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DOI: <https://dx.doi.org/10.4314/acsj.v30i2.8>



EFFICACY OF VEGETABLE OIL EXTRACTS FOR CONTROL OF INSECT PESTS OF TOMATO IN SOUTHERN BENIN

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(Received 3 April 2022; accepted 30 May 2022)

ABSTRACT

Pests are a menace to production of tomato (*Lycopersicon esculentum* Mill.) in sub-Saharan Africa. The objective of this study was to evaluate the efficacy of oil extracts of selected common plants for control of pests of tomato in Benin. The study was carried out on the Togba market garden sites in Benin. The botanical pesticides (*Tephrosia purpurea*, *Ricinus communis*, *Thevetia neriifolia* and Cashew Nut Shell Cold Liquid (CNSL cold) were compared with a biological insecticide (Topbio), a synthetic insecticide (Lambda cyhalothrin) and an untreated negative control. The fish model and the generalised linear mixed or fixed effects model were used to explain the number of caterpillars per plot as a function of the products tested during the different plant phases. *Tephrosia purpurea* oil, cold CNSL, Topbio and lambda cyhalothrin treatments significantly reduced *H. armigera*, *S. littoralis* and *T. absoluta* populations. The average yields of marketable tomato ranged from 7.20 ± 0.89 t ha⁻¹ for the controls and 21.14 ± 3.56 and 20.46 ± 1.98 t ha⁻¹ for the plots treated with *Tephrosia purpurea* and CNSL cold on tomato, respectively. Plots treated with the synthetic insecticide lambda cyhalothrin gave the best yields (31.15 ± 3.20 t ha⁻¹). Of all the extracts tested, cold extracted CNSL and *T. purpurea* oil showed very high larvicidal activity at doses of 10%, compared to *R. communis* and *T. neriifolia* oil on the farm. The larvicidal activity of the extracts observed at low doses on *H. armigera* and *S. littoralis* larvae seems to offer an alternative advantage for the control of tomato pests.

Key Words: *Ricinus communis*, *Tephrosia purpurea*, *Thevetia neriifolia*

RÉSUMÉ

Les ravageurs sont une menace pour la production de tomate (*Lycopersicon esculentum* Mill.) en Afrique sub-saharienne. L'objectif de cette étude était d'évaluer l'efficacité des extraits d'huile de *Tephrosia purpurea*, *Ricinus communis*, *Thevetia neriifolia* et Cashew Nut Shell Cold Liquid (CNSL

cold) pour le contrôle des ravageurs de la tomate. L'étude a été réalisée sur les sites maraîchers de Togba au Bénin. Les pesticides botaniques ont été comparés à un insecticide biologique (Topbio), un insecticide de synthèse (Lambda cyhalothrine) et un témoin négatif non traité. Le modèle poisson *zèbre* et le modèle linéaire généralisé à effets mixtes ou fixes ont été utilisés pour expliquer le nombre de chenilles par parcelle élémentaire en fonction des produits testés lors des différentes phases de la plante. Les traitements à l'huile de *Tephrosia purpurea*, au CNSL cold, au Topbio et à la lambda cyhalothrine ont significativement réduit les populations de *H. armigera*, *S. littoralis* et *T. absoluta*. $20,46 \pm 1,98$ t ha⁻¹ pour les parcelles traitées respectivement avec *Tephrosia purpurea* et CNSL cold sur tomate. Les parcelles traitées avec l'insecticide de synthèse lambda cyhalothrine ont donné les meilleurs rendements ($31,15 \pm 3,20$ t ha⁻¹). De tous les extraits testés, l'huile de CNSL cold et de *T. Purpurea* extraite a montré une activité larvicide très élevée à des doses de 10% par rapport à l'huile de *R. communis* et de *T. neriifolia* à la ferme. L'activité larvicide des extraits observée à faible dose sur les larves de *H. armigera* et *S. littoralis* semble offrir un avantage alternatif pour la lutte contre les ravageurs de la tomate.

Mots Clés : *Ricinus communis*, *Tephrosia purpurea*, *Thevetia neriifolia*

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is a major household and commercial crop in sub-Saharan Africa. The nutritional importance of tomato fruit lies in its richness in nutrients such as essential amino acids, vitamin C, lycopene and β -carotene. The WHO (2002) estimates that adequate consumption of its fruits would reduce the incidence of heart disease by 31%, stroke by 11% and gastro intestinal cancers by 20 to 30%.

Numerous pest constraints limit sustainable tomato production in sub-Saharan Africa, with the main one being the noctuid moth *Helicoverpa armigera* (Hübner, 1808) (Lepidoptera: Noctuidae), which attacks tomato crops, particularly during flowering. The females lay eggs on the first leaf below the flower clusters; then, from the 3rd instar, the larvae enter the fruits to feed, while the caterpillars consume only one part and then attack another (Torres-Vila *et al.*, 2002). Singh (1975) showed that eggs are deposited preferably on the lower surface of young leaves. Several fruits are attacked during the larval life, usually on the same bunch (Poitout and Bues, 1979). The moth causes depreciation of the fruit due to the presence

of a gallery, in addition to yield losses due to fruit drop and rot.

