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Quality and yield of the *Cucumis sativus* var. Jawell crop under two pest control systems in the Sonoran desert, Mexico

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ABSTRACT

Objective: To compare a commercial pest control program vs a biological pest control program in cucumber (*Cucumis sativus* var. Jawell) cultivation, evaluating quality and production standards.

Design/methodology/approach: The study was carried out in high-tech glass greenhouses, under a cooling system with damp walls and extractors, heating by irradiation, and automated irrigation. Two treatments were evaluated: biological pest control in area A and a commercial control program in area B, both in Persian cucumber (*Cucumis sativus*) of the Jawell variety; each area of 160 m^2, separately, and 41,600 plants for each area. For biological control, the mite (*Amblyseius swirskii*) was released for the control of thrips; the wasp (*Aphidius colemani*) was released for aphid control; the mites (*Phytoseiulus persimilis*) and (*Amblyseius californicus*) for red spider control and application of the entomopathogenic nematode (*Steinernema fetiae*). The chemical control was in accordance with COFEPRIS (2019). The variables were fruit quality total production and incidence of pests in a completely randomized experimental design, and the t-student statistical test and Mann-Whitney test were done for the variables weight quality and loss ($P \geq 0.05$). A correlation was made between the incidence of thrips (*Thrips tabaci*) and the incidence of biological control.

Results: The biological control method was just as efficient as the chemical control method, in variables such as fruit weight, number of boxes obtained of quality cucumber, and incidence of pests and their biological control.

Study limitations/implications: It is important to perform more studies under field conditions where biotic and abiotic factors are different and in other regions, in addition to testing other registered biological products.

Findings/conclusions: Biological and chemical control are complementary, an integrated control would help to slowly adapt a company for a subsequent application of biological control, easing regularization and certification procedures that involve the use of chemicals. A more continuous release of *A. swirskii* is proposed and distributed during the cultivation weeks.

Keywords: management, phytosanitary, pests, system, production, organic.

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INTRODUCTION

Pests such as fungus gnat (*Bradysia* sp), thrips (*Thrips* spp), aphids (*Aphis* sp, *Myzuz persicae*), red spider (*Tetranychus urticae*), among the most common, are present in cucumber cultivated in greenhouses, which if not controlled can cause damage to the crop. Therefore, proper phytosanitary management within the greenhouse is essential. There is commonly the application of commercial pest control programs where only chemical products are used (Rubio and Fereres, 2005; Carrero and Planes, 2008); however, the demand to reduce the use of agrochemicals has prompted the study of other alternatives, such as biological control, in which natural enemies are used. One of the main advantages of greenhouse production is that it is possible to maintain controlled conditions that favor the release of beneficial organisms to achieve a reduction in the use of phytosanitary inputs (Carrero and Planes, 2008; Blom *et al*., 2010; Bale *et al*., 2008; Aguado *et al*., 2009; Pizano de Márquez, 1997; Roberts and Hutson, 1999; Rogg, 2001; Bealmear, 2010).

Some of the beneficial organisms studied for the pests mentioned are the wasp *Aphidius colemani* for the control of aphids (*Aphis gossypii*); the mite *Amblyseius swirskii* for the control of thrips (*Thrips* spp); the mite *Phytoseiulus persimilis* and the thermite *Amblyseius californicus* for the control of red spider mite (*Tetranychus urticae*); and the nematode *Steinernema feltiae* for the control of larvae of the fungus gnat fly (*Bradysia* sp) (Carrillo *et al*., 2003). With the use of these beneficial organisms, the objective of this study was to compare a commercial pest control program and a biological pest control program in *Cucumis sativus* var. Jawell, under the premise that biological control can replace commercial control, obtaining results of equal fruit quality and equal production.

MATERIALS AND METHODS

This study was carried out in high-tech greenhouses (Casasano IMP, 2019), since they have equipment that conditions the optimal development of the crop (cooling system for damp walls and extractors, irradiation heating system, automated irrigation system, and glass infrastructure which allows maximum use of light). The study area is located at 31° 13′ 11.17″ N, 110° 58′ 24.77″ W, and an altitude of 1241 m. The study evaluated the treatments of biological pest control in area A and commercial control in area B, both in Persian cucumber (*Cucumis sativus*) of the Jawell variety.

