GSAR Journal of Agriculture and Veterinary Sciences
ISSN: 3048-9075 (Online)
Abbreviated key title: Glob.J. Agri.Vet.Sci.
Frequency: Monthly
Published By GSAR Publishers
Journal Homepage Link- https://gsarpublishers.com/journal-gjavs-home/

OPEN ACCESS

Drought Stress and Pest Control with Biopesticides in Apple and Pecan

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Article History

Received: 01/07/2026
Accepted: 06/07/2026
Published: 08/07/2026

Vol – 3 Issue –7

PP: -01-07

Abstract

Global warming, caused by greenhouse gases and population growth, has increased solar radiation that heats the Earth's surface and transforms it into latent heat, raising the temperature. Drought stress occurs with stomatal closure in crop leaves, causing temporary wilting. Biopesticides are alternatives to synthetic ones, repel insects and control diseases in a sustainable way. The objective was to evaluate the efficiency and efficacy of a biopesticide. In apples in 2023 and pecan in 2024, both in Coahuila, Mexico. In 2023, with: A.- Without application and B.- With application of 2 L of biopesticide one liter at the be-ginning and the second 10 days later, with three repetitions. In pecan A.- With syn-thetic insecticide and fungicide and B.- With the application of the biopesticide. The repellency index at 20 days after application (DDA) the control reached 5.3 and the biopesticide with 1 butterfly, the repellency index at 20 DDA, 0.39 and the effectiveness of the biopesticide was 75.3%. In pecan, the repellency of the synthetic was 0.25 at 20 DDA and of the biopesticide was 1.5. In apple tree diseases, the severity without application was 6.75 % and the biopesticide 1.67 %, in pecan with synthetic the severity was 2.0 % and the biopesticide 5.21, %, the effectiveness of the biopesticide was 61.6%.

Drought stress is reduced by the effect of Nordihydroguaiaretic Acid, which decrease damage from hydrogen peroxide (H_2O_2) that kills cells, in sustainable form.

Keywords: *Environmental Stress, Sustainable, Ingredients.*

INTRODUCTION

Global warming is a reality, in 2022, at the poles the temperature increased more than 4° C, in the tropics between 2° to 4° C and at the equator by less than 2° C. (Armstrong *et al*., 2022), in January 2026, Greenland has the hottest month in its history with 0.2°C (Forbes, 2026). The intensity of solar radiation has increased by heating the surface and transforming it into latent heat, which has led to the increase in temperature (Huang *et al*., 2025).

Drought stress, due to the latent heat, stops the transpiration of the crop and causes stomatal closure and reduces the absorption of carbon dioxide (CO_2) and the water content in leaf cells, photosynthesis decreases, evaporating the water on the surface of the leaf and closing the occlusive cells of the stomata due to the accumulation of abscisic acid (ABA), this causes temporary wilting occurs from 10:00 a.m. to 5:00 p.m. in spring and summer (Stamatis *et al*., 2024; Huang *et al*., 2025).

In 1960 the green revolution began and in 1970 wheat was tolerated to abiotic and biotic stress conditions that allowed food production to double worldwide, increasing the use of agrochemicals in agriculture. Adverse impacts have been due to the excessive use of pesticides on water quality, soil health, problems such as resistance and tolerance of pest insects, genetic variation in plants, toxic residues in food and food have created tools such as integrated pest management (IPM); (Yadav *et al*., 2022).

The effect of Nordihydroguaiaretic Acid (NDGA) is a polyphenol and antioxidant, used as biopesticide on pests: *Spodopera littoralis* (Black Doughnut) had a control of 24%, in *Myzus persicae* (Green Aphid) it had a repellency effect of 6.3% (Pérez *et al*., 2020). Kaempferol is used as biopesticide because inhibits mitochondrial function of the fungi *Aspergillus fumigatus*, *Aspergillus niger*, *Candida*, *Albicans* and *Saccharomyces cerevisiae*, at a concentration of 256 µg/mL, (Jan *et al*., 2022). In potato tubers (*Solanum tuberosum* L.), reduces damage to *Pectobacterium atrosepticum* (Ramaroson *et al*., 2022). Kaempferol is flavonoid, controls *Rhizoctonia solani*, of 49.5%, and

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Fusarium oxysporum through inhibition of mycelial growth (Song *et al*., 2011).

