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CROP PROTECTION

RESEARCH PAPER

Nitrogen fertilization sources and insecticidal activity of aqueous seeds extract of *Carica papaya* against *Spodoptera frugiperda* in maize

Rodolfo Figueroa-Brito[1,3], Patricia Villa-Ayala[1], Jesús F. López-Olguín[2], Arturo Huerta-de la Peña[3], Juan R. Pacheco-Aguilar[4], and Miguel A. Ramos-López[4]

[1]Centro de Desarrollo de Productos Bióticos. Instituto Politécnico Nacional. Carretera Yautepec-Jojutla, km 6, Calle Ceprobi No. 6, San Isidro, Yautepec, C.P. 62731, Morelos, Mexico.

[2]Centro de Agroecología y Posgrado MasAgro, Instituto de Ciencias, Benemérita Universidad Autónoma de Puebla. 14 Sur 6301, Ciudad Universitaria, 72570, Puebla, Mexico.

[3]Colegio de Postgraduados. Campus Puebla. Carretera Federal México-Puebla, km 125.5, Santiago Momoxpan, San Pedro Cholula, Puebla. 72760. Mexico.

[4]Facultad de Química, Universidad Autónoma de Querétaro. Cerro de las Campanas s/n, Col. Las Campanas, C.P. 76010, Santiago de Querétaro, Querétaro, Mexico.

Abstract

R. Figueroa-Brito, P. Villa-Ayala, J.F. López-Olguín, A. Huerta-de la Peña, J.R. Pacheco-Aguilar, and M.A. Ramos-López. 2013. Nitrogen fertilization sources and insecticidal activity of aqueous seeds extract of *Carica papaya* against *Spodoptera frugiperda* in maize. Cien. Inv. Agr. 40(3): 567-577. The damage caused by the fall armyworm *Spodoptera frugiperda* Smith (Lepidoptera: Noctuidae) to vegetative-stage maize cultivated with chemical nitrogen fertilizers, vermicompost, and *Carica papaya* L. (Caricaceae) seed extract was estimated. Each shoot was infested with one first instar larva of *S. frugiperda*. The variables measured included the percentage of germination, length of the second and fifth leaves, stem diameter and plant height, and the estimation of damage caused by *S. frugiperda* larvae on maize. The results indicated that vermicompost helped seed germination on a relation 3:1 from black soil and vermicompost, the emergence was 100%, while the emergence with black soil was 80%. The ammonium sulfate increased the length of the second and fifth leaves 89.6% and 160.4% respectively, augmented the stem diameter and the plant height 290.2% and 13.3% respectively, respect to water treatment. The exogenous nitrogen sources stimulate *S. frugiperda* to cause more damage to the plant, the treatment urea showed 70% of damage, with phosphonitrate 62.3% and with ammonium sulfate 51.8%, when were evaluated without aqueous seed extract of *C. papaya*. Ammonium sulfate + aqueous extract of *C. papaya* seeds showed the lowest insect damage to maize with 29.6%.

Key words: Aqueous extract, Caricaceae, chemical fertilizers, damage, fall armyworm, *Spodoptera frugiperda*.

Introduction

Maize *Zea mays* L. (Poaceae) is a cereal crop adapted for various ecological conditions; it represents the cereal crop with the highest production worldwide, with 867.5 million tons being produced in 2011 (USDA, 2011). In Mexico, the total surface cultivated with maize was 6.866 million ha in 2011, and the total production in 2011 was estimated to be 20.256 million tons (SAGARPA, 2011). However, this production is insufficient to satisfy the national demand; consequently, it is

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Corresponding author: agromyke@yahoo.com

necessary to import it. Pests and diseases reduce the quality and yield of maize, and the excessive use of inorganic fertilizers (i.e. nitrogen fertilization) causes nutritional deficiencies and decreased pest resistance (Díez *et al.,* 2000).

The fall armyworm *Spodoptera frugiperda* Smith (Lepidoptera: Noctuidae) is the principal insect pest for maize, because it attacks during all developmental stages. In Mexico, this insect causes crop losses between 20-100% (Del Rincón *et al.,* 2006). The principal damage occurs in the initial developmental stage of the plant, 30 days after sowing, when the insect feeds off the leaves and shoots, especially in the meristem.