The cucumber plant was sown in summer (August) in a greenhouse, in rock wool cubes as an inert substrate of porous consistency with high water retention capacity and a dimension of 10 × 10 × 6 cm (Grodan®). Three weeks later, it was transplanted to inert coconut fiber pillows measuring 100 × 20 × 8 cm (Millennium®). Each experimental area was 160 m^2 separately. The sowing density was 3.42 plants m^{-2} modified from Carrillo *et al*. (2003) due to business requirements. Both treatments, area A (biological control) and area B (commercial control), were managed with the same strategy in relation to humidity, temperature, fertilization, irrigation and cultivation tasks.

Biological control program. It consisted in the release of the mite (*Amblyseius swirskii*) for the control of thrips, the release of the wasp (*Aphidius colemani*) for the control of aphids, the mites (*Phytoseiulus persimilis*) and (*Amblyseius californicus*) for the control of red spider mite, and the application of the entomopathogenic nematode (*Steinernema fetiae*). The organisms and the doses used were based on the recommendations made by the Koppert biological systems company and are indicated for each beneficial organism (Malais and Ravensberg, 2006).

Amblyseius swirskii. The mite *Amblyseius swirskii* was applied to control thrips (*Bemisia tabaci*) (Van Emden and Harrington, 2007; Cédola and Polack, 2011). The dose used was 100 mites per m^2. Two mite releases were carried out, during weeks 40 and 41 corresponding to the first two weeks after transplantation of the cucumber crop, this so that the beneficial organism was established in the crop before the appearance of the pest in week 42, period in which this pest has been already detected in the study area. A total of 2,080 sachets were placed for each release (week 40 and 41).

Aphidius colemani. Application of the wasp *A. colemani* was used to control aphids (*Aphis gossypii*). The dose used was 2 wasps per m^2. Two releases were made during weeks 40 and 43, period in which this pest has already been detected in the study area. The first application was made with the objective of establishing the organism and the second was carried out in the first appearances of the pest (week 46).

Phytoseiulus persimilis* and *Amblyseius californicus. Applications of the mites *Phytoseiulus persimilis* and

Amblyseius californicus were made for control of the red spider mite (*Tetranychus urticae*). The commercial product SPIDEX, which contains *P. persimilis* and the SPICAL product, which contains *A. californicus*, were used. The dose of *P. persimilis* adults was 50 mites per m^2 in all releases. Five releases were made at 41 weeks for the organism to establish itself and at 42, 43, 44 and 45 weeks when the first red spider mite colony was found. The dose used for *A. californicus* was 200 mites per m^2. Two releases were made in weeks 40 and 43. The introduction of *P. persimilis* and *A. californicus* in the greenhouse was carried out by placing 50 points evenly distributed in the biological control area.

Steinernema feltiae. Application of the nematode *Steinernema feltiae* was carried out for the control of fungus gnat (García, 2008). The dose used in this experiment was 500,000 EPNs per m^2. Six applications were made from weeks 40 to 45. The first application was to establish the organism and the others were because of the presence of the pest to be controlled. The introduction done manually to all the plants in the biological control area (Area A), since it could not be carried out by the irrigation system because when the organism passes through the sand filter, the population decreases and this affects its efficiency.

Traditional commercial control. It consisted of a conventional pest control management program used in local greenhouses according to COFEPRIS (2019). The thrips control program was the only one where biological release of the mite *Amblyseius swirskii* was carried out in addition to the application of chemicals. This is because the thrips pest is the one that requires more attention, since it causes malformations to the fruit, affecting its quality and causing greater economic loss. The chemicals Actara (Thiametoxam), Beleaf (Flonicamid), Confidor 350 sc (Imidacloprid), Plenum 50 gs (Pymetrozine) and Talstar 100 CE (Bifenthrin) were applied for control of aphids. Tracer (Spinosad), Exalt (Spinetoram) and Beleaf (Flonicamid) were used for control of thrips. Agirmec (Abamectin) and Talstar (Bifenthrin) were applied for control of red spider mites, and finally, Trigard (Cyromazina) for the control of fungus gnat larvae.