Vegetable production in tropical Africa is dependent on use of chemical pesticides (Obopile *et al.*, 2008; Ahouangninou *et al.*, 2011). Although this is a gainful option for increasing crop yields, their negative impact on human and environmental health has been a matter of concern. Sæthre *et al.* (2011) found pesticide residues in vegetables sold in markets in southern Benin. Moreover, during phytosanitary treatments, the part of the pesticides that penetrates the soil by leaching can be harmful to the soil microflora; particularly to earthworms that play an important role in maintaining soil fertility. Pesticides can be harmful to antagonists (competitors, predators and parasites) of target pests.

Fortunately, there exist alternative methods of pest control with less documented risks. These include plant extracts from *Azadirachta indica* (A. Juss) (Meliaceae), *Hyptis suaveolens* (L.) (Lamiaceae) and *Carica papaya* (L.) (Caricaceae) (Ketoh *et al.*, 2002), which are locally available within the farmers' jurisdiction in sub-Saharan Africa. Alternative pest control methods allow for the best use of local resources, improve product quality, reduce

production costs, and promote productivity, thereby improving producers' livelihoods (Adétonah, 2007). This study evaluated the larvicidal properties of vegetable oil extracts of selected common plants on major tomato pests in the farming environment of Benin.

MATERIALS AND METHODS

Study area. The study was conducted from March 2021 to February 2022 during the dry and rainy seasons on a plot located within the market garden site of Togba in Benin. The region belongs to the tropical sub-equatorial climate regime, with a climate characterised by four seasons, including two rainy seasons and two dry seasons. The average annual rainfall varies between 1100 and 1200 mm and the annual temperature varies between 25 and 28 °C (Kouakou *et al.*, 2014).

Plant material. The biocidal activity of four plants (*R. communis*, *T. purpurea*, *T. neriifolia* and *A. occidentale* on *P. xylostella* and *H. armigera*) was tested on tomato (Table 1). These plants were chosen based on a review of available literature on the insecticidal properties of these plants and their medicinal properties (Akpo *et al.*, 2017). The plant materials used were collected between September 2020 and March 2021. Mature senesced seeds of *T. neriifolia* were collected from the hill and coastal departments. Mature cashew seeds that had fallen by themselves were also collected from various fields in the

commune of Glazoue and Savalou. As for the *T. purpurea*, its organs were produced in a private estate in the commune of Abomey-Calavi. Tomato seed (Mogale variety) was used to carry out the field trials. The choice of this variety was based on its versatility in both dry and rainy seasons, and its resistance to bacterial and fungal diseases. Besides, the crop is widely grown by market gardeners in the surveyed sites; and yet harbours the most formidable pests. This crop was grown in collaboration with the market gardeners.

Experimental setup. The experimental setup was a randomised complete block design, with 5 replicates in each block (Fig. 1). The unit plot was 7.8 m x 1.6 m, with 1 m between plots and 2 m between blocks. Plant spacing was 0.4 m within rows and 0.7 m between tomato rows. Five vegetable oil extract treatments (Table 2) were compared with a Lambda cyalothrin as the negative control.

Preparation of the insecticide spray was by diluting a quantity of the commercial formulation (taken with a graduated syringe) with a specified quantity of water (measured with graduated test tubes), according to the manufacturer's recommended rate for phytosanitary treatment of crops. Dilution of the synthetic insecticide was carried out to obtain the dose of active ingredients per hectare, taking into account the dose recommended by the supplier.

Tomato plants were transplanted at three weeks of age on each plot. The plots were

TABLE 1. Parts of the plants used for the vegetable oil extracts in the tomato pesticide experiment in Benin

Species	Parts used	Nature of extracts	Methods
<i>Ricinus communis</i>	seeds	Vegetable oil	Soxhlet
<i>Thevetia neriifolia</i> juss	seeds	Vegetable oil	Soxhlet
<i>Tephrosia purpurea</i>	seeds	Vegetable oil	Soxhlet
<i>Anacardium occidentale</i>	Seed hulls cold	CNSL cold	Embrittled without prior treatment submitted to extraction

watered twice a day for the first four weeks; and once, thereafter. Approximately 15 g of NPK fertiliser was applied to each plot, one week after transplanting; and two weeks later a mixture of NPK and urea was applied around the plants. The field was fertilised with cattle composted manure two weeks after transplanting.

Treatment applications. A total of six insecticide applications were made to the crops in the six-week interval, at a rate of one application per week. The applications were made with two OSATU backpack pressure-maintained sprayers, model STAR 16 AGRO. One was used to apply the synthetic pesticide (Lambda cyhalothrin), and the other to apply the vegetable oil extracts and Topbio. These sprayers were chosen for their ease of use of the equipment (one-handed device, possibility of treating the underside of the leaves and adjustment of the spray from the device).

The different products were sprayed one after the other on each experimental plot. After spraying an extract, the pump used for the treatment was cleaned. In order to achieve a homogeneous treatment and to reach a high pest population, the sprays were directed to cover the lower and upper leaf surfaces of each plant. Treatments started on the 16th day after transplanting the tomato crop. They were spread over the different tomato crop cycles, 66 and 84 days, respectively. Treatments were administered per week (Diabaté *et al.*, 2008; Gnago *et al.*, 2010).

