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Impact of insecticides on *Brevicoryne brassicae* (L.) and its influence on broccoli yield in Guaytacama, Cotopaxi, Ecuador

Impacto de insecticidas sobre *Brevicoryne brassicae* (L.) y su influencia en el rendimiento del brócoli en Guaytacama, Cotopaxi, Ecuador

Authors

[1]***José Gabriel Ugsha Sabando***
jose.ugsha4298@utc.edu.ec

[2*]***Dorys T. Chirinos***
dorys.chirinos@utm.edu.ec

[1]***Eliana Granja Guerra***
eliana.granja@utc.edu.ec

[1]***Mario Javier Chuquiana Caiza***
mario.chuquiana8747@utc.edu.ec

[1]Universidad Técnica de Cotopaxi, Dirección de Posgrado, Maestría en Sanidad Vegetal, Latacunga, Cotopaxi, Ecuador.
[2]Universidad Técnica de Manabí, Facultad de Ingeniería Agronómica, Portoviejo, Manabí, Ecuador.
*Correspondence author.

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Abstract

Broccoli (*Brassica oleracea* var. *italica*) is an important vegetable due to its nutritional value and for Ecuador it constitutes an export crop. Its cycle can be affected by pests such as the cabbage aphid, *Brevicoryne brassicae* (L.) (Hemiptera: Aphididae) that, by extracting the photoassimilates, can damage the flower head causing loss of its commercial value. These pests are treated with organo-synthetic insecticides but their application can generate ecological imbalances, and insect resistance to pesticides. This research aimed to evaluate the effect of insecticides on *B. brassicae* populations and crop yield. In Guaytacama, Cotopaxi, a plot (1,600 m^2) was planted, divided into four complete blocks at random, including 13 treatments: azadirachtin (doses: 1,000; 1,500 and 2,000 mL·ha^{-1}), Sophora extract (doses: 600, 800 and 1,000 mL·ha^{-1}), la,mbdacyalothrin (doses: 200, 250 and 300 mL·ha^{-1}), azadirachtin + capsaicin + allicin (doses; 2,000; 2,500 and 3,000 mL·ha^{-1}) and untreated check. The number of aphids, control effectiveness and yield (t·ha^{-1}) were evaluated. The results showed smaller aphid populations (3.5-4.4 individual), higher efficiency (94.5-98.7%) and higher yield (18.5-19.7 t·ha^{-1}) in lambdacyhalothrin (dose: 300 mL), in azadirachtin + capsaicin + allicin (dose: 3,000 mL) and in *Sophora* extract (dose: 1,000 mL). The effectiveness controlling *B. brassicae* and high yields detected in botanical insecticides make their use promising for the sustainable management of pests in this important export crop of Ecuador.

Keywords: aphids; botanical insecticides; organo-synthetics; efficacy; productivity.

Resumen

El brócoli (*Brassica oleracea* var. *italica*) es una hortaliza importante debido a su valor nutricional y para Ecuador constituye un cultivo de exportación. Su ciclo puede verse afectado por plagas como el áfido de la col, *Brevicoryne brassicae* (L.) (Hemiptera: Aphididae) que al extraer los fotoasimilados, puede dañar la cabeza floral haciendo que pierda su valor comercial. Estas plagas son tratadas con insecticidas órgano-sintéticos pero su aplicación puede generar desequilibrios ecológicos y resistencia de insectos a plaguicidas. Esta investigación tuvo como objetivo evaluar el efecto de insecticidas sobre poblaciones de *B. brassicae* y sobre el rendimiento del cultivo. En Guaytacama, Cotopaxi se sembró un lote (1.600 m^2), dividido en cuatro bloques completos al azar, incluyendo 13 tratamientos: azadiractina (dosis: 1.000, 1.500 y 2.000 mL·ha^{-1}), extracto de *Sophora* (dosis: 600, 800 y 1.000 mL·ha^{-1}), lambdacialotrina (dosis: 200, 250 y 300 mL·ha^{-1}), azadiractina + capsaicina + alicina (dosis; 2.000, 2.500 y 3.000 mL·ha^{-1}) y un testigo no tratado. Se evaluó el número de áfidos, la eficacia de control y el rendimiento (t·ha^{-1}). Los resultados mostraron menores poblaciones de áfidos (3,5-4,4 individuos), superior eficacia (94,5-98,7%) y mayor rendimiento (18,5-19,7 t·ha^{-1}) en lambdacialotrina (dosis: 300 mL), en azadiractina + capsaicina + alicina (dosis: 3000 mL) y en extracto de *Sophora* (dosis: 1,000 mL). La efectividad en el control de *B. brassicae* y los altos rendimientos detectados en los insecticidas botánicos hace su uso promisorio para el manejo sostenible de plagas en este importante cultivo de exportación de Ecuador.

Palabras clave: áfidos; insecticidas botánicos; organo-sintéticos; eficacia, productividad.

Introduction

The *Brassica oleracea* L. (Brassicaceae) is a diploid plant of great agricultural importance, which includes common crops such as broccoli, cauliflower, brussel sprouts and others (Golicz et al., 2016). The part of the broccoli (*B. oleracea* var. *italica* Plenck) that is consumed is the flower head, while the stalks and leaves are discarded (Li et al., 2022; Gomez y Sánchez, 2023). Nagraj et al. (2020) mentioned that the broccoli contains vitamins, antioxidants, and anticarcinogenic compounds, hence it is regarded as a highly nutritional vegetable. Bioactive compounds such as polyphenols, carotenoids polyphenols, flavonoids, carotenoids, sulforaphane and glucosinolates, are also present in broccoli (Nagraj et al., 2020; Li et al., 2022).

