Effects of Five Species of Chenopodiaceae on the Development and Reproductive Potential of Copitarsia decolora (Lepidoptera: Noctuidae)

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Effects of five species of Chenopodiaceae on the development and reproductive potential of *Copitarsia decolora* (Lepidoptera: Noctuidae)

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Abstract

Modern agriculture aims to reduce continuous applications of synthetic chemical pesticides for pest control because of issues such as pollution, loss of trade and disruption of biological control agents, potentially leading to pest outbreaks. Botanical insecticides are a good alternative to synthetic pesticides, as they have lower environmental hazard, are biodegradable and can be used shortly before harvesting. We tested the effect of essential oils (EOs) and aqueous extracts (AEs) of Chenopodiaceae plants (*Dysphania ambrosioides (=Chenopodium ambrosioides)*, *Chenopodium album*, *C. berlandieri* subsp. nuttalliae*, C. graveolens* and *Beta vulgaris*), incorporated into the diet under lab conditions, on a widely distributed insect pest in America, the cabbage pest, *Copitarsia decolora* Guenée 1852 (Lepidoptera: Noctuidae). The EO of *C. graveolens* at 0.5% reduced the larvae and pupae weight by 30 and 15%, respectively; increased the larval period length by 17% and reduced fecundity and fertility by 80 and 85%, respectively related to the control. EOs of *C. berlandieri* and *B. vulgaris* at 0.5% increased larval and pupal period length by 22% and 38% and both reduced fecundity and fertility by 99% related to the control. None of the plant extracts tested caused immediate *C. decolora* mortality, but EOs reduced mean survival time and reproductive capacity of the insect. This is the first report of *C. berlandieri* EO effect against an insect pest. The EOs of *C. graveolens*, *B. vulgaris* and *C. berlandieri* have great potential as alternatives to synthetic chemicals for insect control and deserve further exploration.

Key Words: essential oil, *Chenopodium graveolens*, *Beta vulgaris*, fecundity, mean survival time

Resumen

La agricultura moderna trata de reducir la aplicación continua de productos sintéticos para controlar plagas debido a la contaminación que producen, la restricción a ciertos mercados y el daño a agentes de control biológico que pudieran dar lugar a la aparición de plagas. Los insecticidas botánicos son una buena opción ya que son biodegradables, tienen un impacto mínimo en el ambiente y pueden usarse poco tiempo antes de la cosecha. Probamos el efecto biológico de los aceites esenciales (EOs) y extractos acuosos (AEs) de varias plantas Chenopodiaceae (*Dysphania ambrosioides (=Chenopodium ambrosioides), Chenopodium album*, *C. berlandieri* subsp. nuttalliae*, C. graveolens* y *Beta vulgaris*) en condiciones de laboratorio, sobre un insecto plaga de amplia distribución en América, la palomilla de la col *Copitarsia decolora*. El AE de *C. graveolens* al 0.5% redujo el peso de las larvas y pupas en 33 y 15%, respectivamente; prolongó el periodo larval en un 17% y redujo la fecundidad y fertilidad en 80 y 85%, respectivamente con respecto al control. Los AEs de *C. berlandieri* y *B. vulgaris* al 0.5% prolongaron en un 22% el periodo larval y en un 38% el periodo pupal y ambos inhibieron la fecundidad y fertilidad en un 99% con respecto al control. Ninguna planta probada tuvo un efecto insecticida inmediato pero AEs redujeron significativamente el tiempo medio de vida y la capacidad reproductiva del insecto. Este es el primer reporte de la actividad del AE de *C. berlandieri* contra un insecto plaga. Los AEs de *C. graveolens*, *B. vulgaris* y *C. berlandieri* tienen gran potencial como alternativa a los productos sintéticos y merecen ser más estudiados.