Improved soil fertility could cause some plants to become more susceptible to certain insects (Nicholls and Altieri, 2008). Van Dusen (1988) demonstrated that high rates of nitrogen fertilization cause an increase of *S. frugiperda* infection when compared to other insect pest populations. Additionally, the low abundance of insect herbivores on organic crops has been attributed to low plant nitrogen content (Jahn *et al.,* 2005; Birkhofer *et al*., 2008; Altieri *et al.,* 2012; Jactel *et al.,* 2012; Rusch *et al.,* 2013). Phelan *et al.* (1995) demonstrated that, under greenhouse conditions, females of *Ostrinia nubilalis* Hübner (Lepidoptera: Pyralidae) oviposited significantly more eggs in maize plants cultivated with chemical fertilizers nitrogenous than in plants cultivated with organic soils with manure cow. These results demonstrate that soil fertilizer management can affect plant quality, which, in turn, can affect insect pest abundance and consequent levels of damage (Brévault *et al.,* 2007; De Groote *et al.,* 2010; Ratnadass *et al.,* 2012).

Many practices have been implemented to control *S. frugiperda* infestations; the most utilized practice has been the application of organophosphate insecticides such as Malathion® and Parathion-methyl®, which are dangerous to the farmer's health (De Liñán, 2009). Alternatively, seven applications every eight days of extract from leaves of *Azadirachta indica* A. Juss. (Meliaceae) or *Gliricidia sepium* Kunth (Fabaceae) (5 mL L^{-1}), reduces the damage from insect pest and also increases maize production in 37.6 and 35.8% with *G. sepium* and *A. indica* respectively (Montes-Molina *et al.,* 2008). Additionally, the application of powder of Mamey, Maradol, Amarilla and Hawaiana varieties from *Carica papaya* L. (Caricaeae) at 15 or 10%, in artificial diet, demonstrated mortality of 90% with all varieties at 15% after 72 h and the same mortality with Mamey, Maradol and Amarilla varieties after 96 h at 10% (Franco *et al.,* 2006).

The use of chemical fertilizers nitrogenous strengthens maize plant vigor, but these plants become more "desirable" to insect pests such as *S. frugiperda* (Rusch *et al.,* 2013). The synthetic insecticides used in the control of this insect pest could be dangerous to the environment and to human health; alternatively, the use of organic fertilization and/or botanic insecticides improves soil fertility, reduces maize damage, and increases production (Montes-Molina *et al.,* 2008; Ratnadass *et al.,* 2012).

This aim of this study was evaluate the effect of fertilizer organic or nitrogenous and the application of *C. papaya* aqueous extract on the mortality *S. frugiperda* larvae and estimate the damage of maize plants grown under greenhouse conditions.

Materials and methods

Rearing of S. frugiperda

In July 2005, 153 *S. frugiperda* larvae of different instars were collected from maize crops in Yautepec, State of Morelos, Mexico, located on the geographic coordinates 18° 53′ N latitude and 99° 04′ W longitude, at altitude of 1210 meters above sea level. The larvae were collected from the meristems of plants 15 days post-seeding. The larvae were reared with an artificial diet (Burton and Perkins, 1987) in the Entomology Laboratory of Centro de Desarrollo de Productos Bióticos, Instituto Politécnico Nacional, Yautepec, Morelos. The insects were individually deposited in plastic glasses (3 cm height and 3.5 cm diameter) with toppers. The larvae passed to the pupal stage in the same glasses. When the adults emerged, they were placed in waxed paper bags containing one plastic Petri dish of 10 cm diameter with cotton moistened with a 10% sugar solution. These adults mated with each other randomly. The F_2 larvae were used in the bioassay.

Seed extract of C. papaya

Fruits of *C. papaya* Maradol were allowed to dry in shade for 15 days at room temperature (28 °C ± 5), after which then they were crushed using an electric mill (model MF 10 Basic, lKA-Werke GMBH and Co. Germany) with a mesh of 0.25 mm. Twenty grams of the seed powder was deposited in an Erlenmeyer flask with 1 L of distilled water to be macerated for 12 h at room temperature. The mix was then filtered using sterile filtered paper (Whatman® No. 5), and the solution was used immediately in the bioassay at 20%, we increase 5% over the concentration of papaya seed extract of the insecticidal activity reported by Franco *et al.* (2006) who mixed with artificial diet on *S. frugiperda*.