For these reasons, broccoli is a crop in high demand. Along with cauliflower (*B. oleracea* var. *botrytis* L.), they occupy approximately 1,378,085 ha of farmed land worldwide, from which 25,843,741.37 t of produce have been obtained (Food and Agriculture Organization of the United Nations (FAO), 2024). In Ecuador, in 2022, 8,725 ha were cultivated, yielding 135,259 t of broccoli (Ministerio de Agricultura y Ganadería (MAG), 2024). The province of Cotopaxi is the main producer of this crop, wherein 7,697 ha yield 125,146 t of produce, which represents 92.52% of national production (MAG, 2024). Eighty percent of production is exported, and the remaining 20% is reserved for local consumption (Pazmiño et al., 2015). Broccoli exports have provided the country with 171 millions of income, with the main destinations being Japan (43%), United States (32%) and Germany (9%) (MAG, 2023).

The productivity of this crops is limited by various biotic factors, such as anthropod pests (Panwar et al., 2023). Among the pest species, there are caterpillas and moths (Lepidoptera), mites (Acari) and aphids (Hemiptera) (Karso et al., 2022). This order, the cabbage aphid, *Brevicoryne brassicae* (L.) and the green peach aphid, *Myzus persicae* (Sulzer) (Hemiptera:Aphididae) cause damage by extracting the photoassimlates of Brassicaceae (Costello and Altieri, 1995; Karso et al., 2022; Panwar et al., 2023). While *B. brassicae* prefers to attack plants belonging to the *Brassica* genus, the *M. persicae* has broader range, eating around 400 plant species (Panwar et al., 2023).

Although both plants can form colonies on various organs (stems, leaves, flower head) of the plant, *B. brassicae* prefers to eat young tissue, which makes it a very dangerous phytophagus for broccoli, because the flower heads lose their commercial value when the flower pods are damaged (Costello and Altieri, 1995; Ambrosino et al., 2007). In Ecuador, the *B. brassicae* is the main representative of the *Brassica* genus (Cerda et al., 2019).

Because the damage caused by *Brassica* pests is very influential, chemical pesticides such as pyrethroids, neonicotinoids, avermectins are used to effectively combat the pests (Mahmood Ahmed et al., 2018; Mpumi et al., 2020; Falcon-Alvarado et al., 2023). Pyrethroid lambdacyhalothrin is specifically for aphid control and other *Brassica* pests, due to its broad spectrum of action (Gill et al., 2013; Mpumi et al., 2020; Panwar et al., 2023). However, its use causes collateral damage such as a reduction in biodiversity of ecosystems, environmental pollution, and resistance to the pesticide in insects (Mpumi et al., 2020; Falcon-Alvarado et al., 2023; Panwar et al., 2023). Broccoli is important for Ecuador for both the national and international markets (MAG, 2023). For this reason, it is necessary to implent methods for pest control that could produce flower heads using as little organic-synthetic pesticides as possible (Murillo y Giraldo, 2023). The use of pesticides based on azadirachtin, *Capsicum* alkaloids, and *Sophora* (Fabaceae) among others of botanical origin could be promising for the management of aphids in brassicas such as broccoli. (Mpumi et al., 2020; Panwar et al., 2023). Ngosong et al. (2021) mentioned that the neem tree *Azadirachta indica* A. Juss (Meliaceae) contains azadirachtin, a triterpenoid that has shown to have growth regulatory activity and antifeedant effects in great number of pests.

Aji and pepper extracts have also been used as organic pesticides with great efficiency against capsaicinoids, secondary metabolites that are produced only in the genus *Capsicum* (Claros et al., 2019). It is important to point out that the use of aji and garlic extracts for pest control in brassicas is not widely studied. On the other hand, plant species from the *Sophora* genus have been used as aphidicides, because they contain varius alkaloid compunds that are toxic against aphididae species (Ma et al., 2018). Garlic, *Allium sativum* L. also has a series of secondary metabolites like alicine, with insecticide properties (Meriga et al., 2012; Kumar, 2017).

These insecticides must be tested for control pests, and compared to chemical insecticides like lambda-cyhalothrin, in order to confirm its efficacy. This process should also be paired with testing the effect of pest control in broccoli yield. Therefore, this studied had the objective to evaluate the effect of three organic and one chemical insecticides, in various doses on *B. brassicae* populations, as well as the broccoli yield in Guaytacama, province of Cotopaxi, the most important broccoli producer region in Ecuador.

Materials and methods

This studied was carried out between april and june 2023, in the Guaytacam parish (coordinates: 0°48'50.82" S; -78°38'12.33" O) located at 2,906 masl, in the municipality of Latacunga, Cotopaxi province (figure 1).