Palabras Clave: Aceite esencial, *Chenopodium graveolens*, *Beta vulgaris*, fecundidad, tiempo medio de vida

Botanical insecticides are a viable alternative to synthetic insecticides, and they degrade quickly, retard the development of insecticide-resistance, can be used shortly before harvest (Kühne 2008; Silva-Aguayo 2013) and are environment friendly. An example is UDA-245, a *Chenopodium*-based natural insecticide (Chiasson et al. 2004; Bostanian et al. 2005). Components of Chenopodiaceae species such as *Dysphania ambrosioides* (L.) Mosyakin & Clemants (formerly *Chenopodium ambrosioides*) have been reported to produce several effects in insects. They reduced larval weight and number of progeny of *Sitotroga cerealella* (Olivier; Lepidoptera: Gelechiidae) (Gemechu et al. 2013); repelled or killed Coleoptera *Sitophilus zeamais* (Motschulsky) (Chu et al. 2011) and a commercial product derived from *D. ambrosioides* killed the long tailed mealy bug *Pseudococcus longispinus* (Targioni & Tozzetti) (Cloyd & Chiasson 2007). Other species affected by this plant are lepidopterans (*Pieris* spp.), coleopterans (*Popillia japonica* (Newman), *Leptinotarsa* spp.*, Callosobruchus maculatus* and

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Phyllobius spp.), and dipterans (*Aedes* spp. and *Cochliomyia hominivorax* (Coquerel)). *Chenopodium graveolens* ((Willd.) W. A. Weber) has been reported to be toxic to the lepidopteran *Tuta absoluta,* the hemipteran *Bemisia tabaci* (Gennadius) and the thysanopteran *Frankliniella schultzei* (Trybom) (Barbosa et al. 2011). *Chenopodium album* (L.) reduces larval growth, pupal weight and kills the larvae of the noctuid *Mamestra configurata* (Walker). The methanolic extract of foliar parts of *Beta vulgaris* L. (Caryophyllales: Amaranthaceae) (10 g/100 mL) repelled and reduced the fecundity in the spider mite *Tetranychus cinnabarinus* (Boisduval; Trombidiformes: Tetranychidae) (Mansour et al. 2004). Alkaloids, steroids, flavonoids, phenols, and saponins found in Chenopodiaceae plants has been identified and have been deemed to be responsible for various biological effects on insects (Ibrahim et al. 2007; Kokanova-Nedialkova et al. 2009).

We evaluated the effect of essential oils (EOs) and aqueous extracts (AEs) of 5 Chenopodiaceae plants: *Chenopodium album* (L.)*, D. ambrosioides*, *C. berlandieri* subsp. *nuttalliae* ([Saff.] H. D. Wilson & Heiser)*, C. graveolens* ([Willd.] W. A. Weber)*,* and *Beta vulgaris* rubra (L.) on the development and reproductive potential of an important pest in North, Central and South America, i.e., *Copitarsia decolora* (Guenée) (Lepidoptera: Noctuidae). This moth is a pest of Brassicaceae species such as cabbage (*Brassica oleracea* var. capitata), cauliflower (*Brassica oleracea* var. botritys), broccoli (*Brassica oleracea* var. italica) (Suárez-Vargas et al. 2006), and other important economic plants like onion (*Allium cepa* L.), garlic (*Allium sativum* L.; Alliaceae), coriander (*Coriandrum sativum* L.; Apiaceae), potato (*Solanum tuberosum* L.; Solanaceae), strawberry (*Fragaria* spp.; Rosaceae), apple (*Malus* spp. Rosaceae), corn (*Zea mays* L.; Poaceae), asparagus (*Asparagus officinalis* L.; Liliaceae), spinach (*Spinacia oleracea* L.; Amaranthaceae) among others (Moreno & Serna 2006; Angulo & Olivares 2003, 2010). Cabbage shipments exported from Mexico to the USA are strictly monitored for the presence of *C. decolora* for quarantine purposes (USDA 2013). Control of *C. decolora* larvae in México is attempted by using various broad spectrum insecticides.

Materials and Methods

INSECT LABORATORY COLONY

We reared our insects according to Callado-Galindo et al. (2013) and separated genders according to Angulo & Olivares (2010). Adults (10-12 females and 6-8 males) were caged in 20 × 20 × 20 cm acrylic cages and 6-cm diam Petri dishes with cotton were used to dispense a 10% honey solution. The colony was maintained in a brood chamber at 20 ± 5 °C , 50 ± 5% RH and 12:12 h L:D.