Quercetin is a flavonoid, controls the oriental leafworm (*Spodoptera litura*) with 625 mg/kg, reducing survival and pupation (Gautam *et al*., 2021). The use of quercetin with beneficial microorganisms such as *Trichoderma viride*, *Pseudomonas fluorescens*, *Metarhizium anisopliae*, *Bauveria bassiana* and *Bacillus thuringiensis* because it is a flavanol increases the concentration of signals in the symbiosis between the beneficial microorganism and the plant for the control of pathogenic fungi and bacteria (Bora *et al*., 2022).

Allicin is a pungent sulfur, inhibits spore germination, protein and DNA synthesis, mycotoxin production, denatures the membrane and its functions, modifies the hyphae and mycelium of the fungus (Perelló *et al*., 2013). Allicin prevents the insect from feeding, is repellent, inhibitor of its body renewal in the insect's larval and respiration stage, alteration of the cuticle and reduction of the fecundity of the pest insect (Pratap, 2023). Azadirachtin has effect at concentration of 20% it has a repellent effect, while it has an insecticidal effect at 80% on the pest *Stephanitis pyrioides* (Shimat, 2020). Control of *Bemisia tabaci* in tomato cultivation of 97% at 3 days in a single application (López y Estrada, 2005).

Cinnamaldehyde used as biopesticide has been effective in the control of *Colletotrichum gloeosporioides*, *Gliocephalotrichum microchlamydosporum* and *Botryodiplodia theobromae* (Sivakumar *et al*., 2002). Cinamaldehyde has a lethal dose of LC50 = 25.43 ± 1.0423 $\mu g/cm^3$, causing a mortality of 96% of *Dermanyssus gallinae* in larvae and eggs, (Bordin *et al*., 2021). Capsaicin has antimicrobial and antioxidant (Riquelme and Matiacevich, 2017) and antifungal (Moreno *et al*., 2012) properties.

There is no information on these ingredients applied together in a biopesticide, (Covarrubias and Díaz, 2023).

The apple moth (*Cydia pomonella* L.), is the most important pest worldwide in pear and apple trees; because without control the damage by fruits bored by the larvae ranges between 20 and 70% and with control does not exceed 1% (Sánchez *et al*., 2020).

Apple scab (*Venturia inaequalis*) exists worldwide, the damage of the fungus to leaves, young and ripe fruits is caused by asci and ascospores with subcuticular lesions, its control is with synthetic fungicides after petal fall with applications every 10 to 14 days depending on the intensity of rainfall (Agrios, 2005).

The nut screwworm (*Acrobasis nuxvorella*), is the most important pest of the fruit during the growth and filling of the nut, from freshly pollinated, growing and filling almonds, damage can reach up to 40% of production (Chávez *et al*., 2024).

Walnut hairy spot (*Mycosphaerella caryigena*) is an important disease in Mexico and the United States, it affects the leaves of the pecan tree, causing lesions and defoliation, the defoliation will be at least 90%. (Samaniego *et al*., 2015).

The objective of the study was to evaluate the efficiency and effectiveness of a biopesticide based on natural organic compounds in apple and walnut cultivation and his effect in drought stress.

Research Elaborations

In apples trees, the study was made in an apple orchard in the Rancho Nuevo ejido, Los Lirios, in Arteaga, Coahuila, during the spring-summer 2023 cycle. Two treatments were made: A.- Without application and B.- With application of 1 L of biopesticide how repellent and with a second application how biofungicide 10 days after the first application, each with four repetitions, the treatments are shown in Table 1. The biopesticide contains NDGA, kaempferol, quercetin, allicin, azadirachtin, cinnamaldehyde and capsaicin (Diaz y Covarrubias, 2023).

Table 1. Concentration of biopesticides applied to apple and walnut trees.