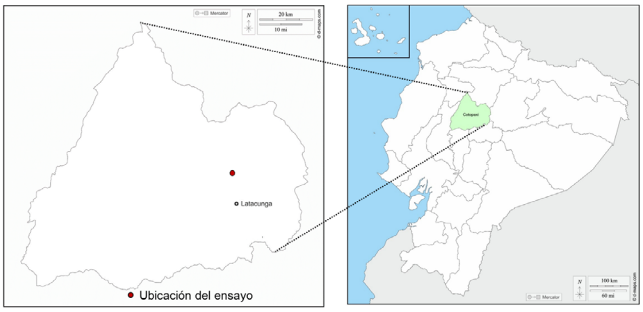

Figure 1. Map of Ecuador and the Cotopaxi province highlighting the area of analysis. The map was made with free software at https://d-maps.com/

The life zone where the study was carried out is a humid montane forest (Holdridge, 1967). During the period of testing, the weather variables were sourced from a nearby weather station, which registered precipitation levels and minimum and maximum temperatures (table 1).

Tabla 1. Precipitation, maximum and minimum temperatures registered in the area of study April-June 2023.

Month	Precipitation (mm)	Maximum temperature (°C)	Minimum temperature (°C)
April	61.5	16.85	8.12
May	35.0	17.96	8.95
June	81.5	16.63	8.49

The assay was conducted on a experimental plot of 1,600 m^2 (22 x 72 m) in which hybrid broccoli plants Steel® possessing life cycles of 95 days. The lot was divided in four plots chosen at random, where 12 treatments with insecticides were applied, plus one more plots without any intervention for the absolute control.

Each plot measured 30 m^2 (5 x 6 m). The furrows were planted in double rows with a separation of 1,00 m between furrows and the plants were sown at a distance of 0.20 m. On a total of 52 blocks resulting from 13 treatments, four of them were tested. Three botanical insecticides and one chemical insecticides where each tested at three dosage levels (low, medium, high) after the recommendations on their technical sheet. Each plot had an absolute control by repetition. Thus, the 13 treatments were tested as shown in table 2.

The plot was subjected to all necessary agricultural practices for optimal crop development. The first fertilization was carried out in the second week after the transplant, in which 30 kg of N, 72 kg of P, 35 kg of K_2SO_4 y 200 kg f $CaSO_4$ were applied per ha. The second fertilization was carried out during week five after the transplant, in which 150 kg of N, 180 kg of K, 50 kg of Ca y 20 kg of Mg were applied per ha. The third fertilization was done on the third week, with 120, 170, 50 and 30 kg·ha^{-1} of N, K, Ca and Mg. A last fertilization was done on week 10 of the crop cycle, with 100 kg of N and 80 kg of K per ha. Weed control was carried out during weeks 3, 5, 8 and 10 of the crop cycle.

Table 2. Treatment with tested insecticides.

No	Commercial product	Treatment	Active ingredient	Dose·ha^{-1}
1	Nimbo®	Azadirachtin	17%	1,000 mL
2				1,500 mL
3				2,000 L
4	Forte®	*Sophora* extract	1.5%	600 mL
5				800 mL
6				1,000 mL
7	Ninja®	lambda-cyhalothrin	50 g·L^{-1}	200 mL
8				250 mL
9				300 mL
10	Butanika®	Azadirachtin + capsaicin + allicin	6% + 5.5 % + 15%	2,000 mL
11				2,500 mL
12				3,000 mL
13		Control (non-treated)		

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For the disease control, copper at 5.34% was used to fight off mushrooms on flower heads with a dose of 1.5 L·ha^{-1} during weeks 8, 9 and 10 of the cycle. They were irrigated with sprinklers every three days for an hour.

The treatments were sprinkled on a weekly basis starting on week 2 after the transplant. For testing the effect of the treatments, 15 plants were selected at random from the central rows of the experimental plots, and the number of aphids were counted. The first count was done before the first sprinkling of the pesticides. During the tests, the existing leaves after the first two weeks were observed and afterwards the leaves of the upper, middle and lower stratus. On weeks 7 and , besides the leaves, the aphids were present during the inflorescences. With this, it was possible to determine the number of aphids per plant after 8 counts. (1 count per week).

Based on the formula proposed by Henderson and Tilton (1955) for different initial populations, the efficacy of insecticides (in percentage, %):

$$\%Efficacy = [1 – (Nca \times Ntd)/(Ncd \times Nta)] \times 100$$

N = number of individuals.

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t = treated plots.

c = untreated plots (control).

d = after the treatment.

a = before the treatment.

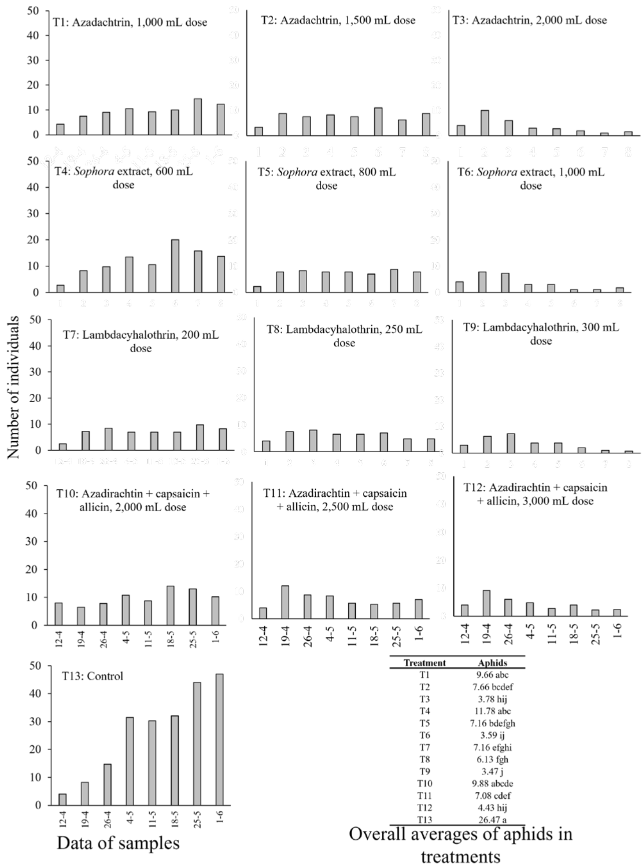
The broccoli was harvested on week 12 of the cycle. From each of the central row, five plants were selected at random and were the flower heads were weighted using a scale. Considering the average weight of the flower heads from each treatment and a density of 64,000 plants·ha^{-1} the yield was measured in t·ha^{-1} for each treatment.