Control of aphids. The chemical products used were: Actara (Thiametoxam), Beleaf (Flonicamid), Confidor 350 sc (Imidacloprid), Plenum 50 gs (Pymetrozine) and Talstar 100 CE (Bifenthrin). The doses applied were those as low as recommended in the commercial product; this criterion is the one applied for every product evaluated in this study. The application was made in week 40 and 46, period of aphid presence.

Control of thrips. The release of the organism *Amblyseius swirskii* was carried out in the same way and distribution as explained previously in the biological control. For control of thrips, the commercial chemical products used, normally managed by the company in which the experiment was carried out, were: Tracer (Spinosad), Exalt (Spinetoram) and Beleaf (Flonicamid). The application was carried out on weeks number 2, 45, 46 and 52, when more than 60 thrips were quantified in the total count of the traps in the compartment.

Control of red spider mite. To control the red spider mite pest, commercial chemical products were used normally managed by the company where the experiment was carried out, the chemical products were Agrimec (Abamectin) and Talstar (Bifenthrin), the application of the products was carried out for both based on commercial specifications. The application was made in week 48 and 49, in the presence of the first spider colony.

Control of fungus gnat. To control the fungus gnat fly in the commercial pest control greenhouse area, the commercial chemical product normally managed by the company where the experiment was carried out was used; the product was Trigard (Cyromazina). The application was carried out in weeks 42, 45, 47, 50 and 51, when the presence of the first larva was observed in any of the cubes.

Variables evaluated

The parameters evaluated to determine the effectiveness of cucumber pest control methods under greenhouse conditions were: fruit quality, total production and incidence of thrips.

Fruit sampling. In order to eliminate the variability and keep the criteria in fruit sampling constant, a single person was assigned to carry out this task. 10 boxes were cut daily in the biological control area and 10 boxes daily in the commercial control, during the 77 days that the crop was in production. The size of the cucumber for cutting was measured according to the commercial characteristics; a minimum length of 5'', maximum of 6'', a minimum diameter of 1'' and a maximum of 1¼'', medium green color, and oblong shape, established by the company Mastronardi Produce México S.R. de C.V. The cutting box was considered complete when it was filled with two batches of cucumber, placed across the width on each side, as managed by the company to avoid damaging the fruit.

Fruit quality. As previously described, during the 77 days of crop production, 10 boxes were taken from the biological control area and the commercial control area daily, these boxes were weighed to obtain their net weight, then the fruit considered waste was removed, which did not have the required physical quality, such as deformed fruit, overripe fruit (excess size), mechanical damage (scars, bumps, bruises), damage from thrips (scar). This fruit, removed due to quality deficiency, was weighed to obtain the weight loss. The rest of the fruit that met the quality characteristics was weighed and considered quality weight.

Production. The production yield was calculated by counting the total boxes obtained during the 77 days of production. To determine the total kilograms of quality production and yield per square meter, the average quality weight of the boxes evaluated was calculated and multiplied by the total boxes produced.

Incidence of thrips. The presence of thrips in the cucumber crop is an indicator of production risks, since this pest is the one that causes the greatest loss to the producer, by deforming the cucumber fruits, affecting their commercial quality, considered waste by not complying with the characteristics of commercial quality, so it is important to evaluate the incidence of thrips (*Bemisia tabaci*). In the biological control program and the commercial control program, the incidence was determined by monitoring the thrips population during the 12 weeks of production. In the same weeks of production, the population of *Amblyseius swirskii* was analyzed to relate the behavior of the pest to its predator. Twenty HORIVER® adhesive traps were used for monitoring, which were placed in the treatment area and in the control area. The Koppert Company recommends up to 5 traps per 1,000 m^2. The traps were strategically distributed to be monitored once a week. The traps were placed at the height of the head of the plant. The monitoring consisted of quantifying the thrips adhered to the trap (Figure 1).

In addition to the trap count, three plants were inspected, the one located under the trap and the two continuous. The inspection consisted of checking a flower and the underside of a leaf from each of the three plants with the help of a 10 × 22 mm plastic 5X magnifying glass. The flower was selected by checking the middle part of the plant of each of the three plants and to inspect the leaf, a leaf from the low stratum was selected in the first plant, in the second plant a leaf from the middle stratum, and in the third plant a leaf from the upper stratum (Garza and Molina, 2008). This was done once a week.