Ingredient	Repellent	Biofungicide
	mg/kg	
Nordihydroguaiaretic Acid	325	708
Kaempferol	44	49
Quercetin	4,868	9,742
Capsaicin	4,005	80
Allicin	59	55
Cinnamaldehyde	542	104
Azadirachtin	2.5	1.5

Irrigation sections were used and the samplings were in the central part of the unit to avoid the effect of boarding, for which a block design was had with 4 replications and 2 treatments.

For scab sampling, the sample size was 4 leaves from the middle part of the tree, in 5 trees for a total of 20 leaves per repetition and 80 leaves per treatment.

The diseases were measured on July 27, of 2023, which corresponds to 31 days after applying because the effects occurred after July 10 due to the presence of rains that stimulated the infection of scab or hairy spot (Mendoza, 1990), and are:

$$\%\ \boldsymbol{of\ infection} = \sum_{i=1}^{n=7} (n\ x\ V)/\boldsymbol{Category\ x\ N}$$

Where:

n = number of leaves in each index category

V= numerical value in each index category

N = Number of leaves in the sample for each repetition = 20

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Category = is the highest value of the index = 6 and is shown in Table 2.

Table 2. Severity indices for foliar damage

Índex	% of foliar surface
0	No damage
1	0.1 - 1.0
2	1.1-12.5
3	12.6-25.0
4	25.1-50.0
5	50.1 -75.0
6	75.1 -100

The effectiveness of the biopesticide was measured with the following model

$$\%\ \boldsymbol{of\ effectiveness} = \frac{\%\ \boldsymbol{of\ mt} - \%\ \boldsymbol{of\ mtra}}{\%\ \boldsymbol{mt}}\ \boldsymbol{x\ 100}$$

Where:
mt= is the severity in the control in apple or synthetic in walnut
mtra= is the severity in the Biopesticide

For the sampling of moth, it was made in barley wing traps with pheromone and was made in readings on a daily basis, during the study period, which was 20 days.

The repellency effect is measured as:

$$\boldsymbol{Repellency\ index} = \frac{\boldsymbol{2G}}{\boldsymbol{G + P}}$$

Where:
G= is the percentage of insects in the treatment.
P = is the percentage of insects in the control.
The repellency index is classified as neutral if the index is equal to one, attractant if it is greater than one, and repellent if it is less than one.

In Pecan Tree, the biopesticide was evaluated with the producer's management in the Santa Martha pecan orchard, in the municipality of Zaragoza, Coahuila in 2024. The biopesticide (Table 1), at the same dose applied to the apple tree with the repellent at the beginning and the biofungicide 10 days later, it was used in nut screwworm (*Acrobasis nuxvorella*), and hairy spot (*Mycosphaerella caryigena*), were determined the percentage of infection, effectiveness and repellency index. The producer used Azodrin ((Dimethyl (E)-1-methyl-2-(methyl carbamoyl) vinyl phosphate) 56.00%, against screwworm and Tilt (Propiconazole 25%), against hairy spot. The samplings were carried out for 20 days.

The treatments evaluated were: 1) synthetic. - 1 L/ha of insecticide synthetic and 1 L/ha of synthetic fungicide at 10 days from insecticide application and 2) biopesticide. - 1 L/ha of repellent and the second application after 10 days with 1 L/ha of biofungicide then the treatments of synthetic insecticide Azodrin were only one application at same time of biopesticide repellent and synthetic fungicide Tilt at same time of biofungicide 10 days later.

For hair spot sampling, the sample size was 4 leaves from the middle part of the walnut tree, in 5 trees for a total of 20 leaves per repetition and 80 leaves per treatment.

The repellency of nut screwworm was measured with pheromone traps from the beginning of study until 20 days of application.

The irrigation sections were used and the samplings were in the central part of the unit in pecan orchard to avoid the effect of boarding, for which a block design was had with 4 replications and 2 treatments.

The analysis was made with the SAS program first with UNIVARIATE and Shapiro-Wilk ($p > 0.05$) for normality and homogeneity of variance, followed by ANOVA and Tukey ($p > 0.05$) to differentiate effects (SAS, 2022).