Data analysis. The normality of variables. number of individuals and yield were analyzed with a Shapiro-Wilks test ($P<0.05$). The yield was normal, but the number of aphids was not, thus some transformations were applied (square root, arcsine). After the transformations, it was not possible to get the normality of the number of aphids, therefore this variable was analyzed with a non-parametric Friedman test ($P<0.05$). The effectiveness of aphid control was analyzed between treatments using the non-parametric Kruskall-Wallis test ($P<0.05$). The yield measured in t·ha^{-1} was analyzed using an ANOVA including plots and treatments as variations factors. The medians were compared using Tukey tests ($P<0.05$). An analysis of exponential regression between the number of aphids in the plant (X axis) and an extimated yield in t·ha^{-1} (Y axis) ($P<0.05$). The analysis were done using the software Infostat 2020 version (Di Rienzo et al., 2020).

Results and discussion

Brassica brassicae per treatment. Figure 2 shows that, during the initial count, before the plaguicide sprinkling, and in the second test, the populations were similar between treatments. The populations began to change after the third week of testing, after which the number of aphids in the untreated plot differed conspicuosly compared to the treated plots that showed the greatest number of individuals (26.5 aphid·plant^{-1}). Regarding the treated plots, the number of aphids varied depending on the treatment, which resulted in significant differences as detected by the Friedman test ($P<0.05$).

The *B. brassicae* populations were smaller in the plots sprinkled with a 300 mL dose of lambda-cyhalothrin, with no variations compared to those that were achieved with a 1,000 mL *Sophora* extract, as well as with azadirachtin + capsaicin + allicin applied at doses of 2,500 mL and 3,000 mL. The treatments with azadirachtin at a 1,000 mL dose, the *Sophora* extract at 600 mL, and azadirachtin + capsaicin + allicin at 2,000 mL did not reduce the *B. brassicae* populations, and were significantly superior on these treatments as detected by the Friedman test (figure 2).



Treatment	Aphids
T1	9.66 abc
T2	7.66 bcdef
T3	3.78 hij
T4	11.78 abc
T5	7.16 bdefgh
T6	3.59 ij
T7	7.16 efghi
T8	6.13 fgh
T9	3.47 j
T10	9.88 abcde
T11	7.08 cdef
T12	4.43 hij
T13	26.47 a

Figure 2. Number of *B. brassicae* individuals per broccoli plant of each treatment in the different samples. The table shows the general averages of aphids per treatment. The medians with the same letters did not differ significantly. Comparisons made with the Friedman test (P-value: 0,0001).

Efficacy of treatment. The table 3 shows the control efficacy of *B. brassicae* that is significantly higher than the treatment that included azadirachtin + capsaicin + allicin at a dose of 3,000 L and the treatment with lambda-cyhalothrin at a 300 mL dose.

These high efficacies did not differ from those reached by the *Sophora* extract 1,000 mL, azadirachtin + capsaicin + allicin 2,500 L, lambda-cyhalothrin at a 250 mL dose and azadirachtin at 2,000 mL ($P<0.05$).

Significantly inferior efficacies were observed in the treatments with azadirachtin at 1,000 and 1,500 mL, with *Sophora* extract at 600 mL, con lambda-cyhalothrin at 200 mL and the mix oazadirachtin + capsaicin + allicin at a dose of 2,000 mL.

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Table 3. Efficacy of the tested treatments in the control for *B. brassicae* in broccoli crops. The efficacy was calculated using the Henderson and Tilton equation (1955).

No	Treatment	Efficacy	
1	Azadirachtin, 1,000 mL dose	72.6	c
2	Azadirachtin, 1,500 mL dose	70.1	c
3	Azadirachtin, 2,000 mL dose	93.1	ab
4	*Sophora* extract, 600 mL dose	71.0	c
5	*Sophora* extract, 800 mL dose	82.4	bc
6	*Sophora* extract, 1,000 mL dose	94.5	ab
7	Lambda-cyhalothrin, 200 mL dose	70.3	c
8	Lambda-cyhalothrin, 250 mL dose	89.2	abc
9	Lambda-cyhalothrin, 300 mL dose	96.7	a
10	Azadirachtin + capsaicin + allicin, 2,000 mL dose	80.4	bc
11	Azadirachtin + capsaicin + allicin, 2,500 mL dose	88.4	abc
12	Azadirachtin + capsaicin + allicin, 3,000 mL dose	98.7	a

Comparisons made with the test Kruskall-Wallis (H= 30.95, P-value: 0.0011). The medians with the same letter did not differ significantly.