Data collection. Insect counts were taken at three phenological stages of the crop (Table 2); three days after treatment, using a sample of 10 plants per plot. Both healthy and *Bémisia tabaci* attacked plants; by caterpillars (*Helicoverpa armigera*, *Spodoptera littoralis*) were recorded. The observation was made on 10 plants (5 consecutive plants on each of the two lateral lines of each elementary plot). A plant was considered infested when at least one leaf harbors a pest or when the plant shows

damage or symptoms of attack. This was done in the following order:

- (i) Count of attacked green fruits (holes) on 10 fruits (5 fruits on each of the two lateral lines) as soon as the tomato fruits appear;
- (ii) Count of healthy green fruits on 10 fruits (5 fruits on each of the two lateral lines) as soon as the tomato fruits appear;
- (iii) Count of ripe fruits with holes on 10 fruits just after harvest (5 fruits on each of the two lateral lines); and
- (iv) Count of healthy ripe fruits on 10 fruits just after harvest (5 fruits on each of the two lateral lines).

Yield estimates. Yield data were obtained by weighing tomato fruits without holes or infestations as assessed by the growers. Harvests for yield estimation were made on the two lateral lines of the board only. The yield per plot was extrapolated to yield per hectare.

Data analysis. Data collected were processed using Microsoft office Excel 2016, for data processing; and analysed using R Core Team software (version 3.6.3-2020). The fish model and the generalised linear mixed or fixed effects model were used to explain the number of caterpillars per elementary plot, as a function of the products tested during different plant phases. One-factor analysis of variance (ANOVA, $P < 0.05$) was also performed in this study. Significant means were compared using SNK (Student-Newman-Keuls), 5% probability threshold.

RESULTS

Helicoverpa armigera. During the vegetative phase of tomato, the reduction in *H. armigera* numbers varied significantly compared to the

control, across treatments ($F= 15.720$; $P < 0.05$). The Newman-Keuls separation test revealed two homogeneous groups based on treatment efficacy (Fig. 1). The first group consisted of *R. communis* oil, *T. nerifolia* oil and the negative control. Despite the difference between these plant oils and the negative control, there was no significant difference in the reduction of *H. armigera* numbers. Compared to the second group, cold CNSL, *Tephrosia* oil and Topbio, these products showed the greatest significant reduction in insect pests, with mean *H. armigera* abundance of 2.2 ± 0.48 , 3 ± 1.2 and 2.4 ± 1.04 per plant, respectively, per treatment. For ricinus oil (9.6 ± 1.04) and *Thevetia* oil (10.08 ± 1.49), the reduction in *H. armigera* numbers was average compared to the control (Fig. 1).

During tomato flowering, the synthetic insecticide and the different botanical pesticides had a significant impact on the

reduction of *H. armigera* numbers compared to the control ($F= 19.7$; $P < 0.05$). The cold CNSL showed the highest efficacy compared to the synthetic insecticide (Table 2). Regarding the flowering-fruiting phase, statistical analyses revealed a significant difference between the efficacy of the insecticidal products botanical compared to the negative control ($F= 7.89$; $P < 0.05$). The Newman-Keuls separation test divided the products used into two homogeneous groups. The first and most efficacious group consisting of synthetic insecticide (1.05 ± 0.96), *Tephrosia* oil (0.8 ± 0.75), *Ricinus* oil (2.3 ± 1.5), *Thevetia* oil (1.8 ± 0.87), CNSL (0.7 ± 0.51), and Topbio (0.6 ± 0.51) showed similar efficacy. The second homogeneous group was the control (7.3 ± 1.19) (Fig. 1). Despite the difference in the reduction of *H. armigera* per treatment, there was no significant difference between the treatments with *T. purpurea* oil,