Results and Discussion

Apple: the treatments had a significant difference between the control and the biopesticide. the effect of the biopesticide as a repellent in apple moths after initial sampling at 10 days after application (DAD) was significant for UNIVARIATE ($p > 0.05$) for equality of variances (homogeneous data) and ANOVA was significant ($p \leq 0.05$) and applied as a biofungicide applied to the following after the count of the 10 DAD, its effect at 20 DDA was significant for UNIVARIATE ($p > 0.05$) and for ANOVA was highly significant ($p \leq 0.01$) in the pest control with Tukey.

In Figure 1, it can be seen that the initial incidence was two apple moths, at 10 days the control had four and the biopesticide had one, but after 20 days the control reached 5.3 and in the biopesticide with a moth, this effect was highly significant (Tukey = $p \leq 0.05$) at 10 and 20 DDA.

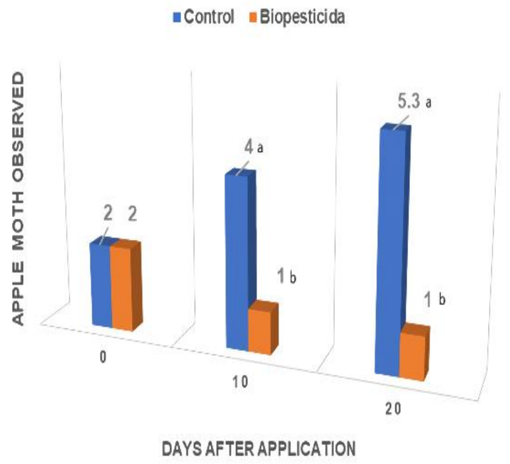

Figure 1. Incidence of apple moth due to the effect of biopesticide a,b = Tukey 0.05.

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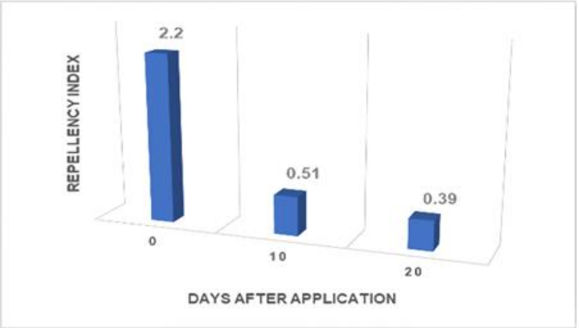

Figure 2. Repellency index to apple moth due to the effect of biopesticide.

The repellency index is shown in Figure 2, where at 10 DDA there is a 0.51 repellency index and at 20 DDA, it reaches 0.39, as mentioned, the repellency index should be less than 1, and according to its values there is greater repellency at 20 DDA of apple moths.

The effect of the biopesticide on diseases such as apple scab is shown in Figure 3, where the severity of the scab in the control was 6.75 % and that of the biopesticide was 1.67 % with a difference of 5.8 percent. The effect of the biopesticide is not similar to the synthetic agrochemical, because even with the application of the biopesticide there was an incidence of scab, of more than 20%, although at a very low value.

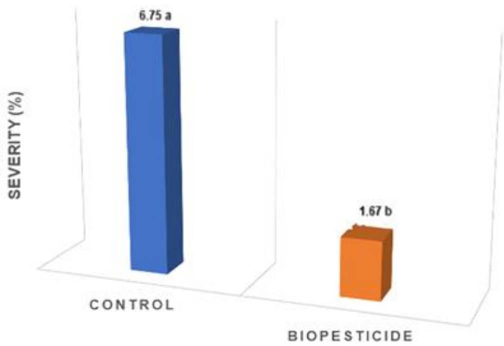

Figure 3. Percentage of severity of apple scab with biopesticide application. a, b = Tukey ($\alpha \leq 0.05$).

The effect of the biopesticide as a biofungicide in apple scab was highly significant with respect to the control ($p \leq 0.01$) measured at 20 DDA. The effect of the biopesticide on diseases such as apple scab is shown in Figure 3, where the severity of the scab in the control was 6.75 % and that of the biopesticide was 1.67 % with a significant difference of 5.8 percent (Tukey $p \leq 0.05$).