Substrates and maize seeds

The maize seed used was of the “San Juan” variety provided by corn producers San Juan Atenco, Puebla. The substrates utilized were black soil and vermicompost of Momoxpan, Puebla. The black soil was sandy loam, pH (6.5), organic matter (0.59%), and macronutrients and micronutrients (mg kg^{-1}): nitrate ($N\text{-}N0_3$ 2.01), phosphorus (15.4), potassium (139), calcium (495.62) and magnesium (88.36) as sodium (23.74), iron (16.79), copper (0.96) and boron (0.24), respectively.

The vermicompost was produced with vegetable waste and agricultural waste collected from nearby local market and agricultural farm. Agricultural wastes mainly include straw, dry leaves of crop plants, weeds while vegetable wastes include unused, rotten vegetable parts. Vermicomposting was carried out as worm bin (100 × 100 × 120 cm). After partial decomposition of waste in pit, main species of earthworm *Lumbricus terrestris* L. (100 individuals per pit, worm bin) were released. The process of vermicomposting was followed as described by Kumar and Raheman (2012). Finally, well-ferment vermicompost was obtained. The uniformly mixed samples (100 g) of all manures were collected immediately from the pits for nutrients analysis.

The vermicompost a pH (9.49), organic matter (46.34%) and macronutrients and micronutrients (mg kg^{-1}): total nitrogen (1.65%), nitrate ($N\text{-}NO_3$ 502.53 mg kg^{-1}), phosphorus (0.39%), potassium (2.31%), calcium (2.82%) and magnesium (0.62%) as sodium (23.74%), iron (6213.3 mg kg^{-1}), copper (39.78 mg kg^{-1}), boron (36.23 mg kg^{-1}) and zinc (112.79 mg kg^{-1}).

Bioassay

Some plastic bags (33 × 33 cm) were filled with 6 kg of black soil and others with black soil and vermicompost (3:1 w/w) according to Kumar and Raheman (2012). Two seeds were planted in each bag. After 20 days, one of the two maize plants was manually removed of each bag and fertilizers were added (ammonium sulfate 13.6 g bag^{-1}; urea 6 g bag^{-1}; phosphonitrate 6.56 g bag^{-1}) with 50% of the N, all added when the plants were in phase V8, *i.e.* the vegetative phase when the plants have eight leaves (López *et al.,* 1999).

The following treatments were evaluated: 1) black soil (BS) + ammonium sulfate (AS); 2) BS + AS + aqueous extract of *C. papaya* seeds at 20 g L^{-1} (AECPS) was applied to the foliage six rows of five maize plants, *i.e.* a total of 30 plants, with a hand pump as in normal agricultural practices; 3) BS + vermicompost (VE); 4) BS + VE + AECPS; 5) BS + urea (U); 6) BS + U + AECPS; 7) BS + phosphonitrate (PN); 8) BS + PN + AECPS; as positive controls: 9) BS + AECPS; 10) BS + Malathion® (2 μL/ 14 mL), and as a negative control: 11) BS. Treatments were distributed randomly, with six repetition per treatment and five plants per repetition.

After 3 h of sprayed the *C. papaya* seeds extract, the meristem from all plants were infested with one first instar larva of *S. frugiperda* using a fine brush. The variables measured included the following: rate of emergence (two weeks after planting), length of the second and fifth leaves, stem (diameter), and plant height from the soil surface to the inclusion of the last leaf. The damage by *S. frugiperda* larvae was estimated with valuation scale using by Mihn (1984), to *S. frugiperda* with a nine-level scale. The calculating from incidence and severity of the damage was the average of the estimated damage of 30 plants per treatment.

Statistical analysis

Data were assessed for normality and homoscedasticity prior to analysis. An analysis of variance and orthogonal analysis were used followed by a comparison using the Tukey test. In some cases Kruskal-Wallis non-parametric analysis of variance was used when data violated these assumptions and could not be corrected using a transformation (SAS INSTITUTE, 2002. SAS System for Windows, release 9.0. SAS Institute, Cary, NC, USA).

Results

Emergence percentage

The emergence of the “San Juan” variety of maize was significantly different between BS + VE (3:1) (100% emergence) and BS alone (80% emergence) (P≤0.0001, Figure 1); consequently, it was necessary to replant BS treatments to obtain 100% emergence.