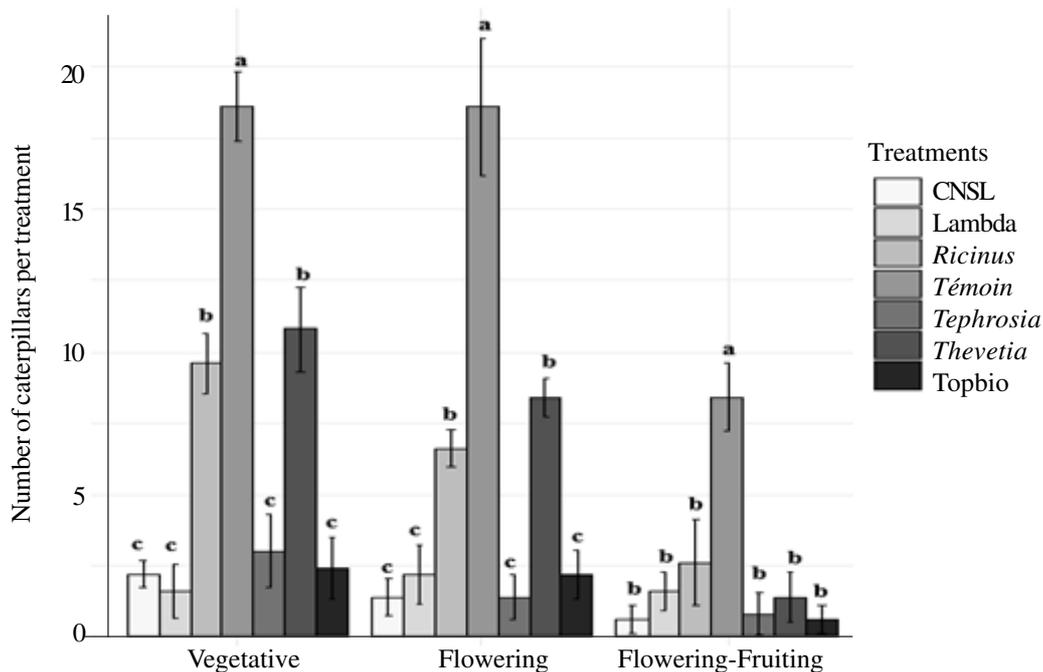


Figure 1. Effect of botanical oil extracts on *H. armigera* population at different stages of tomato plant growth. Treatments with the same letters are not significantly different at the 5% threshold (Analysis of variance followed by SNK) SNK Vegetative=31.0; SNK Flowering=16.7 and SNK Flowering-Fruiting=5.8, CNSL = Cashew Nut Shell Cold Liquid.

cold CNSL and the chemical insecticide lambda cyhalothrin during the flowering and fruiting phase of tomato.

***Spodoptera littoralis*.** During tomato vegetative phase, there were significant differences between the efficacy of different products used to control *Spodoptera littoralis* ($F= 10.472$; $P < 0.05$). The Newman-Keuls test showed a high reduction in number of *S. littoralis* per treatment with the botanicals compared to the control. On the other hand, the synthetic insecticide controlled the entire

population of *S. littoralis* during the vegetative phase of the tomato (Fig. 2).

During flowering, there was a significant difference between the efficacy of botanical extracts ($F= 8.314$; $P < 0.05$). The Newman-Keuls test revealed two homogeneous groups; namely Cold CNSL, Tephrosia, and Topbio constituted the first homogeneous group. The second homogeneous group consisted of *R. communis* oil, *T. neriifolia*, and the zero dose negative control. No caterpillars of *S. littoralis* were found on tomato plants treated with lambda cyhalothrin insecticides.

TABLE 2. Structure of treatments used in the tomato experiment

No objects	Substances	Doses	Observations
T0	Untreated control	0	No treatment
T1	Oil extract of <i>Tephrosia purpurea</i>	10% of formulation	Normal dose
T2	Oil Extract of <i>Thevetia neriifolia</i>	10% of formulation	Normal dose
T3	Oil Extract of <i>Ricinus communis</i>	10% of formulation	Normal dose
T4	Cold extract Cashew balm	10% of formulation	Normale dose
T5	Topbio	125 ml /16l water/ ha	Standard dose
T6	Lambda cyalothrine	25 ml/10l water / ha	Reference control

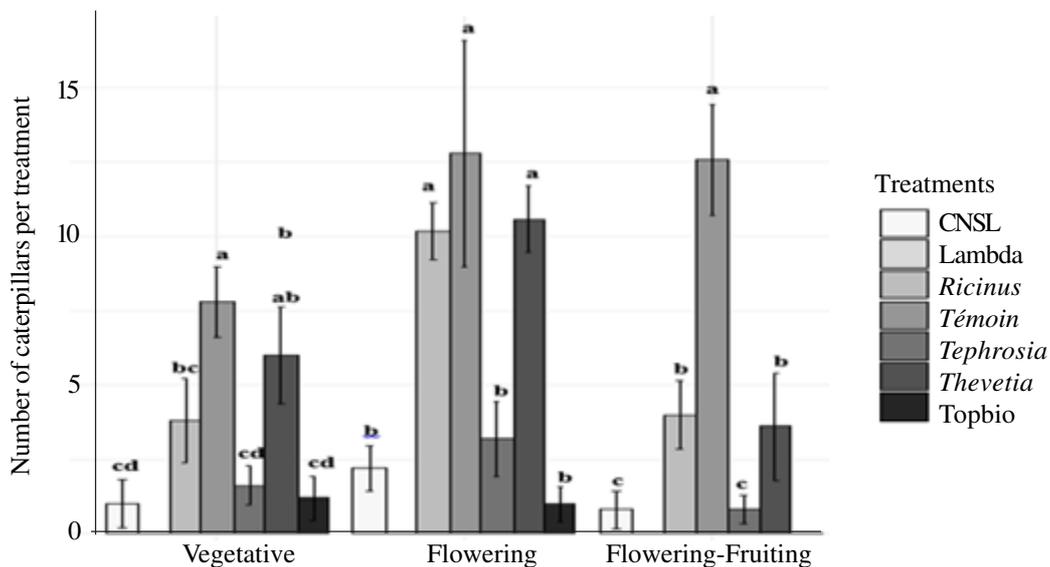


Figure 2. Effect of botanical oil extracts on *Spodoptera littoralis* population at different stages of tomato growth. Treatments with the same letters are not significantly different at the 5% threshold (Analysis of variance followed by SNK) SNK Vegetative=22.2; SNK Flowering=30.6 and SNK Flowering-Fruiting 14.4, CNSL = Cashew Nut Shell Cold Liquid.