ORIGIN OF PLANT MATERIAL

Chenopodium album was collected from Jumiltepec, Morelos State, *C. graveolens* from Juchitepec, México State and *D. ambrosioides*, *C. berlandieri* subsp. *nuttalliae* and *B. vulgaris* were bought from Cuautla local market, Morelos, México. Plants were identified by Dr. Rolando Ramírez at University of Morelos State Herbarium (HUMO) where specimens were deposited.

ESSENTIAL OILS AND AQUEOUS EXTRACTS

The whole plant of each of the 5 above-mentioned Chenopodiaceae species was used to obtain EOs and AEs. Essential oils were obtained by steam distillation according to Jardim et al. (2008). In brief, 4 L of chopped plant material was placed in a 12 L round-bottomed flask. Steam was passed through the material until no additional oily material was recovered. Water was removed from the solution by freezing and addition of anhydrous sodium sulfate. The resulting oil was kept at 4 °C in a brown glass container.

All plant material used for AEs was dried for 24 h at 50 °C in a laboratory stove, except for the beet root that was sliced (3-5 mm) and dried under a conventional fan oven for 4 d. The dried material was turned into a powder in an electric mill (IKA® WERKE, model MF 10 basic) and filtered through a no. 40 mesh sieve. Aqueous extracts (w/v) were obtained by soaking the dried powder in water in a 500 mL Erlenmeyer flask under constant stirring for 24 h at 150 rpm. The resultant extracts were filtered twice through gauze and was dried in an extraction hood before use.

BIOASSAYS

Three bioassays were conducted; 2 for EOs and 1 for AEs. We tested 0.1 and 0.5% (v/v) EOs of *C. album, C. graveolens, C. berlandieri* subsp. nuttalliae*, D. ambrosioides* and *B. vulgaris*. Tween 20™ was added to EOs (1:5) to stabilize the solution prior blending it into the diet. Diet alone and diet with Tween 20 (called stabilizer from now on) were used as controls.

We tested 5% aqueous extracts (w/v) of *C. album, C. graveolens, C. berlandieri* var. nuttalliae*, D. ambrosioides* and *B. vulgaris*. Normal diet was used as the control. For all bioassays, 60 newly-hatched larvae were individually tested and reared separately in 30 mL transparent plastic containers for each treatment and kept under the same conditions. Diet was replaced twice weekly. For each treatment we recorded larval mortality, the weight of the larvae and pupae, the duration of the larval and pupal periods and adult fecundity, fertility and longevity.

EFFECT ON FECUNDITY AND FERTILITY

Male and female moths from the same treatment were allowed to mate in transparent acrylic boxes (20 × 20 × 20 cm). After mating, females were placed individually into plastic bags. According to Callado-Galindo et al. (2013) females oviposit more than 90% of their egg load by day 10 of the oviposition period, thus we collected eggs masses daily for 10 d and incubated the eggs under the same conditions as the colony on damp filter paper in 6-cm diam Petri dishes. Adults were fed a 10% honey solution from small-perforated Eppendorf tubes until they died. Fecundity was defined as the total number of eggs laid by a female and fertility as the number of eggs that produced larvae.

STATISTICAL ANALYSIS

We used a one-way Analysis of Variance or Kruskal-Wallis procedure followed by a Holm-Šidák test, depending on the normality of the data. Mean survival time (from larval to adult death) were obtained from Kaplan-Meier curves followed by a Gehan-Breslow Test (Rich et al. 2010). All statistical analyses were conducted in SigmaPlot 11 and the rejection probability was set at 0.05. Reported values are mean ± SE unless otherwise stated.

Results

LARVAL AND PUPAL WEIGHTS

Essential oils at 0.1% and 0.5% significantly reduced larval weight (H = 38.5, df =6, 400, $p \leq 0.001$ and H = 67, df = 6, 205, $p \leq 0.001$, respectively), in treatments in which larva were fed *C. graveolens* and *B. vulgaris* EOs at 0.1%. These treatments caused significant weight reductions of 15% and 14%, in relation to the control (Table 1). EOs of *C. graveolens* and *D. ambrosioides* at 0.5% significantly reduced the larval weight by 33% with respect to the control (Table 1). There was

Table 1. Effects of essential oils and aqueous extracts of Chenopodiaceae plant species on mean (± SE) *Copitarsia decolora* larval weights (mg).