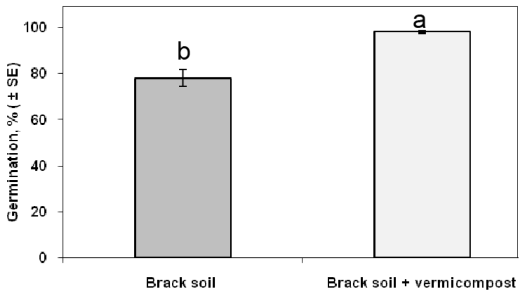

Figure 1. Percentage of emergence of maize var.“San Juan” with black soil and black soil + vermicompost.

Length of the second and fifth leaves

The effect of different treatments on the length of the second leaf was significant (P≤0.0001). The mean differences in the orthogonal test occurred by the type of fertilization (P≤0.0001) and the interaction between fertilization and papaya extract application (P=0.0040). The maize plants fertilized with AS showed the largest second leaves (94.8 cm). This effect was higher in the treatment AS + AECPS (106 cm) (Table 1).

Similar results were observed for the fifth maize leaf, where the mean differences in the orthogonal test were significant according the type of fertilization (P≤0.0001) and the papaya extract application (P≤0.0001). The AS or AS + AECPS treatments were more significant, with leaf length increases of 144 and 152 cm, respectively (Table 1).

Diameter of stem and height of maize plants

The effects of different treatments on the diameter of the stem differed significantly (P≤0.0001) (Table 1) with fertilization type (P≤0.0001) and papaya extract application (P≤0.0229). The AS and AS + AECPS treatments had the most significant effects, with diameter of stems of 23.8 mm and 25.1 mm diameter, respectively, who were statistically equal to the PN + AECPS and U + AECPS

Table 1. Leaf length, stem diameter and height of maize treated with chemical or organic fertilization, with or without aqueous extract of *C. papaya* seeds.

Treatment	Length (cm)		Diameter (mm)	Height (m)
	Leaf 2	Leaf 5	Stem	Plant
Ammonium Sulfate	94.8 ± 3.2 b	144.0 ± 3.7 ab	23.8 ± 3.6 ab	1.7 ± 0.3 ab
Ammonium Sulfate + Extract[1]	106.0 ± 5.1 a	152.0 ± 6.1 a	25.1 ± 2.5 a	2.2 ± 0.3 a
Urea	76.3 ± 3.4 c	90.1 ± 3.9 de	19.5 ± 1.6 bc	1.4 ± 0.2 bc
Urea + Extract[1]	78.6 ± 6.5 c	96.1 ± 6.0 d	21.5 ± 3.6 abc	1.6 ± 0.3 ab
Phosphonitrate	70.1 ± 5.6 cd	125.6 ± 3.2 c	18.0 ± 3.1 cd	1.5 ± 0.2 bc
Phosphonitrate + Extract[1]	76.6 ± 5.1 c	134.8 ± 3.2 bc	23.2 ± 2.3 abc	1.6 ± 0.3 ab
Vermicompost	70.1 ± 2.2 cd	84.8 ± 6.5 e	7.5 ± 2.8 ef	1.3 ± 0.2 bc
Vermicompost + Extract[1]	69.0 ± 4.1 cd	90.0 ± 4.1 de	8.3 ± 3.1 ef	1.5 ± 0.3 bc
Control Water	50.0 ± 5.7 e	55.3 ± 4.6 f	6.1 ± 2.3 f	0.9 ± 0.1 c
Control Extract[1]	55.1 ± 9.3 e	58.1 ± 7.3 f	10.3 ± 2.3 ef	0.9 ± 0.2 c
Control Malathion	60.0 ± 4.9 de	63.1 ± 8.8 f	12.8 ± 2.1 de	1.3 ± 0.4 bc

[1]Extract= aqueous extract of *C. papaya* seeds; Means (± SE) with a different letter in a column represent significant differences between treatments (Tukey's test, P≤0.05).

treatments who also stimulated diameter stem (23.2 and 21.5 mm, respectively). The diameter stems of plants treated with VE and VE + AECPS were significantly equal to that of the controls.

In relation to plant height, the effects of the treatments were significant between fertilization types (P≤0.0001) and papaya extract application (P=0.0106). The AS + AECPS and AS treatments induced maize plant growth of 2.2 and 1.7 m, respectively. The U + AECPS and PN + AECPS treatments were also increased the height of the corn plant (1.6 m, Table 1).

Table 2. Damage of *Spodoptera frugiperda* larvae in maize.