During the flowering-fruiting phase, there were significant differences ($F= 6.175$; $P < 0.05$) between the efficacy of the different products tested (Fig. 2). The Newman-Keuls separation test revealed two groups and the negative control. The first homogeneous group consisted of CNSL and *Tephrosia*; while the second homogeneous group consisted of *Ricinus* and *Thevetia*. Compared to the negative controls, there was a significant difference in the reduction of *S. littoralis* caterpillars between the biological products and the synthetic chemical, on the one hand, and the zero dose controls on the other during the fruiting phase.

***Tuta absoluta*.** During the vegetative phase, the number of *T. absoluta* harvested from the control plot were 12 ± 0.91 per treatment. On the other hand, treatments with CNSL had 1.8 ± 0.63 *T. absoluta*, 2 ± 1.63 for *T. purpurea* oil, 6.6 ± 1.3 for *R. communis* oil, 8.4 ± 1.26 for *T. nerifolia* oil, 1.8 ± 1.03 for Topbio and

0.6 ± 0.01 for the synthetic insecticide lambda cyhalothrin. There were significant differences ($F = 5.321$; $P < 0.05$) between the efficacy of the different products used compared to the control. The different plant extracts showed average efficacy compared to the negative control and the synthetic insecticide (Fig. 3). During flowering, *T. absoluta* harvested after treatment were 1 ± 0.81 for cold CNSL, 1 ± 1.04 for *T. purpurea* oil, 6 ± 0.70 for *R. communis* oil, 8 ± 1.35 for *T. nerifolia* oil, 1.05 ± 0.65 for Topbio biological insecticide, and 13.01 ± 3.11 for the zero-dose negative control, respectively (Fig. 3). Plots treated with the synthetic insecticide completely eradicated the *T. absoluta* population.

There were significant differences between the efficacy of these different products ($F= 8.650$; $P < 0.05$). The Newman-Keuls test revealed three homogeneous groups; the first group being Cold CNSL, *Tephrosia* and Topbio constituted. The second homogeneous group consisted of *Ricinus*, *Thevetia* and negativ

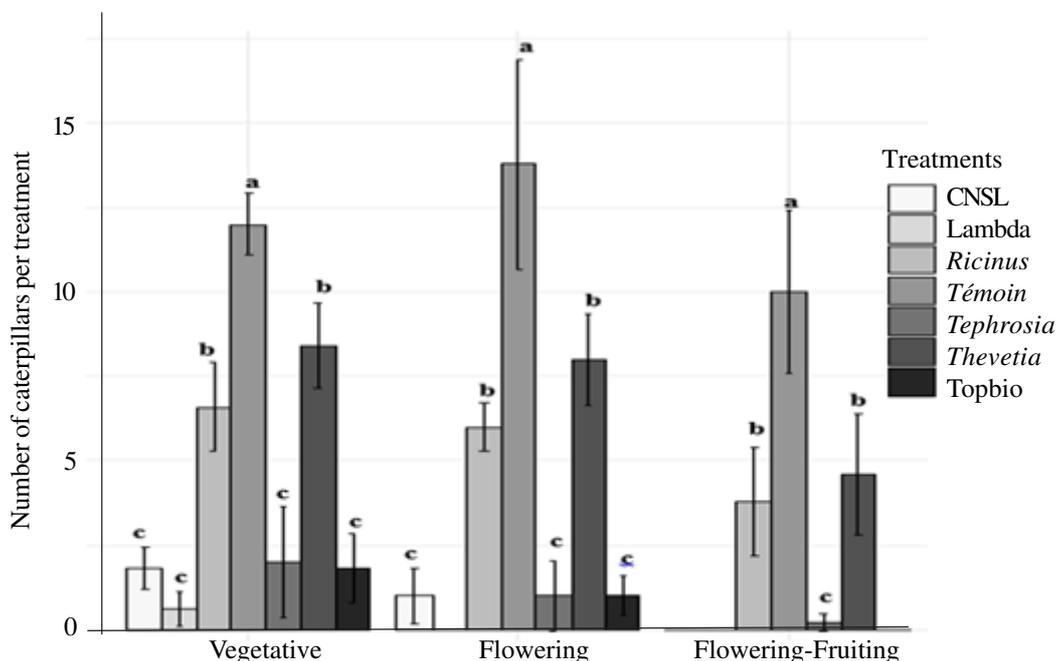


Figure 3. Effect of botanical oil extracts on *Tuta absoluta* population in tomato plants. Treatments with the same letters are not significantly different at the 5% threshold (Analysis of variance followed by SNK) SNK Vegetative=18.6; SNK Flowering=20.0 and SNK Flowering-Fruiting=10.3, CNSL= Cashew Nut Shell Cold Liquid.

Control. During the flowering-fruiting phase, there were significant differences ($F = 12.517$; $P < 0.05$) between the efficacy of the different products tested (Fig. 3). The Newman-Keuls separation test revealed two homogeneous groups and the negative control. The first group comprised of cold CNSL and Topbio. The second homogeneous group consisted of *Ricinus* and *Thevetia*.