Pecan: there was no significant difference in control of nut screwworm between the biopesticide and the synthetic at 10 and 20 DDA. The repellent effect at 10 DDAs (Figure 4) was 1.8, compared to the synthetic insecticide, which was 1, which indicates that the repellent effect is reduced with the application of synthetic insecticide. The effect of a biopesticide will never exceed the effect of a synthetic insecticide.

The repellency effect at 20 DDA was 1.5, compared to the synthetic insecticide of 0.63, which indicates that the repellency effect when a synthetic insecticide is applied is reduced because the insecticide kills the pest and the biopesticide repels it.

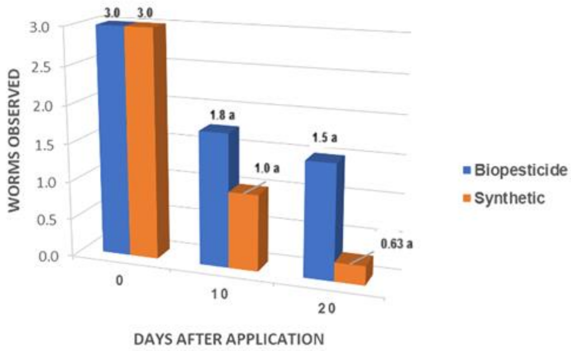

Figure 4. Incidence of pecan screwworm due to the effect of biopesticides and synthetic insecticide. a,b = Tukey ($\alpha \leq 0.05$).

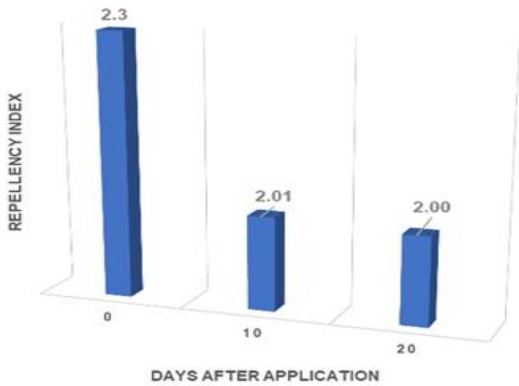

Figure 5. Repellency index of pecan screwworm due to the effect of biopesticide and synthetic insecticide.

The repellency index (Figure 5) is reduced to 2.01 at 10 DDA and from 2 at 20 DDA, which indicates that biopesticides do not have the effect of synthetic insecticide.

Regarding the severity of the hairy spot, if it had homogeneous data and with ANOVA was a highly significant difference ($p \leq 0.01$) in the control of the fungus, it is shown in Figure 6, significant difference (Tukey $p \leq 0.05$) was found where the severity of the synthetic insecticide was 1.5 lower than the severity obtained by the biopesticide, which was 5.5, a difference of 4.0, which indicates that the synthetic fungicide presented greater control than the biopesticide, so the biopesticide presented an efficacy of 61.6%.

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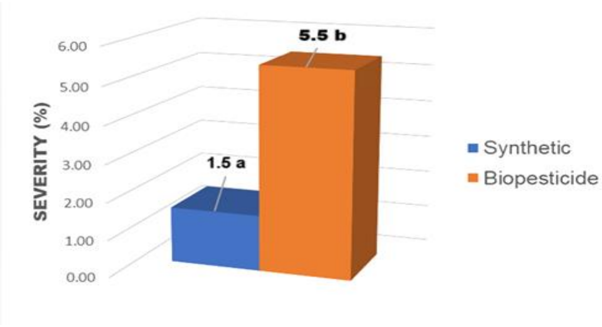

Figure 6. Percentage severity of pecan hairy spot with biopesticide and synthetic application. a,b = Tukey ($\alpha \leq 0.05$).

The effect of the biopesticide as a repellent and biofungicide with the mixed ingredients each this is an initial evaluation, because there is no similar product. The effectiveness of the biopesticide was estimated, which resulted in 75.3% in apple trees, and 61.6% in pecan, SENASICA (2023), indicates that an organic product must have an effectiveness greater than 60% (Covarrubias and Díaz, 2023).