Treatment	Damage (%)	
	Without extract	With extract
Urea	70.0 a	56.6 c
Phosphonitrate	62.3 b	35.1 e
Ammonium Sulfate	51.8 c	29.6 f
Vermicompost	32.3 ef	31.1 ef
Control Water	46.3 d	-
Control Extract	-	11.6 g
Control Malathion	8.6 g	-

Means (± SE) with different letters represent significant differences between treatments (Tukey's test, P≤0.05).

Damage to maize plants from S. frugiperda

The effect of the treatments on damage estimation was significant by fertilization type (P≤0.0001), papaya extract application (P≤0.0001), and interaction between fertilizer and papaya extract application (P≤0.0001) (Table 2).

The *S. frugiperda* larvae cause more damage to maize plants fertilized with U, PN, and AS, causing 70, 62.3, and 51.8% damage, respectively. Moreover, plants treated with VE presented less damage (32.3%) (Table 2).

All treatments (except vermicompost) that included the aqueous extract of *C. papaya* seeds inhibited damage caused by *S. frugiperda* larvae (VE + AECPS except), the most evident being AS + AECPS (29.6%), followed by VE + AECPS and PN + AECPS treatments (31.1 and 35.1%, respectively). In plants treated with U + AECPS, the damage was 56.6%. However, in the positive control treatments with BS + Malathion® and BS + AECPS, insects caused 8.6 and 11.6% damage, respectively.

Discussion

In this research, the use of vermicompost stimulated the emergence of maize seeds; this improvement resulted in better initial growth of the plants. Moreover, with sowing in black soil, it became necessary to reseed to increase emergence rates. A study by Sinha *et al.* (2010) determined that vermicompost improved plant growth, color, and brightness of the leaves in maize, wheat, and tomato. There were also fewer incidences of pests and diseases and a reduction in water demand on tomato and maize plants, thus significantly reducing the need for chemical pesticides.

Nitrogen fertilization increased diameter of stem of corn plants when compared with plants grown in vermicompost. Ammonium sulfate was the nitrogen fertilizer with the greatest ability to increase the length leaves, diameter stems and height of maize plants. Phosphonitrate and urea stimulated diameter stem. Residual effects of N or P based manure or compost application increased the biomass and crop production for one year and influenced soil properties for several years. Also the residual effects of manure and compost applications significantly increased soil electrical conductivity and pH levels and plant-available P. In the present study the vermicompost contained nitrogen, phosphorus and electrical conductivity in the range of composted cow for good growth of corn, except that the pH was slightly elevated. With the application of the biomass was formed vermicompost of corn plants (except diameter stem) similar to the biomass of the corn plants with chemical fertilizers urea and phosphorus, however the application of ammonium sulfate growing maize plants was better.

Farmers in Patzun, Guatemala changed from organic fertilizers ("postura" of combining any available materials: ashes, lime, crop residues, weeds, and manure from goats, cows, horses, rabbits, and chickens in a mulch pile or well cow manure) by urea but observed the negative consequences of this change, with an increase in insect pests in the maize crops (Morales *et al.,* 2001).

Some studies demonstrate that augmented nitrogen fertilizers increase populations of *Frankliniella occidentalis* Pergande (Thysanoptera: Thripidae) in tomato (Brodbeck *et al.,* 2001), *Aphis gossypii* Glover (Hemiptera: Aphididae) in cotton (Nevo and Coll, 2001), *Nilaparvata lugens* Stål and *Sogatella furcifera* Horvath (Hemiptera: Delphacidae) in rice (Lu *et al.,* 2007). Other researchers have shown that populations of *Ostrinia nubilaris* Hubner (Lepidoptera: Crambidae) (Phelan *et al.,* 1995), *Diabrotica virgifera* LeConte (Coleoptera: Chrysomelidae) (Moeser and Vidal, 2004) and *Peregrinus maidis* Ashmead (Hemiptera: Delphacidae) (Wang *et al.,* 2006), increased in maize when fertilized with nitrogen.