Compared to the negative control, there was a significant difference between the products used on the one hand, and between the products and the negative control on the other at the 5% threshold during the three vegetative phases of the plant.

Abundance of *B. tabaci* adults. There was a significant effect of the botanical oil extracts on *B. tabaci* population during the three phases of tomato plant growth ($F = 9.875$; $P < 0.05$). The Newman-Keuls test showed a high reduction in the number of *B. tabaci* per treatment with cold CNSL and *T. purpurea*, compared to the positive controls with the synthetic chemical pesticide lambda cyalothrin. There was no significant difference from the number of *B. tabaci* on the treated tomato plots, despite the higher number of *B. tabaci* on the plots treated with *T. purpurea* and cold CNSL oil ($F = 5.56$; $P > 0.05$). There was a significant difference between the negative controls and the plots treated with biological

and chemical insecticide ($F = 13.74$; $P < 0.05$). The organic pesticides based on *T. purpurea* oil extract and cold CNSL had similar efficacy with the pesticide commonly used by farmers to control *B. tabaci* ($P = 0.00$). *Tephrosia purpurea* oil, cold CNSL, and the synthetic pesticide significantly reduced the number of *B. tabaci* on tomato compared to the control ($F = 10.89$; $P < 0.05$). *Ricinus communis* and *T. neriifolia* oil also significantly reduced the number of *B. tabaci* per treatment compared to the control ($P = 0.01$) (Table 3).

Attacked and healthy green fruits, and attacked and healthy ripe fruits. There were significant differences between the efficacy of different plant oil extracts on the number of attacked tomato green fruits compared to the negative controls ($F = 7.890$ and $P < 0.05$). The Newman Keuls separation test again classified the results into three homogeneous groups. The first homogeneous group consisted of the synthetic chemical lambda cyalotrin and the biological insecticide Topbio. The second homogeneous group consists of the cold CNSL and *T. purpurea* oil. The third group consisted of *R. communis* oil and *T. neriifolia*. The last group consisted of the negative control. In relation to the number of healthy green fruit, there existed differences between the treated plots on the one hand ($F = 12.567$ and $P < 0.05$) and between the

TABLE 3. Adult *Bemisia tabaci* per tomato treatment after application of different plant oil extracts

Treatment	Number of <i>Bemisia tabaci</i> adults per plant
Témoin (T1)	15,24 ± 1,31a
Huile de <i>T. purpurea</i> (T2)	6,45 ± 0,07 b
CNSL à froid (T3)	7,23 ± 0,05b
Huile de <i>R. communis</i> (T4)	10,87 ± 0,08 c
Huile de <i>T. neriifolia</i> (T5)	11,88 ± 0,08 c
Topbio (T6)	4,97 ± 0,04b
Lamba cyalothrine (T7)	4,05 ± 0,06b

Means followed by the same letter are not significantly different (Analysis of variance followed by SNK test at 5% threshold)

treatments and the control on the other (F=9.714 and P <0.05).

From these results, the products were classified into three homogeneous groups by the Newman Keuls separation text. The first group consisted of the synthetic chemical lambda cyhalotrin and the biological insecticide Topbio. The second group consisted of the cold CNSL, *T. purpurea* oil ; while the third group consisted of *R. communis* oil, *T. neriifolia*. The last group consisted of the negative control.

Regarding the number of attacked ripe fruits, there was a significant difference between the attack rates of ripe fruits obtained with the different botanical extracts and the negative control (F= 0.907; P <0.05). Regarding the number of healthy ripe fruits, statistical analyses also revealed a significant difference between treatments on the quality of healthy fruits obtained (F= 10.254; P <0.05). At this level, the Newman Keuls separation test put the averages of healthy ripe fruit quality per plant into four homogeneous groups. The first group was the treatment with Topbio and lambda cyhalotrin. The second group consisted of the cold CNSL and *T. purpurea*. The third group consisted of *R. communis* and *T. neriifolia*; while the fourth

group consists of the negative control (Table 4).

Marketable tomato fruit yields. Marketable tomato fruit yields were significantly different for the various treatments (F(6,14) = 15.21; df = 10; P = 0.0016). A yield of 29.15 ± 0.75 t ha⁻¹ was highest on plots treated with the synthetic chemical insecticide lambda cyhalotrin (Fig. 4). This was followed by plots treated with the biological insecticide Topbio, cold CNSL, *T. purpurea* oil, *R. communis* and *T. neriifolia*; with respective yields of 26.05 ± 2.16 , 20.94 ± 1.27 t, 20.08 ± 0.31 , 15.60 ± 0.31 and 13.14 ± 0.15 t ha⁻¹. The lowest yields were obtained on the plots treated with Thevetia oil and on the control.