Treatments	EOs 0.1%	EOs 0.5%	AEs 5%
B. vulgaris	715 ± 27 a	619 ± 31 ab	791 ± 23
C. album	830 ±25 bc	614 ± 10 ab	837 ± 24
C. berlandieri	755 ± 24 ab	702 ± 26 bc	818 ± 24
C. graveolens	707 ± 24 a	555 ± 25 a	833 ± 24
D. ambrosioides	793 ± 23 abc	551 ± 24 a	759 ± 25
Control	835 ± 18 c	834 ± 21 c	757 ± 26
Stabilizer	855 ± 24 c	778 ± 41 c	NT

NT = Not tested
Means in the same column followed by the same letter are not significantly different ($p > 0.05$).

Table 3. Effects of essential oils and aqueous extracts of Chenopodiaceae plant species on mean (± SE) *Copitarsia decolora* larval period (d).

Treatments	EOs 0.1%	EOs 0.5%	AEs 5%
B. vulgaris	24.12 ± 0.75 b	33.08 ± 0.35 bc	32.21 ± 0.34
C. album	24.52 ± 0.75 b	30.82 ± 0.47 b	31.32 ± 0.34
C. berlandieri	25.91 ± 0.77 b	33.89 ± 0.69 c	31.05 ± 0.34
C. graveolens	25.47 ± 0.75 b	32.31 ± 0.45 bc	30.98 ± 0.35
D. ambrosioides	27.38 ± 0.75 b	33.10 ± 0.56 bc	30.93 ± 0.36
Control	22.86 ± 0.58 a	27.60 ± 0.31 a	33.69 ± 0.38
Stabilizer	26.88 ± 0.75 b	33.80 ± 0.68 bc	NT

NT = Not tested
Means in the same column followed by the same letter are not significantly different ($p > 0.05$).

not a statistical difference between the aqueous control and the stabilizer. Larvae treated with AEs had similar weights ($F = 2.1$, df = 5, 328, $p > 0.05$; Table 1).

EOs significantly affected pupal weights at both concentrations (Table 2) ($H = 37.5$, df = 6, 353, $p \leq 0.001$ at 0.1% and $H = 53.6$, df = 6, 173, $p \leq 0.001$ at 0.5%). At 0.5%, EOs of *C. graveolens* and *B. vulgaris* produced significantly lighter pupae than the control (15% and 12%, respectively). No AEs significantly reduced pupal weights in relation to the control but *C. berlandieri* significantly increased it albeit this increase was negligible ($F = 3.4$, df = 5, 259, $p = 0.005$; Table 2).

LARVAL AND PUPAL PERIOD LENGTH

All EOs at 0.1% and 0.5% increased the duration of the larval period in relation to the control ($H = 60.9$, df = 6, 400, $p \leq 0.001$ and $H = 92.6$, df = 6, 205, $p \leq 0.001$, respectively; Table 3). The largest increases at 0.1% were produced by *D. ambrosioides* (20%), *C. berlandieri* (13%) and *C. graveolens* (11%), respectively. At 0.5%, *C. berlandieri* (22%), *D. ambrosioides* and *B. vulgaris* (19%) produced the longest larval period. In both concentrations, these figures were not significantly different from those of the stabilizer treatment. No difference in duration of the larval period was observed with AEs ($H = 5.4$. df = 5, 331, $p > 0.05$, Table 3).

No significant difference was observed in the durations of the pupal period of insects treated with EOs at 0.1% (H = 7.9, df = 6, 353, $p > 0.05$; Table 4). However at 0.5% concentration, all EOs increased the length of the pupal period length in relation to the control ($F = 74.917$, df = 6, 172, $p < 0.001$; Table 4), there was a significant increase of 41% with *C. album* and 38% with *C. berlandieri* with respect to the control. A significant difference in the durations of the pupal period was observed in insects fed with AEs in that a significant 9% pupal period increase was observed for *C. album* and a 7% increase with both *C berlandieri* and *D. ambrosioides* with respect to the control ($F = 3.4$, df = 5, 259, $p = 0.005$; Table 4).