In this study, only sporadic focus points of aphids and red spider mite were presented, which did not represent a risk to the crop, since they were controlled without major problems by removing leaves in cultivation practices, which were part of the crop management without being related with pest control, so only the incidence of thrips (*Bemisia tabaci*) was evaluated.

Statistical analysis. A completely randomized experimental design was applied. To analyze the total number of boxes produced, the t-student statistical test was used for normal data between two independent samples and the Mann-Whitney test was used to compare the variables weight quality and weight loss with the data obtained during 77 days, with a level of significance of $P \geq 0.05$ to determine differences. A correlation (r) was made between the incidence of thrips (*Thrips tabaci*) and the incidence of the biological control *Amblyseius swirskii*, to compare the biological control (A) and the commercial control (B) (Cervantes *et al.*, 2011).

RESULTS AND DISCUSSION

Based on the method described and under the conditions described, the results obtained in this study are indicated below.

Fruit quality. During the 77 days that the fruit harvest lasted, a record was kept of the quality weight and weight loss of 10 boxes of the commercial control treatment and 10 boxes of the biological control treatment. The average boxed quality weight obtained was 4.95 kg in the boxes from production under biological control and 4.89 kg in the boxes from production under commercial control (Figure 1). There was no statistically significant difference between the treatments ($P \leq 0.05$). The average quality weight did not show differences ($P \leq 0.05$) in both treatments, results compared with those obtained by Cervantes *et al*. (2011) and Paredes *et al*. (2013).

Among the advantages in the use of biological pest control, there is to reduce the problems of regulation and certification that the use of chemical products involves, by reducing the number of applications and avoiding the excessive use of chemical products in biological control as shown in reports by Grijalva *et al*. (2011), where the use of biological control reduces chemical residues in vegetables (Pardo, 2010), favorable cost/benefit ratio and the ease of performing releases (Leigh *et al*., 2010). The average weight loss per box harvested from the biological control treatment was 0.46 kg. In the case of the boxes from production under commercial control, it was 0.47 kg (Figure 1).

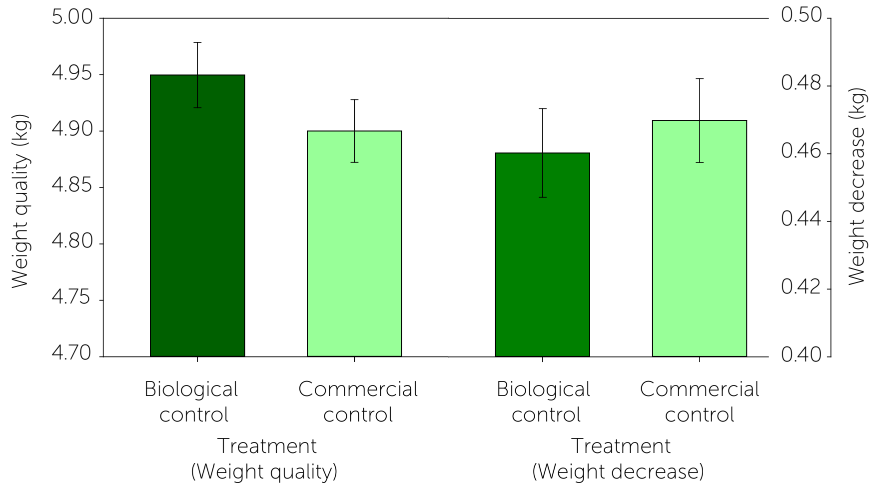

Figure 1. Average weight of the boxes obtained from the fruit quality and average weight of the boxes obtained from the fruit decrease from production under commercial and biological pest control. The bars represent the mean value ± EE of ten repetitions.