DISCUSSION

The significant decrease in numbers of *H. armigera*, *Tuta absoluta* and other insects such as *B. tabaci*, *S. frugiperda* and *H. undalis* as the plants physiologically evolved (Table 4) was probably due to the fact that these species attack the tomato crop just at a specific phenological level and mentioned above, were the first to be treated. In fact, the active materials contained in the biopesticides sprayed

TABLE 4. Effect of botanical oil extracts on the number of attacked green fruit, healthy green fruit, attacked mature fruit and healthy mature fruit per tomato plant

Treatment	Attacked green fruit	Healthy green fruit Attacked	Attacked ripe fruit	Healthy ripe fruit
Témoin (T0)	4,32 ± 1,48aA	5,68 ± 1,00cA	4,54 ± 1,30aA	5,46 ± 0,09cA
Huile de <i>T. purpurea</i> (T1)	1,80 ± 0,09cdB	8,20 ± 2,40aA	1,10 ± 0,28cdB	8,90 ± 1,06aA
CNSL à froid (T2)	1,33 ± 0,08cdB	8,6752 ± 2,56aA	1,05 ± 0,11cdB	8,95 ± 1,29aA
Huile de <i>R. communis</i> (T3)	2,45 ± 0,90cB	7,55 ± 1,85bA	2,70 ± 0,33bB	7,30 ± 0,86bA
Huile de <i>T. neriifolia</i> (T4)	2,74 ± 0,91cB	6,26 ± 1,85bA	3,21 ± 0,33bB	7,79 ± 0,96bA
Topbio (T5)	0,81 ± 0,05ceB	8,96 ± 2,66aA	1,00 ± 0,04ceB	9,00 ± 1,75aA
Lambda Cyalothrine (T6)	0,50 ± 0,01deB	9,50 ± 1,79aA	1,00 ± 0,00ceB	9,00 ± 1,78aA

In the same column, the means followed by the same lower case letter are not significantly different (Analysis of variance followed by the SNK test at the 5% threshold). In the same row, the means followed by the same capital letter are not significantly different (Analysis of variance followed by the SNK test at the 5% threshold)

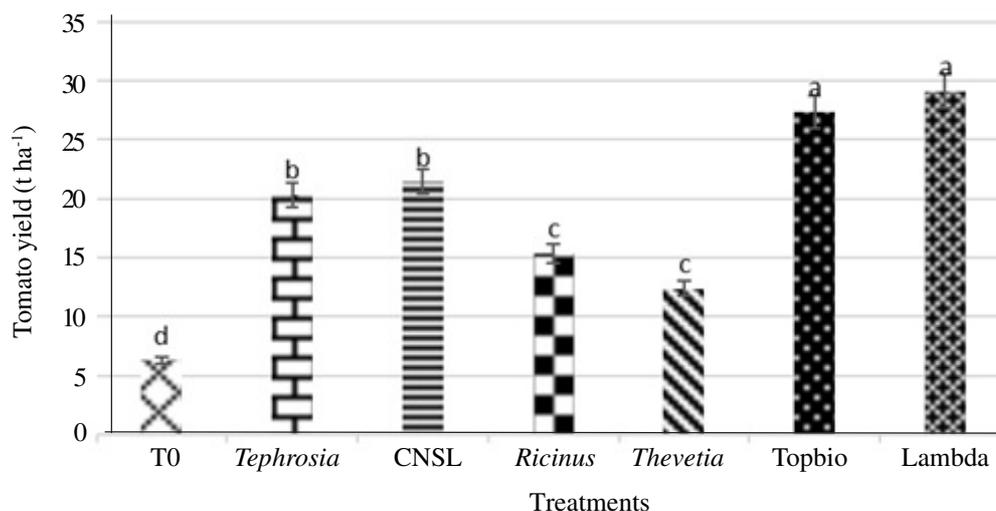


Figure 4. Fruit yield of marketable tomato plants treated with different botanical oil extracts. Means followed by the same letter are not significantly different (Analysis of variance followed by SNK test at 5% threshold). SNK = 28.8, CNSL = Cashew Nut Shell Cold Liquid.

on the fruiting bodies that served as food for these species had effects on them; effects that are manifested by the reduction of their feeding and even by their mortality. The use of natural compounds from plant products, resulting from the secondary metabolism of plants, is a potential source for botanical pesticides (Philogène, 2009). These are easily biodegradable, less toxic and have less potential impact on the environment and health (Regnault-Roger *et al.*, 2008).

The results of the effect of biopesticides on the density of tomato pests showed a significant difference compared to the observations made on these pests in the untreated plots, which hosted more pests than the other treated plots (Table 4). The results obtained during our trials on tomato cultivation in the farming environment also showed that the oil of *T. purpurea* and the cold CNSL were the best phytosanitary treatment product, compared to the biological control (Topbio) and the synthetic chemical insecticide (Lambda cyhalothrin) (Sotondji *et al.*, 2020). Oils from *R. communis* and *T. neriifolia* were also efficacious for managing insect pests including *H. armigera*, *S. fugiperda*, *T. absoluta* and *B. tabaci* on tomato. These results corroborate

the studies on the larvicidal effect of different plant extracts by several authors (Kétoh *et al.*, 2002; Sanda *et al.*, 2006; Agboka *et al.*, 2009). The different botanical pesticides, namely *T. purpurea* oil, *R. communis*, cold CNSL, *T. neriifolia* and Topbio had no clear efficacy on tomato caterpillars (*Spodoptera littoralis* and *Tuta absoluta*) compared to the positive control, the synthetic insecticide Lambda cyhalothrin (Table 4).