FECUNDITY AND FERTILITY

In *C. decolora* fed with EOs of *B. vulgaris*, and *C. graveolens* at 0.1% there was a significant reduction in fecundity (82% and 69%, respectively) compared to the control ($F = 22.7$, df = 6, 101, $p < 0.001$; Table 5). Further significant reductions in fecundity were obtained with 0.5% EOs of *B. vulgaris, C. berlandieri, D. ambrosioides* and *C. graveolens* (99, 94, 88 and 80%, respectively) ($F = 38.5$, df = 6, 74, $p < 0.001$; Table 5). At 5% AEs of *D. ambrosioides*, *C. berlandieri* and *B. vulgaris* significantly reduced fecundity by 70, 58 and 51%, respectively ($F = 14.4$, df = 5, 97, $p < 0.001$; Table 5).

Essential oils of *Beta vulgaris* and *C. graveolens* at 0.1% significantly reduced the number of fertile eggs by 89% and 75%, respectively ($F = 24.9$, df = 6, 101, $p < 0.001$) (Table 6) and at 0.5% concentration, fertility was reduced by 99, 96, 93 and 85% by *B. vulgaris*, *C. berlandieri*, *D. ambrosioides* and *C. graveolens* respectively ($F = 36.6$, df = 6,74, $p < 0.001$). The largest reduction on fertility (75%) with AEs was caused by *D. ambrosioides* and *C. berlandieri* ($F = 13.4$, df = 5, 97, $p < 0.001$) (Table 6).

MEAN SURVIVAL TIME

Beta vulgaris essential oil at 0.1% produced a significantly shorter mean survival time (56.4 ± 3.1 d) than *D. ambrosioides* (65.9 ± 2.2 d). Days alive did not differ between control (58.7 ± 2.2 d) or the stabilizer (63.6 ± 2.6 d) treatment (Gehan-Breslow Test = 29.941, df = 6, $p < 0.001$). However, at 0.5%, essential oils of *C. graveolens, D. ambrosioides, C. berlandieri* and *B. vulgaris* significantly reduced the mean survival time by 55, 53 and 52 % for the last 2 plant species, as compared

Table 2. Effects of essential oils and aqueous extracts of Chenopodiaceae plant species on mean (± SE) *Copitarsia decolora* pupal weights (mg).

Treatments	EOs 0.1%	EOs 0.5%	AEs 5%
B. vulgaris	375 ± 7 ab	334 ± 8 ab	404 ± 5 a
C. album	380 ± 6 ab	374 ± 3 bc	420 ± 5 ab
C. berlandieri	385 ± 6 ab	364 ± 9 bc	429 ± 5 b
C. graveolens	369 ± 6 a	322 ± 6 a	421 ± 5 ab
D. ambrosioides	389 ± 6 bc	370 ± 5 bc	420 ± 5 ab
Control	374 ± 5 ab	380 ± 3 c	406 ± 6 a
Stabilizer	404 ± 6 c	395 ± 6 c	NT

NT = Not tested
Means in the same column followed by the same letter are not significantly different ($p > 0.05$).

Table 4. Effects of essential oils and aqueous extracts of Chenopodiaceae plant species on mean (± SE) *Copitarsia decolora* pupal period (d).

Treatments	EOs 0.1%	EOs 0.5%	AEs 5%
B. vulgaris	25.73 ± 0.54	31.70 ± 0.40 b	27.69 ± 0.43 ab
C. album	26.09 ± 0.50	35.39 ± 0.69 c	28.32 ± 0.39 b
C. berlandieri	25.54 ± 0.50	34.58 ± 0.81 c	27.81 ± 0.41 b
C. graveolens	25.40 ± 0.50	32.00 ± 0.59 b	27.19 ± 0.42 ab
D. ambrosioides	26.58 ± 0.46	29.73 ± 0.62 b	27.82 ± 0.44 b
Control	25.66 ± 0.41	25.00 ± 0.30 a	25.92 ± 0.46 a
Stabilizer	26.43 ± 0.49	23.35 ± 0.59 a	NT

NT = Not tested
Means in the same column followed by the same letter are not significantly different ($p > 0.05$).