Moreover, the use of vermicompost reduces pest and disease incidences and also reduces water demand in maize and tomato crops. In the present study we observed less damage from the larvae of *S. frugiperda* and 'reduced demand of water' for irrigation in plants grown on vermicompost. Sinha *et al.* (2010) mentioned composts work as a 'slow-release fertilizer' whereas chemical fertilizers release their nutrients rather quickly in soil and soon get depleted. This corn plants develop in vermicompost are less "succulent and palatable" to insect pests, such as the larvae of *S. frugiperda*. The use of 20 or 40% vermicompost in tomato and cucumber grown under greenhouse conditions resulted in reduced damage by *Acalymma vittatum* F. and *Diabrotica undecimpunctata* Barber (Coleoptera: Chrysomelidae), and *Manduca quinquemaculata* Haworth (Lepidoptera: Sphingidae) (Yardim *et al.,* 2006). In our study, maize plants that were developed with 25% of vermicompost under greenhouse conditions, had less damage caused by the larvae of *S. frugiperda* developed plants with chemical fertilizers urea, phosphonitrate or ammonium sulfate. The use of vermicompost water solutions (1:5) as aqueous extracts at 5, 10, and 20% sprayed on *A. vittatum* and *Manduca sexta* L. (Lepidoptera: Sphingidae) in cucumber and tomato suppressed the establishment and damage of both insect pests (Edwards *et al.,* 2010). In this research, the use of aqueous extract from *C. papaya* seeds reduced *S. frugiperda* damage in maize plants fertilized with any nitrogen source except with vermicompost, where the damage was same with or without application of extract from *C. papaya*. Previous studies with *C. papaya* seeds demonstrated that powder, aqueous, and acetonic extracts, their fractions, and pure compounds exhibited activity against *S. frugiperda* larvae (Figueroa-Brito, 2002a, b; Franco *et al.,* 2006).

The commercial botanical insecticides of neem have proved effective in protecting corn crop. With the application of these insecticides botanicals, the larvae *S. frugiperda* only caused minimal damage (Oleonim 80 CE® and Oleonim 50 CE®: 0.07 and 0.06 larvae/plant) or moderate (Neem oil extract® and Neem Azal-T/S®: 25.8-17.5%) on maize plants (Pérez *et al*., 1997; Lima *et al.,* 2008; Gutiérrez-García *et al.,* 2010), while in our study 11.6% was the percentage of plant damage to corn treated aqueous extract of *C. papaya*.

Leaf extracts from *A. indica* and *Gliricidia sepium* Kunth (Fabaceae) (5 mL L^{-1}) reduced damage rates in maize (18 and 23%) (Montes-Molina *et al.,* 2008), is significantly higher than the aqueous extract of *C. papaya* (11.6%) of our study. These extracts reduced the emission of carbon dioxide (CO_2) in urea-amended soil and the emission of nitrous oxide (N_2O) in unamended soil when incubated at 40% water holding capacity (Méndez-Bautista *et al.,* 2009). The main fatty acid components of the *C. papaya* chloroformic seed extract were, oleic acid, palmitic acid, and stearic acid, these acids caused larval viability of 33.3, 48.5, and 62.5% when exposed to 1,600 ppm respectively against *S. frugiperda* (Pérez-Gutiérrez *et al.,* 2011), so the reduction in corn injury by the application of the aqueous extract of seeds of *C. papaya* may be due to the presence of these acids.

There are several studies analyzing the scope and impact of organic fertilizers in Latin America as agroecological technologies used by NOGs on maize farming systems, such as EPAGRI, AS-PTA in Brazil, COAGRES in El Salvador (COAG, 2004), and ALTERTEC in Guatemala (Pretty, 1997). Phelan *et al.* (1995) mentioned that the adequate and prolonged management of organic matter in the soil could induce better resistance of the plants to insect pests. In this sense, the use of botanic products can help to reduce insect pests, diseases, and others problems in the soil (Altieri and Nicholls, 2000). Rao (2003) showed that application of manure, neem paste, and vermicompost reduced populations of *S. litura* and *H. armigera* in peanut when compared with chemical fertilizers. A similar effect happened in our study, with the application of vermicompost and seed extract of *C. papaya* decreased the percentage of corn damage caused by *S. frugiperda* compared with chemical nitrogen fertilizers. These studies showed that soil management fertilization affects plant susceptibility to insect pest attack. Crops that grow in soils with high organic matter content and high biological activity exhibit fewer pest incidences (Altieri *et al.,* 2012). On the other hand, agricultural practices with excessive use of chemical fertilizers create nutrient imbalances and also reduce plant defense. A similar effect was observed in this study: maize plants with nitrogen fertilization grew more but with greater damage by *S. frugiperda*. In contrast, the incorporation of vermicompost increased the germination of maize seeds, and like the vermicompost + aqueous extract of *C. papaya* seeds reduced the damage of *S. frugiperda* in the maize plants grown with nitrogen fertilization by these damage was greater than one application aqueous extract *C. papaya* or Malathion, this is attributable to the larvae of *S. frugiperda* prefer to feed on green plants “succulent” developed corn nitrogen source that weak plants developed yellow and vermicompost. Altieri and Nicholls (2003) shows that the ability of a crop plant to resist or tolerate insect pests and diseases is tied to optimal physical, chemical and mainly biological properties of soils. Soils with high organic matter and active soil biology generally exhibit good soil fertility. Crops grown in such soils generally exhibit lower abundance of several insect herbivores, reductions that may be attributed to a lower nitrogen content in organically farmed crops.