Estimated yield and population density of *B. brassicae* ($t \cdot ha^{-1}$), the variance analysis detected differences between treatments, but not between plots (table 4).

Table 4. Variance analysis for the estimated yield ($t \cdot ha^{-1}$). R^2= 0.92; CV= 2.83%.

F.V.	SC	gl	CM	F	p-value
Model	94.61	15	6.31	26.22	<0.0001
Treatment	93.68	12	7.81	32.45	<0.0001
Repetition	0.93	3	0.31	1.29	0.2918
Error	8.66	36	0.24		

The yields were higher in the plots treated with the chemical insecticide (lambda-cyhalothrin) at a dose of 300 $mL \cdot ha^{-1}$, as well as in the plots that were sprayed with botanical insecticides based on the mixture of azadirachtin + capsaicin + allicin at doses of 3,000 L and *Sophora* base extract at a dose of 1,000 mL (table 5). On the other hand, yields were significantly lower in the plots that were treated with azadirachtin at a dose of 1,000 mL and with lambda-cyhalothrin at a dose of 200 mL without differences with the untreated plot (control).

The decrease of broccoli yield could, at least in part, be linked to the population density of *B. brassicae*. The calculated exponential regression equation (figure 3) indicated that, when the *B. brassicae* population density increased, the yields decreased, and the yield variance according to the populations was explained in approximately 41%.

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Tabla 5. Estimated yield $t \cdot ha^{-1}$ of broccoli in the different treatments tested.

No.	Treatment	Yield ($t \cdot ha^{1}$)	
1	Azadirachtin, 1,000 mL dose	16.1	fg
2	Azadirachtin, 1,500 mL dose	16.8	ef
3	Azadirachtin, 2,000 mL dose	18.2	bcd
4	*Sophora* extract, 600 mL dose	17.2	def
5	*Sophora* extract, 800 mL dose	17.6	cde
6	*Sophora* extract, 1,000 mL dose	18.5	abc
7	Lambda-cyhalothrin, 200 mL dose	15.2	g
8	Lambda-cyhalothrin, 250 mL dose	17.9	bcde
9	Lambda-cyhalothrin, 300 mL dose	19.7	a
10	Azadirachtin + capsaicin + allicin, 2,000 mL dose	16.9	ef
11	Azadirachtin + capsaicin + allicin, 2,500 mL dose	17.5	cde
12	Azadirachtin + capsaicin + allicin, 3,000 mL dose	18.9	ab
13	Control (untreated)	14.8	g

Median comparison done with the Tukey test (P<0.05). Medians with the same letter did not differ significantly.

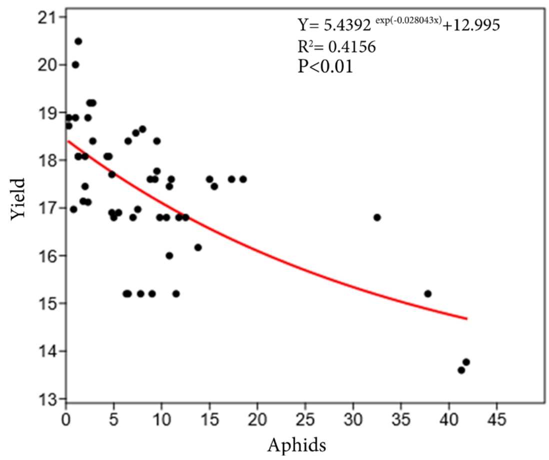

Figure 3. Exponential equation between the number of *B. brassicae* individuals per plant (X axis) and the broccoli yield (Y axis).

Based on the population density of *B. brassicae*, the efficacy of the control and estimated yield, three treatments with insecticides, the organic-synthetic, the lambda-cyhalothrin applied to a dose 300 $mL \cdot ha^{-1}$, and two of botanic origin, that is, the mix of azadirachtin + capsaicin + allicin sprinkled at 3,000 mL and the *Sophora* extract at a dose of 1,000 mL showed higher efficacy for the control of *B. brassicae* in broccoli and the least effect on yields.

The efficacy of these insecticides with regards to aphid control have been tested on broccoli and other brassicae with similar results and contrasting with those of this study.

Falcon-Alvarado et al. (2023) applied various treatments with botanic extracts for aphid control on cabbages, *B. oleracea* var. *capitata* L., using neem leaf extract (dose: 20%) observing general averages of seven aphids per plant, and a control efficacy of 61.5% 45 days after testing. This was similar to what was obtained in this study at low and medium doses of azadirachtin, and lower to the high dosage results tested for the same extract. A seed extract of *A. indica* was prepared at 5% and applied to control cabbage pests (*B. oleracea* var. *capitata*) in a field study conducted between 2016 and 2017 in the Ketu-Sur municipality, Volta region, Ghana (Ngosong et al., 2021). The results showed the efficacy of the extract, with post-implementation averages lower than one individual per *B. brassicae* leaf (Ngosong et al., 2021). These population densities, if apported to individuals per plant, were similar to the observed ones in the study when azadirachtin was applied at high doses.