Table 5. Effects of essential oils and aqueous extracts of Chenopodiaceae plant species on mean (± SE) *Copitarsia decolora* fecundity. Number of mating pairs per treatment shown in parentheses.

Treatments	EOs 0.1%	EOs 0.5%	AEs 5%
B. vulgaris	28 ± 4.33 c (12)	1 ± 0.47 d (10)	61 ± 11.76 cd (15)
C. album	144 ± 7.38 ab (15)	46 ± 5.91 c (10)	165 ± 20.5 a (16)
C. berlandieri	126 ± 8.55 ab (12)	7 ± 1.89 d (12)	52 ± 9.76 d (18)
C. graveolens	48 ± 4.07 c (13)	25 ± 7.16 cd (10)	111 ± 14.09 bc (15)
D. ambrosioides	103 ± 9.99 b (15)	15 ± 1.19 d (10)	37 ± 10.45 d (18)
Control	155 ± 11.34 a (17)	130 ± 10.77 a (8)	126 ± 10.83 ab (17)
Stabilizer	121 ± 15.86 ab (12)	96 ± 12.71 b (13)	NT

NT= Not tested.
Means in the same column followed by the same letter are not significantly different ($p > 0.05$).

to the control (65.0 ± 2.6 d) (Fig. 1). The control and the stabilizer (54.9 ± 3.3 d) had similar mean survival time (Gehan-Breslow Test = 39.4, df = 6, $p < 0.001$). Aqueous extracts at 5% did not have an effect on mean survival time (Gehan-Breslow Test = 3.2, df = 5, $p > 0.05$). It ranged from 52.6 ± 3.6 d (control) to 63.5 ± 2.4 d (*C. album*).

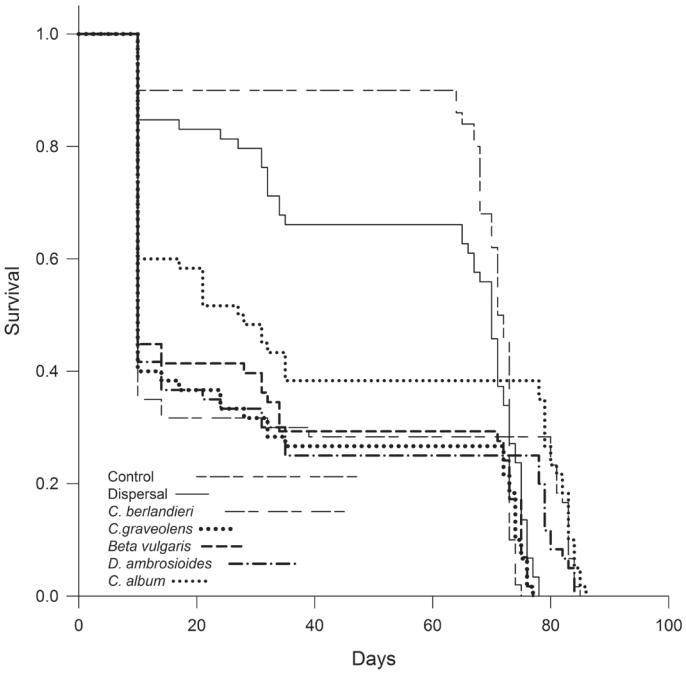

Fig. 1. Survival curves of *Copitarsia decolora* insects fed diets containing 0.5% of essential oils extracted from 5 species of Chenopodiaceae.

Discussion

Our results show that EOs from Chenopodiaceae plants negatively affect growth and reproduction of *C. decolora*. Most EOs treatments reduced larvae and pupae weight and increased the duration of the larval and pupal period compared with the control groups. Also, the inclusion of EOs into the diets reduced mean survival time and produced large larvae mortality during the first 10 days of the experiments. Most important is the reduction on fertility; this ranged from 70 to 99% with EOs at 0.5% and from 10 to 75% with EAs. Aqueous extracts also reduced fertility by 10 to 75%. The use of EOs or AEs for managing *C. decolora* may reduce the selection pressure on the populations by delaying or preventing the onset of insecticide resistance. In addition, low reproductive potential will further reduce the next generation of the pest.