The azadirachtin is an insecticide that controls aphids, thrips, whiteflies, weevils, and leafhoppers (Ellickel *et al.*, 2023). The capsaicin that acts as a repellent for the apple tree aphid *(Eriosoma lanigerum*), applying an extract of 500 mg of hot chili pepper at an efficiency of 51% after 7 days of application (Vashisth *et al.*, 2024). The cinnamon oil with 60% cinnamaldehyde at a dose of 1 L/ha showed a 60% lower control of scab in apple trees than the biopesticide used (Tianna *et al.*, 2023). The allicin has an effect on the apple snail (*Pomacea canaliculata* L) which is a mollusk that parasitizes the tree, with a control of 60% after 24 h of application (Pascual, 2024).

The concentrations of NDGA in the biopesticide were 325 and 708 mg/kg, it is in the range of these studies, but with applications of 10 mg/mL (10,000 mg/kg) the effectiveness is 72% (Pérez *et al.,* 2020). NDGA is associate with ABA that participates in stomatal closure, coloration, total soluble solids, and fruit firmness [Jia *et al.*, 2023). The kaempferol, applied to apples, increases the intrinsic quality of the fruits, increasing shelf life (Wang *et al.*, 2020). The quercetin applying at 1.36 mg/kg, phenolic acids, unsaturated fatty acids, ursolic and oleanolic acid acetates, and catechin in apple are increased (Petkova *et al*., 2023). Kaempferol and quercetin are flavanols that activate plant defense mechanisms, heterodimers as quercetin/NDGA 5′− 5′, have antimicrobial activity against *L. monocytogenes*, *S. aureus*, *Escherichia coli* and *Enterobacter cloacae* (Ngubane *et al*., 2023).

The pecan nut screwworm is controlled entomophagous insects, predators and parasitoids (Chavez *et al*., 2024). Pecan trees are sporadically affected by downy spot (*Mycosphaerella caryigena*) and fungal twig die back (*Phomopsis* spp.), but the use of chitinases, is at alternative to natural control of this diseases (Cervantes *et al.*, 2023).

In apple the biopesticide its effect in the field was 75.3% effective, which is unlikely to exceed 80%, it cannot compete with a synthetic insecticide (Suganthy and Sudha, 2023).

The effect of climate change and the increase in direct radiation (Stamatis *et al*., 2024), produces a stomatal closure causing temporary wilting in the crops, photosynthesis is modified, CO_2 ingress is reduced, and O_2 concentration in cells is increased, this increase the reactive oxygen species (ROS) such hydrogen peroxide (H_2O_2), superoxide (O_2^-), and singlet oxygen (O_2) are produced to initiate signaling pathways (Martin *et al*., 2022). The stomatal closure with increase the ABA concentration in cells guards in the stomata, this increase of ABA accelerates cell softening and induces changes in cell wall structure, whereas NDGA inhibits softening and maintains cell wall integrity (Liu et al., 2025). The NDGA reduce the concentration of H_2O_2, in cells by increase the SOD (Ascorbate peroxidase), CAT (Catalase) and (APX) Ascorbate peroxidase (Li *et al*., 2023). Excess H_2O_2, at 10 nM can damage the membrane cell in the leaves and kill the cells of leaves (Ruiz-Sáenz *et al*., 2025), NDGA regulate the concentration of ROS molecules and use them to control pathogenic viruses and fungi (Jan *et al*., 2022). This is an alternative to protect plants from drought stress damage (Covarrubias *et al*., 2025).

The use of biopesticides hasn´t impact because the marketing rate is low (3%), while insecticides are 60% and fungicides are 19% (Covarrubias and Diaz, 2023).

Conclusions

The biopesticide was effective in repellent pest insects and efficacy in diseases in apple crops. Their response in effectiveness exceeded Mexican standards.

In pecan with application of synthetics, the biopesticide reduces its effect, it has the minimum of efficacy, but could change the synthetic agriculture. The biopesticides controlling drought stress in plants with NDGA.

The biopesticides have potentiality to promote sustainability in agriculture versus chemical pesticide with control sustainable of pest management and drought stress.

Declarations

Consent for publication

The authors consent published in this journal

Competing interests

The authors declare no competing interests.

Acknowledgements

Consejo Nacional de Humanidades, Ciencias y Tecnologías (Conahcyt), for the post-doctoral support to realize this study.

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