For the lambda-cyhalothrin, some experiments showed high and average efficacy of this pyrethoid insecticide. Conciding with the study's findings, the treatments that included lambda-cyhalothrin and imidacloprid showed higher efficacy for the control of Lepidoptera and Homoptera pests of *B. oleracea* in field experiments between 2014 and 2015 at the Faisalabad University, Pakistan (Saeed et al., 2017; Mahmood et al., 2018). Ali y Zedan (2015) carried out a field experiment in the El-Minia region, Egypt to test the effects of various insecticides for *B. brassicae* control on cabbages. Lambda-cyhalothrin evaluated at a dose of 170 $mL \cdot ha^{-1}$ showed an average efficacy of 64.3% in the control of this aphid species. This efficacy is similar to that obtained in this study when lambdacyhalothrin was applied at doses of 200 $mL \cdot ha^{-1}$.

Several brassica pests have developed resistance to being sprinkled with these organo-synthetic insecticides (Joseph et al., 2017; Mpumi et al., 2020; Panwar et al., 2023). These insecticides have also shown adverse effects on natural enemies of brassica pests (Anjum and Wright, 2023; Panwar et al., 2023). Consequently, the impact of lambda-cyhalothrin and other pyrethroids should be considered when designing pest management programs (Mpumi et al., 2020).

In the case of *Capsicum* extracts, laboratory tests have shown 100% efficacy of *C. frutescens* L. alkaloids in the control of the aphid, *B. brassicae* (Habimana and Hakizayezu, 2014). Capsaicinoids extracted from *C. annuum* L. were tested in field experiments in Yunnan, China for the control of various pests. These experiments showed a control efficiency of 77.80 and 89.74% on *B. brassicae* and *M. persicae*, respectively, when these alkaloids were applied at a concentration of 3,000 mL (Li et al., 2019). In contrast to what was obtained in this trial, applications of garlic extracts (60 $g \cdot L^{-1}$) and aji (50 $g \cdot L^{-1}$) reduced the *B. brassicae* populations by 42.05 and 26.36%, respectively (Baidoo and Mochiah, 2016).

Extracts of *Sophora* species have also been tested for aphid control. Ma et al. (2018) reported that alkaloids from *S. alopecuroides* L. showed high insecticidal activity against aphids belonging to the genera *Myzus, Aphis, Macrosiphum and Brevicoryne* with efficacy ranges between 40 to 70%.

A field experiment indicated an efficacy of 85.91% in the control of the rose aphid, *Macrosiphum rosirvorum* L. when extracts of *S. alopecuroides* (15.7%) were sprayed together with *Nicotiana tabacum* L. (1.1%) (Xin et al., 2014).

In this study, the decrease in yields associated with the increase in *B. brassicae* populations was detected. Coinciding with these results, Falcon-Alvarado et al. (2023) noted that yields were lower in cabbage plots that were not treated with insecticides in which the largest aphid populations developed. In oilseed brassica species, field studies found yield declines ranging from 18.3 to 24.5% due to high densities of aphids and lepidopteran caterpillars (Kumar, 2017).

In this assay, the densities of *B. brassicae* decreased the yield of broccoli with a determination of 40% according to the calculated equation. Abiotic factors, pests and diseases also had effects on yield, which could explain the remaining variation. In addition to *B. brassicae*, in Ecuador other pests that caused losses in broccoli are *Leptophobia aripa* (Boisduval) (Lepidoptera: Pieridae) and *Plutella* sp. (Lepidoptera:Plutellidae) (Pazmiño et al., 2015; Gomez and Sánchez, 2023). Given the importance of broccoli for the Ecuadorian economy, research on the evaluation of alternatives to less impact pests represents a significant contribution to sustainable pest management.

Conclusion

The low densities of *B. brassicae*, high control efficiencies, as well as higher yields in botanical treatments, azadirachtin + capsaicin + allicin sprayed at 3,000 mL and *Sophora* extract at a dose of 1,000 mL, mean that their uses may be promising within programs of sustainable pest management. This is especially important in countries that dedicate part of their production to export, such as Ecuador.

Conflict of interest

The authors declare that they have no conflicts of interest in this publication in any of its phases.

References

Ali, R. A. E. and Zedan, O. A. A. (2015). Selectivity of certain insecticides for controlling the cabbage aphid *Brevicoryne brassicae* (L.) and their effect on some predatory insects on cauliflower fields in El-Minia Region-Upper Egypt. *J. Plant Prot. Res. Pathol.*, *6*(10), 1427-1437. https://doi.org/10.21608/jppp.2015.75342

Ambrosino, M. D., Jepson, P. C. and Luna, J. M. (2007). Hoverfly oviposition response to aphids in broccoli fields. *Entomol. Exp. Appl.*, *122*(2), 99-107. https://doi.org/10.1111/j.1570-7458.2006.00499.x

Anjum, F. and Wright, D. J. (2023). Foliar residual toxicity of insecticides to *Brassica* pests and their natural enemies. *J. Econ. Entomol.*, *116*(1), 153-159. https://doi.org/10.1093/jee/toac188

Baidoo, P. K. and Mochiah, M. B. (2016). Comparing the effectiveness of garlic (*Allium sativum* L.) and hot pepper (*Capsicum frutescens* L.) in the management of the major pests of cabbage *Brassica oleracea* (L.). *Sustain. Agric. Res.*, *5*(2), 83-91. https://doi.org/10.5539/sar.v5n2p83