From the vegetative phase of the tomato plants until the fruiting phase, we recorded a significant decrease in *S. littoralis* and *T. absoluta* caterpillars compared to *H. armigera* caterpillars on the plots treated with Lambda cyhalothrin (Table 4). No significant difference was recorded on plots treated with botanical pesticides and synthetic insecticide compared to the *H. armigera* population observed on tomato plants. This could be due to the resurgence of *H. armigera* against some synthetic chemicals.

Bemisia tabaci populations on plots treated with botanical pesticides are similar to those treated with Lambda cyhalothrin. The population of *B. tabaci* was higher in the untreated control plots. These results are consistent with those of Diabaté *et al.* (2008)

who showed that foliar applications of *Jatropha* and aqueous neem resulted in a remarkable effect on *B. tabaci* and *H. armigera*. Indeed, it reduces the number of adults of *B. tabaci* and larvae of *H. armigera* in tomato cultivation, which is the main cause of the inhibition of the release of hormones responsible for growth and metamorphosis. In general, it affects the behaviour of insects (Koul, 2004). It protects the plant from plant pests including insects and herbivores (Marshall *et al.*, 1985).

Solsoloy (2000) and Adebowale and Adedire (2006) also showed that *Jatropha* products significantly reduce high nesting insects and caused total mortality of eggs and larvae, regardless of their concentration. According to these authors, the effects of insecticides could be caused by sterols and terpene alcohols contained in the *Jatropha* produced.

The significant reduction in number of *B. tabaci* and *H. armigera* by application of biopesticides based on *Tephrosia*, cold extracted cashew balsam, *Ricinus* and *Thevetia* in our study sites is related to the inhibition of oviposition exerted on the insects (Sotondji *et al.*, 2020). During the observations on the cabbage plots, the market gardeners also observed in the plots treated with different botanical oils, the significant presence of auxiliary insects (Sotondji *et al.*, 2020). The complementary effects of botanical extracts and natural enemies seem to be the basis for the higher yields obtained in the plots treated with Topbio, *T. purpurea* oil and cold CNSL, and the average yield of *R. communis* and *T. neriifolia* oils on the cabbage and tomato crops. On the other hand, the exaggerated synthetic insecticide treatments are toxic to the natural enemies of the pests, which instead increases the number of lepidopteran pests that cause more damage to the crop (Mondédji *et al.*, 2014)). This is a clear demonstration that the use of botanical pesticides contributes to the protection of the environment (Philogène *et al.*, 2003) compared to the use of synthetic insecticides; while proving its effectiveness on insect pests. On the other hand, the synthetic

insecticide was more effective in reducing populations of *L. erysimi*, *S. littoralis*, *T. absoluta* compared to the different oils and Topbio. However, Lepidopteran damage to tomato decreased its commercial value. Therefore, plots treated with *T. purpurea* oil extracts and CNSL, as well as Topbio gave the best yields of marketable tomato compared to the positive control *Lambda cyhalothrin*. Only the oil extracts of *R. communis* and *T. neriifolia* gave a yield commensurate with the *Lambda cyhalothrin* control. But there was a significant difference between the plots treated with the different products and the untreated controls, in terms of yield. These results are in line with those of Mondédji *et al.* (2014), who showed the efficacy of neem, *Azadirachta indica*, leaf extracts on some insect pests of cabbage in Togo. The studies of Azonkpin *et al.* (2018) also show the effect of botanical biopesticides on pests and their predators in organic cotton crop in Benin. These two authors found a higher yield of the crops on plots treated with botanical insecticides than on those with the synthetic chemical. Several studies have also confirmed the biocidal activity of cashew balsam. In fact, according to Araùjo and Xavier (2009), both types of balsam (cold and hot extracted) contain mainly anacardic acid, cardanol, cardol, 2-methylcardol in different proportions. Kpoviessi *et al.* (2017) showed that cashew balsam can significantly reduce pest populations (aphids, thrips and Maruca) on cowpea crop in the field. These results are similar to those obtained by Kpoviessi *et al.* (2017) who showed that cashew balsam can promote cowpea yield. Similar results were obtained by Mondédji *et al.* (2014), who found that plots treated with *Azadirachta indica* leaf extracts gave the best yields cabbage on marketable cabbage. Similarly, Kambou and Guissou (2011) showed that the use of 400 l ha⁻¹ of aqueous extract of spice substances (*Sinapis nigra* L. [Brassicaceae], *X. aethiopica*, *N. tabacum*) provided green bean yield equivalent to that obtained in plots treated

with a synthetic insecticide such as deltamethrin. Asare-Bediako *et al.* (2014) showed the ability of extracts of *Azadirachta indica*, *Carica papaya*, *Allium* sp., *Capsicum* sp. (Solanaceae), *Anacardium* sp. (Anacardiaceae) to increase okra yield in treated plots. Under natural conditions (open field), Habou *et al.* (2011) confirmed the biocidal activity of *Jatropha* sp oil on cowpea pests and the yield increase compared to the untreated control. The different oil extracts can therefore be used in an integrated pest management program against these major insect pests of cabbage and tomato in southern Benin.

ACKNOWLEDGEMENT

The International Foundation for Science (IFS) financed this project.

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