There was no statistically significant difference ($P \leq 0.05$) between the weight loss of the harvested boxes from the biological control and the weight loss obtained from the boxes from the commercial control. In the results obtained in this study, no significant differences were found in the weight loss ($P \leq 0.05$) in both treatments, commercial control versus biological control of pests. Cervantes *et al*. (2011) report a greater amount of weight loss in biological control than chemical control in their study with tomato. On the contrary, in this study, even when there were no statistically significant differences, the value of the weight loss was higher in the chemical control. This is possibly due to the fact that the evaluation in this study is broader in terms of time, during the entire production cycle corresponding to 77 days, while in the study reported by Cervantes *et al*. (2011) it is only for a short period.

Total production. The evaluation of production during the 77 days after cutting the fruit, the total of boxes obtained during this period, as well as the total weight of the boxes, were measured from the production of the compartments with biological treatment and commercial control. The total of boxes obtained during the period mentioned in production under biological pest control was 27 239 boxes, while the production under commercial control was 28 124 boxes. There was no statistically significant difference between the treatments ($P \leq 0.05$) (Table 1). The total weight of the boxes obtained during the entire period of 77 days of cutting for the 27 239 boxes from production under biological control was 134,796.20 kg and the weight of the 28 124 boxes from production under commercial control was 137,416.10 kg, without showing significant statistical difference (Table 1).

Table 1. Statistical values of the data obtained from the total number of production boxes and total quality weight of the boxes obtained during the harvest from the biological control and commercial control treatment for 77 days.

Control	Number of boxes and kg	Mean	Mean deviation	Range	Standard error
Commercial control boxes	28, 124	365.25	58.88	305	6.71
Biological control boxes	27, 239	353.75	51.31	294	5.85
kg commercial control	137, 416.10	1784.62	328.0	1318.54	37.4
kg biological control	134, 796.20	1750.6	470.56	1965.61	53.6

The total weight obtained gives an average of 11.13 kg/m^2 in the production under biological control and 11.34 kg/m^2 in the production of commercial control. The production obtained in both controls did not show statistically significant differences ($P \leq 0.05$). Studies by González (2009) mention that, despite not presenting differences, production under biological control could be favored in the long term, mainly in the reduction of the use of chemicals, helping to avoid generating resistance from pests towards chemicals and obtaining a biologically controlled production (Mason and Huber, 2001; Lorca, 2009; Devine *et al*., 2008). The conversion from commercial control to biological control turns out to be somewhat gradual in most cases, where some producers reduce the application of broad spectrum chemicals to use the introduction of beneficial organisms and chemical products that are compatible with the beneficial fauna (Nicholls, 2008ab; Devine *et al*., 2008; Pardo, 2010). In this study, only sporadic outbreaks of aphids and red spider mites took place, which did not represent a risk to the crop as considered by the company where the experiment was developed, since they were controlled without major problems by removing leaves in cultivation practices, which were part of the crop management without being related to pest control, so only the incidence of thrips (*Bemisia tabaci*) was evaluated.

Thrips. The chemical productss Belef (Flonicamid), Tracer (Spinosad) and Exalt (Spinetoram) were applied in weeks 45 Belef (Flonicamid), 46 Tracer (Spinosad), 52 Exalt (Spinetoram), and 2 Tracer (Spinosad). The application of the products was decided based on monitoring thrips in traps. A correlation was made to evaluate the biological control and commercial control treatments, observing the behavior of the thrips pests and its biological control, *Amblyseius swirskii*, where the biological control, when applying a linear regression (Table 2), shows that there is a relationship between the decrease in the *A. swirskii* population and the increase in the thrips population (Figure 2ab). In week 43 there is concurrence with the second release of the beneficial organism where the population of *A. swirskii* increased, which when feeding on thrips larvae caused a decrease in the thrips population in the following weeks. In the commercial control treatment, when applying a linear regression (Figure 2ab), the populations of *A. swirskii* are observed in the graph, where there is the same negative trend in both commercial controls with r^2=0.18272 and in the biological control with r^2=0.2731 (Figure 2ab) from week 48, indicating that with less *A. swirskii* there is larger population of thrips. In week 43, which consisted of the second and last release, there is the presence of *A. swirskii* and decreasing the presence of thrips, but in the course of the following weeks it is observed that as there was no constant release of *A. swirskii*, the population of thrips had an upward trend, showing the highest presence in weeks 48 and 2, reaching up to 8 thrips on average per trap (Figure 2ab).