Cerda, H., Carpio, C., Ledezma-Carrizalez, A. C., Sánchez, J., Ramos, L., Muñoz-Shugulí, C., Andino, M. and Chiurato, M. (2019). Effects of aqueous extracts from amazon plants on *Plutella xylostella* (Lepidoptera:Plutellidae) and *Brevicoryne brassicae* (Homoptera:Aphididae) in laboratory, semifield, and field trials. *J. Insect Sci.*, *19*(5), 1-9. https://doi.org/10.1093/jisesa/iez068

Claros Cuadrado, J. L., Pinillos, E. O., Tito, R., Mirones, C. S. and Gamarra Mendoza, N. N. (2019). Insecticidal properties of capsaicinoids and glucosinolates extracted from *Capsicum chinense* and *Tropaeolum tuberosum*. *Insects*, *10*(132), 10.3390/insects10050132. https://doi.org/10.3390/insects10050132

Costello, M. J. and Altieri, M. A. (1995). Abundance, growth rate and parasitism of *Brevicoryne brassicae* and *Myzus persicae* (Homoptera:Aphididae) on broccoli grown in living mulches. *Agriculture, Ecosystems and Environment*, *52*(2-3), 187-196. https://doi.org/10.1016/0167-8809(94)00535-M

Di Rienzo, J. A., Casanoves, F., Balzarini, M. G., Gonzalez, L., Tablada, M. y Robledo, C. W. (2020). *InfoStat versión 2019. Centro de Transferencia InfoStat, FCA*. http://www.infostat.com.ar

Falcon-Alvarado, J., Valverde-Rodriguez, A., Álvarez-Benaute, L., Briceño-Yen, H. y Campos-Albornoz, M. E. (2023). Extractos vegetales en el control del pulgón (*Brevicoryne brassicae* L.) en el cultivo de la col (*Brassica oleracea* var. *capitata*), en Perú. *Manglar*, *20*(4), 317-323. https://doi.org/10.57188/manglar.2023.036

Food and Agriculture Organization of the United Nations (FAO). (2024). *Food and agriculture data*. Datos Sobre Alimentación y Agricultura. http://www.fao.org/faostat/en/#data/QC

Gill, H. K., Garg, H. and Gillett-Kaufman, J. L. (2013). Cabbage aphid *Brevicoryne brassicae* Linnaeus (Insecta: Hemiptera:Aphididae). *In*: *IFAS Extension, University of Florida*, *10*, 1-5. https://doi.org/10.32473/edis-in1014-2013

Golicz, A. A., Bayer, P. E., Barker, G. C., Edger, P. P., Kim, H. R., Martinez, P. A., Chan, C. K. K., Severn-Ellis, A., McCombie, W. R., Parkin, I. A. P., Paterson, A. H., Pires, J. C., Sharpe, A. G., Tang, H., Teakle, G. R., Town, C. D., Batley, J. and Edwards, D. (2016). The pangenome of an agronomically important crop plant *Brassica oleracea*. *Nature Commun.*, *7*, 1-8. https://doi.org/10.1038/ncomms13390

Gomez, J. J. M. and Sánchez, C. E. G. (2023). Oviposition preference of *Leptophobia aripa* (Lepidoptera: Pieridae) on plants of *Brassica oleracea* var. *italica* at different phenological stages. *Bionatura*, *8*(3). https://doi.org/10.21931/RB/2023.08.03.25

Habimana, S. and Hakizayezu, M. (2014). Biocide effect of alkaloids, saponins and flavonoids extracted from chilli against *Brevicoryne brassicae*, cabbage aphids. *Sky J. Agric. Res.*, *3*(11), 234-239. http://www.skyjournals.org/SJAR

Henderson, C. F. and Tilton, E. W. (1955). Tests with acaricides against the brown wheat mite. *J. Econ. Entomol.*, *48*(2), 157-161. https://doi.org/https://doi.org/10.1093/jee/48.2.157

Holdridge, L. (1967). Life zone ecology. Tropical Science Center. https://reddcr.go.cr/sites/default/files/centro-de-documentacion/holdridge_1966_-_life_zone_ecology.pdf

Joseph, S. V., Martin, T., Steinmann, K. and Kosina, P. (2017). Outlook of pyrethroid insecticides for pest management in the Salinas Valley of California. *J. Integr. Pest Manag.*, *8*(1), 1-11. https://doi.org/10.1093/jipm/pmx001

Karso, B. A., Yousif, R., Mustafa, H. and Mohammad, D. (2022). Inventorying the most common broccoli pest insect and assessing the effectiveness of sticky traps in reducing damage. *NTU J. Agric. Vet. Sci.*, *2*(1), 5-8.

Kumar Chaubey, M. (2017). Study of insecticidal properties of garlic, *Allium sativum* (Alliaceae) and bel, *Aegle marmelos* (Rutaceae) essential oils against *Sitophilus zeamais* L. (Coleoptera:Curculionidae). *J. Entomol.*, *14*(5), 191-198. https://doi.org/10.3923/je.2017.191.198

Kumar, S. (2017). Assessment of avoidable yield losses in crop brassicas by insect-pests. *J. Entomol. Zool. Stud.*, *5*(3), 1814-1818.

