an anti-appetite effect and can also acts by directly killing or repelling insects, affect egg-laying by females as well as molting and larval growth of certain arthropods (Stoll, 2002; Bélanger & Musabyimana, 2005; Guèye *et al.*, 2011; Gbedomon *et al.*, 2012; Bernadi *et al.*, 2013). In their study, Mouffok *et al.* (2008) reported the negative effects of azadirachtin on hormonal secretion, morphogenetic development, respiration of several insect species, and on the development of insect tissues (i.e., muscular, nervous, glandular, etc.). They also reported that azadirachtin is an anorexic agent since they are once in contact with it. Hence, the insect no longer eats and it finally dies. The high mortality of *T. evansi* (adults and eggs) recorded with Neem oil witnesses the sensitivity of all life stages of the mite pest to that azadirachtin. Our results showed that Acarius, the chemical insecticide, is not more effective than Neem oil and CNSL in controlling *T. evansi*.

Irrespective of its doses, Neem oil and the 4% or 5% solutions of CNSL, none of the eggs treated with those products survived and none of the survived females could oviposit. Thus, this suggests that *T. evansi* populations treated with Neem oil or CNSL at that concentration could seldom develop pesticide resistance, since no progeny could be expected and that could have survived to adulthood to initiate new populations (Osakabe *et al.*, 2009; Fortin *et al.*, 2012). In contrast, such risks are present with Acarius. Neem oil or

CNSL are derived from a vegetal, and thus, are expected to be less toxic to non-target organisms such as mammals, birds, aquatic fauna, and its use in biological or conventional agriculture (Mouffok *et al.,* 2008; Faye, 2010; Habou *et al.,* 2013). In addition, they are some relatively low-cost acaricide since the half of the recommended dose of Neem oil and a 4% solution of CNSL are enough to get maximal effect within 24 hours after application in the laboratory.

Conclusion

It appears from our results that Neem oil and CSNL could be considered for the integrated management (IPM) strategies against *T. evansi* in tomato fields. However, because our study was conducted in the laboratory, future studies are still needed to explore all the implications of using these biopesticides as alternatives to conventional synthetic acaricides against *T. evansi*, as well as their compatibility with biological control agents such as *Phytoseiulus longipes* Evans on tomato crop.

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