Table 2. Statistical values of the data obtained from the correlation made in the biological control between the thrips plague and its biological control *A. swirskii* from week 42 to week 2.

Biological control	Media	Mean Deviation	Standard Error
Trips (*Bemisia tabaci*)	4.77	2.17	2.01
Amblyseius swirskii	0.74	1.15	1.17

The thrips pest presented a positive correlation against its natural enemy *A. swirskii* in both biological control and commercial control treatments. Arthurs *et al*. (2009), in a greenhouse pepper crop, show how *A. swirskii* controlled the thrips infestation for a test period of 28

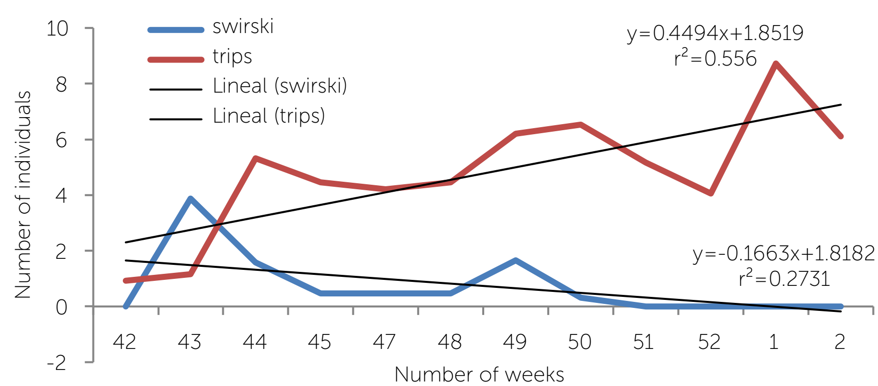

Figure 2a. Incidence of thrips and *A. Swirskii* in treatment under biological control of pests in cucumber cultivation.

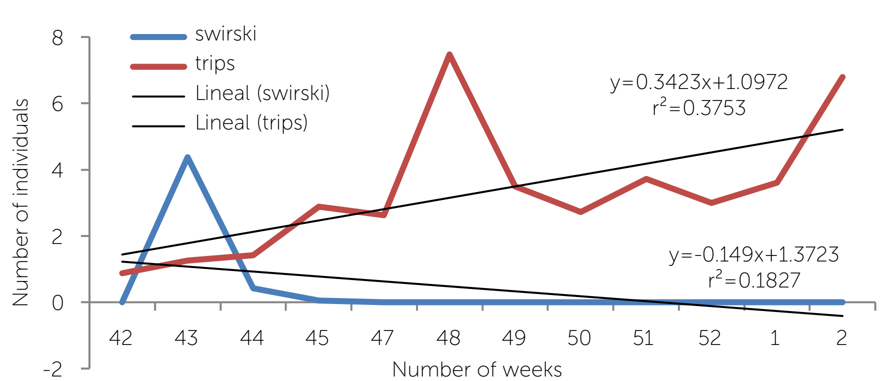

Figure 2b. Incidence of thrips and *A. Swirskii* in treatment under commercial control of pests in cucumber crops.

days. In this study, up to nine on average were found per trap in biological control and eight in commercial control; this increase could be due to the releases of the beneficial organism. A similar behavior was reported by Belda and Calvo (2006), where from week two after the release of *A. swirskii*, the thrips pest was kept under control with no more than an average of 1.8 thrips per leaf evaluated. On the other hand, *A. swirskii* reached 1.96 individuals per leaf on average using the same dose used in this thesis (100 individuals m^2).

CONCLUSIONS

Biological control is a favorable investment in the long term, which requires an initial expense to establish the beneficial insects, whereas chemical control is a constant investment that can generate the appearance of resistance and that requires new doses or products. The biological control program evaluated was just as efficient as the chemical control used in a conventional way. However, in biological control, a release of *A. swirskii* in a more continuous and distributed way is proposed during the weeks of cultivation, which will maintain more uniform and constant populations, to avoid the development of large populations of thrips and allow better control. It is necessary to evaluate both control programs during the spring-summer season to be able to compare their efficiency for each season and annually.

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