The most promising plant was *C. graveolens* as its EOs at 0.1 and 0.5% affected *C. decolora* at various stages. Treatment with these EOs resulted in small larvae and pupae, which would reduce the potential capacity of *C. decolora* to produce eggs as adults. Further such treatment prolonged the larval period and thereby increased the chance of larvae to being killed by predators. Moreover such enhanced larval mortality would strongly reduce reproductive capacity of the population. Rodríguez et al. (1982) found that AEs from *C. graveolens* at 5% had no effect on the biology of the Noctuid *Spodoptera frugiperda* (Smith), however, in our study; this plant significantly reduced the reproductive potential of *C. decolora*. Methanolic extract of leaves and twigs of *C. graveolens* at 1 mg/mL showed trypanocidal activity over *Trypanosoma cruzi* (Zoomastigophora: Trypanosomatidae) after 48 h incubation (Abe et al. 2002), while the hexane extract of leaves and stems of *C. graveolens* (500 mg/L) caused a 98% mortality of *Fasciola hepatica* (Trematoda: Fasciolidae) after 24h (Ibarra-Moreno et al. 2012).

Table 6. Effects of essential oils and aqueous extracts of Chenopodiaceae plant species on mean (± SE) *Copitarsia decolora* fertility.

Treatments	EOs 0.1%	EOs 0.5%	AEs 5%
B. vulgaris	16 ± 2.0 d	1 ± 0.2 d	34 ± 10 b
C. album	132 ± 7.4 ab	36 ± 4.4 c	107 ± 17.2
C. berlandieri	101 ± 8.0 bc	5 ± 1.4 d	30 ± 7.8 b
C. graveolens	37 ± 3.8 d	18 ± 5.3 cd	88 ± 12.8 a
D. ambrosioides	90 ± 8.8 c	9 ± 1.4 d	29 ± 9.4 b
Control	148 ± 11.3 a	123 ± 10.8 a	120 ± 10.5 a
Stabilizer	116 ± 15.8 abc	78 ± 11.8 b	NT

NT, not tested
Means in the same column followed by the same letter are not significantly different ($p > 0.05$).

Another promising plant is *B. vulgaris* as its EOs at 0.5% reduced larval weight, increase the duration of the pupal period and decimated the fecundity and fertility of C*. decolora*. Saponins have been suggested as responsible for the insecticidal activity of *B. vulgaris* because they decreased survival, reduced food intake, reduced weight gain, slowed down development and lowered reproductive potential. It is hypothesized that saponins, due to their bitterness, could either make the food less attractive to eat (repellent/deterrent activity), cause digestive problems, interrupt the molting process or have toxic effects on cells (De Geyter et al. 2007).

Beta vulgaris contains a large number of compounds such as, fatty acids (palmitic, oleic, linoleic, stearic, arachidonic), phenolic acids (syringic, caffeic, vanillic, chlorogenic), alkaloids (betanin), flavonoids (myricetin, quercetin, kaempferol) derivatives of betalains (acid betalamic, betaxatin, betacianin), derivatives of apigenin (vitexin, vitexin-2-O-rhamnoside, vitexin-2-O-xyloside), among others. Some of these compounds have been reported as having insecticidal or repellent effects (Ninfali & Angelino 2013). However, it is difficult to attribute the reduction on reproductive potential of *C. decolora* to any compound without specific tests.

The essential oils of *C. berlandieri* at 5% successfully prolonged the larval and pupal periods and reduced fecundity and fertility > 94%. This

is the first report of insecticidal activity of *C. berlandieri* on larvae of a noctuid. Chaires et al. (2013) reported the presence of phenols and flavonoids in raw and cooked seeds of *C. berlandieri*. In our experiment we used the whole plant, not only the seeds, therefore the quantities of EOs reported by Chaires et al. (2013) could be very different from those involved in our tests. Feeding deterrence of flavonoids has been reported previously by Iwashina (2003).