Li, B., Yang, M., Shi, R. and Ye, M. (2019). Insecticidal activity of natural capsaicinoids against several agricultural insects. *Nat. Prod. Commun.*, *14*(7), 1-7. https://doi.org/10.1177/1934578X19862695

Li, H., Xia, Y., Liu, H. Y., Guo, H., He, X. Q., Liu, Y., Wu, D. T., Mai, Y. H., Li, H. Bin, Zou, L. and Gan, R. Y. (2022). Nutritional values, beneficial effects, and food applications of broccoli (*Brassica oleracea* var. *italica* Plenck). *Trends Food Sci. Technol.*, *119*, 288-308. https://doi.org/10.1016/j.tifs.2021.12.015

Ma, T., Yan, H., Shi, X., Liu, B., Ma, Z. and Zhang, X. (2018). Comprehensive evaluation of effective constituents in total alkaloids from *Sophora alopecuroides* L. and their joint action against aphids by laboratory toxicity and field efficacy. *Ind. Crops Prod.*, *111*, 149-157. https://doi.org/10.1016/j.indcrop.2017.10.021

Mahmood Ahmed, S., Saeed, M., Nawaz, A., Usman, M., Fartab Shoukat, R., Li, S., Zhang, Y., Zeng, L., Zafar, J., Akash, A., Farjad Shoukat, R., Jaleel, W., Zafar, J., Akash, A. and Fartash Shoukat, R. (2018). Monitoring of quantitative and qualitative losses by lepidopteran, and homopteran pests in different crop production systems of *Brassica oleracea* L. *J. Entomol. Zool. Stud.*, *6*(3), 6-12.

Meriga, B., Mopuri, R. and MuraliKrishna, T. (2012). Insecticidal, antimicrobial and antioxidant activities of bulb extracts of *Allium sativum*. *Asian Pac. J. Trop. Med.*, *5*(5), 391-395. https://doi.org/10.1016/S1995-7645(12)60065-0

Ministerio de Agricultura y Ganadería (MAG). (2023). Estado del cultivo del brócoli en Ecuador. In: *Boletin situacional cultivo de brocoli* (Vol. 2). http://sipa.agricultura.gob.ec/index.php/situacionales-agricolas/situacional-brocoli

Ministerio de Agricultura y Ganadería (MAG). (2024). *Agroproductive data*. Ministerio de Agricultura y Ganadería. http://sipa.agricultura.gob.ec/index.php/cifras-agroproductivas

Mpumi, N., Machunda, R. S., Mtei, K. M. and Ndakidemi, P. A. (2020). Selected insect pests of economic importance to *Brassica oleracea*, their control strategies and the potential threat to environmental pollution in Africa. *Sustainability* (*Switzerland*), *12*(9). https://doi.org/10.3390/su12093824

Nagraj, G. S., Chouksey, A., Jaiswal, S. and Jaiswal, A. K. (2020). Broccoli. p. 5-17. *In*: Jaiswal, A. K. (Ed.) *Nutritional composition and antioxidant properties of fruits and Vegetables*, First edition. Elsevier, Campus, Dublin. https://doi.org/10.1016/B978-0-12-812780-3.00001-5

Ngosong, N. T., Boamah, E. D., Fening, K. O., Kotey, D. A. and Afreh-Nuamah, K. (2021). The efficacy of two bio-rational pesticides on insect pests complex of two varieties of white cabbage (*Brassica oleracea* var. *capitata* L.) in the coastal savanna region of Ghana. *Phytoparasitica*, *49*(3), 397-406. https://doi.org/10.1007/s12600-020-00859-8

Panwar, N., Thirumurugan, S. and Kumar, S. (2023). Host plant resistance in Brassicaceae against aphids. p. 1-27. *In*: Kumar S. (Ed.), *Brassica-Recent Advances*. IntechOpen. Princes Gate Court, London. https://doi.org/http://dx.doi.org/10.5772/57353

Pazmiño, O., Flores, M., Vallejo, M. J., Iturra, F., Ramón, P. y Medina, L. (2015). Estudio sobre residuos de plaguicidas en brócoli de exportación y consumo nacional. *Ecuador es calidad: Rev. Científ. Ecuatoriana*, *2*(2). https://doi.org/10.36331/revista.v2i2.12

Saeed, M., Fartab Shoukat, R., Zafar, J. and Muhammad Saeed, C. (2017). Population dynamics of natural enemies and insect pest in different *Brassica oleracea* (cabbage) growing seasons with different production systems. *J. Entomol. Zool. Stud.*, *5*(6), 1669-1674. https://www.entomoljournal.com/archives/2017/vol5issue6/PartW/5-1-239-490.pdf

Xin, H., Rong-Juan, M., Jun, H., Yi-Wan, Z., Zhi-Qing, M. and Xing, Z. (2014). Joint aphidicidal action of alkaloids of *Sophora alopecuroides* L. and nicotine. *Acta Entomol. Sin.*, *57*(5), 557-563. http://www.insect.org.cn/EN/Y201 4/V57/I5/557

Author's contribution statement according to the CRedit classification.

José Gabriel Ugsha Sabando: Conceptualization, Investigation, Formal Analysis, Writing - review & editing. **Dorys T. Chirinos:** Formal Analysis, Writing - review & editing. **Eliana Granja Guerra:** Formal analysis, Writing - review $ editing. **Mario Javier Chuquiana Caiza:** Conceptualization, Investigation, Writing - review & editing.