There are some studies that reports phenolic compounds, extracted from vermicompost, which exhibit feeding deterrent activity against *Helicoverpa armigera* Hübner, *Spodoptera exigua* Hübner and *Spodoptera litura* Fabricius (Lepidoptera: Noctuidae) (Mahanil *et al.,* 2008; Bhonwong *et al.,* 2009). It might be probably that phenolic compounds had in our vemicompost and had deterrent activity against *S. frugiperda* so there are not significantly differences in treatments with or without vermicompost.

In this research, plants with vermicompost showed less development and less damage caused by *S. frugiperda*, that plants treated with nitrogen synthetic fertilizers, this insect pest showed a positive correlation with the nitrogen level, this result was similar with positive correlation between *S. frugiperda* and other crops (Diawara *et al.,* 1991; Davidson and Potter, 1995). It may possible that S. *frugiperda* as other insect pest, prefer maize plants cultivated with chemical fertilizers, to find them more attractive and succulent.

The use of vermicompost with aqueous extract of *C. papaya* seeds can be recommended to be use in Agroecological Pest Management (APM) programs to improve crop development and control of *S. frugiperda*. In future experiments, those vermicompost phenolic compounds might be evaluated against *S. frugiperda* to identify potential feeding deterrent activity against this insect.

In this research, the results showed that vermicompost improved germination of the maize seeds, also the use of nitrogen fertilizers stimulated the damage caused by *S. frugiperda,* and ammonium sulfate induced the highest plant growth and development.

Resumen

R. Figueroa-Brito, P. Villa-Ayala, J.F. López-Olguín, A. Huerta-de la Peña, J.R. Pacheco-Aguilar y M.A. Ramos-López. 2013. Fuentes nitrogenadas de fertilización y actividad insecticida del extracto acuoso de semilla de *Carica papaya* contra *Spodoptera frugiperda* en maíz. Cien. Inv. Agr. 40(3): 567-577. Se estimó el daño causado por el gusano cogollero del maíz *Spodoptera frugiperda* Smith (Lepidoptera: Noctuidae) durante la etapa vegetativa de maíz cultivado con fertilizantes nitrogenados químicos, vermicomposta, y extracto acuoso de semillas de *Carica papaya* L. (Caricaceae). Cada brote se infestó con una larva de primer instar de *S. frugiperda*. Las variables evaluadas incluyen el porcentaje de germinación. Las variables respuesta fueron el porcentaje de emergencia, longitud de la segunda y quinta hoja, diámetro de tallo y altura de la planta; así como la estimación de daño causado por larvas de *S. frugiperda* al maíz. Los resultados indicaron que la vermicomposta ayudó a la emergencia de la semilla, en una relación 3:1 de suelo con vermicomposta alcanzó 100% de emergencia, mientras que solo con suelo, la emergencia fue de 80%; el sulfato de amonio incrementó el tamaño de la segunda hoja y quinta hoja 89,6 y 160,4% respectivamente, aumentó el diámetro de tallo y la altura de la planta 290,2 y 13,3%, respecto al tratamiento donde solo se aplicó agua. Las fuentes de nitrógeno estimularon que *S. frugiperda* ocasionara más daño a la planta, el tratamiento con urea presentó 70% de daño, con fosfonitrato 62,3%, con sulfato de amonio fue de 51,8% sin extracto acuoso de semillas de *C. papaya*. El tratamiento con sulfato de amonio + extracto acuoso de semillas de *C. papaya* registró el menor daño del insecto al maíz con 29,6%.

Palabras clave: Caricaceae, daño, extracto acuoso, fertilizantes químicos, gusano cogollero.

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