Kemabonta & Okogbue (2002) reported that the *D. ambrosioides* (*C. ambrosioides*) ethanolic extract at 5% applied on seeds killed 54% of adult *Callosobruchus maculatus* (Fabricus) (Coleoptera: Bruchidae) and reduced their oviposition rate by 72%. However, ethanolic extracts of *D. ambrosioides* (*C. ambrosioides*) failed to affect larval development and survival of the pyralid *Hypsipyla grandella* (Zeller) (Mancebo et al. 2000). Twenty four h after spraying tomato (*Lycopersicon esculentum* [Mill.]; Solanaceae) parcels with ethanolic leaf extract of *C. ambrosioides* at 5%, the treated parcels presented minor numbers of adults of *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) (Barbosa et al. 2011) suggesting a repellent effect. *Dysphania ambrosioides* (*C. ambrosioides)* aqueous extract at 10% reduced oviposition by 98% in *Plutella xylostella* (L) (Lepidoptera: Plutellidae) (Medeiros et al. 2005) and killed 20% of second instar larvae of noctuid *Anticarsia gemmatalis* (Hübner) (Barbieri & Fiuza, 2004).

According to Tapondjou et al. (2002), the main constituents of *C. ambrosioides* EOs from leaves are *α*-terpinen (37.6%), cymol (*p*-cymen) (50.0%), *cis-β*-farnesen (1.4%), ascaridole (3.5%) and carvacrol (3.3%). Similarly, Jardim et al. (2008) reported α-terpinen (0.9%), p-cymene (2.0%), (Z)-ascaridole (61.4%), carvacrol (3.9%) and (E)-ascaridole (18.6%). The biological effect of this oil (Bakkali et al. 2008) has been attributed to ascaridole and could be responsible for the effect of this plant on *C. decolora*. However, Harwood et al. (1990) tested the effect of limonene and α-pinene, components of the EOs of *C. ambrosioides* and *C. album* on the noctuid *Peridroma saucia* (Hübner) (Lepidoptera: Noctuidae) and found that limonene at 2% reduced larval feeding, development and pupation rate.

The application of UDA-245, an essential oil extract from *C. ambrosioides* var. near ambrosioides, is effective in controlling the green peach aphid, *Myzus persicae* (Sulzer) (Homoptera: Aphididae), the Western Flower thrips, *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae), and greenhouse whitefly, *Trialeurodes vaporariorium* (Westwood) (Homoptera: Aleyrodidae). UDA-245 produced no side effects on the parasitoids *Encarsia formosa* (Gahan) (Hymenoptera: Aphelinidae) (Chiasson et al. 2004), *Orius insidiosus* (Say) and *Aphidius colemani* (Viereck) (Bostanian et al. 2005). Based on these results, Chiasson et al. (2004) suggested that a greenhouse integrated pest management (IPM) program using a botanical such as UDA-245 could effectively control infestations of major pests present while having a negligible effect on biological control agents.

The noctuid *M. configurata* fed on lentils *Lens culinaris* cv. 'chilean' and *C. album* plants suffered great larval mortality, and a highly reduced pupal weight (Turnock 1985). Conversely, *C. album* failed to cause any larval and pupal weight loss, produce a shorter larval period and had no effect on larval survival. Even in a choice experiment *M. configurata* larvae preferred this plant over the cabbage family species, *Brassica rapa* (L), *B. napus*., *B. juncea*, *Sinapis alba* (L), and *Thlaspi arvense* (L) (Brassicaceae), the Compositae *Cirsium arvense* (L), the Fabaceae (=Leguminosae) *Pisum sativum* (L) *a*nd *Medicago sativa* (L), and the Linaceae *Linum usitatissimum* (L) (Dorsdall & Ulmer 2004) indicating a differential effect of *C. album* to different insects.

Copitarsia decolora fed as larvae with *Tagetes filifolia* (Lag) (Asteraceae: Compositae) essential oil at 0.01% had an 85% reduction in fecundity but similar fertility the control (Barajas 2009). In our case, the EO of *B. vulgaris* at 0.5% drastically reduced both parameters indicating that this plant species may performance more effectively in pest management, regardless of the concentration of the EO.

The development and use of EOs as tool for pest management requires more information about the response of the larvae to sprayed cabbage plants and on the physical contact with the EOs. Evaluation of phytotoxicity as well as development of formulation is mandatory before attempting to use EOs in the field.

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