

ARTICLE

Planting in association with Cempoalxochitl (*Tagetes erecta*) decreases thrip density in gladiolus crops

O plantio associado à planta *Tagetes erecta* (Cempoalxóchitl) diminui a densidade de trips em plantações de gladiólos.

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Abstract

The gladiolus (*Gladiolus grandiflorus*) is a cut flower of great economic, social, and cultural importance that is widely appreciated for its striking colors and morphology. Thrips are one of the main pests for production, increasing management costs and decreasing flower quality. Thrips are mainly controlled with synthetic insecticides, but associated planting has been a promising area of management alternatives. In this study, we evaluated the effect of association of gladiolus with cempoalxochitl on thrip population density under three planting treatments: gladiolus monoculture (GM), cempoalxochitl monoculture (CM), association of one row of cempoalxochitl with one row of gladiolus (1C-1G), and one row of cempoalxochitl with two rows of gladiolus (1C-2G). We counted thrips captured in yellow traps placed at random throughout each treatment over the full summer growing cycle. Thrips were present throughout the cycle in all treatments. However, the gladiolus grown in associated planting treatments (1C-1G and 1C-2G) had lower thrip density, lower area under the incidence progress curve, and higher flower quality than the Gladiolus grown monoculture (GM). The association of these two ornamental crops is a sustainable control option given the preference of thrips for *Tagetes erecta* and its potential to host thrips' natural enemies. The results are a starting point for integrating thrip management measures for the development of sustainable ornamental horticulture.

Keywords: Crop association, *Gladiolus grandiflorus*, *Tagetes erecta*, thrips (Thysanoptera: Thripidae).

Resumo

O gladiólo (*Gladiolus grandiflorus*) é uma flor de corte de grande importância econômica, social e cultural, amplamente apreciada por suas cores e morfologia marcantes. Os trips são uma das principais pragas da produção, aumentando os custos de manejo e diminuindo a qualidade das flores. O controle dos trips é feito principalmente com inseticidas sintéticos, mas o plantio consorciado tem se mostrado uma área promissora para o manejo alternativo. Neste estudo, avaliamos o efeito da associação de gladiólo com cempoalxóchitl na densidade populacional de trips em três tratamentos de plantio: monocultura de gladiólo (GM), monocultura de cempoalxóchitl (CM), associação de uma fileira de cempoalxóchitl com uma fileira de gladiólo (1C-1G) e associação de uma fileira de cempoalxóchitl com duas fileiras de gladiólo (1C-2G). Contamos os trips capturados em armadilhas amarelas colocadas aleatoriamente em cada tratamento durante todo o ciclo de crescimento do verão. Os trips estiveram presentes durante todo o ciclo em todos os tratamentos. No entanto, o gladiólo cultivado em tratamentos de plantio associados (1C-1G e 1C-2G) apresentou menor densidade de trips, menor área sob a curva de incidência e maior qualidade das flores do que o gladiólo cultivado em monocultura (GM). A associação dessas duas culturas ornamentais é uma opção de controle sustentável, dada a preferência dos trips por *Tagetes erecta* e seu potencial para hospedar inimigos naturais dos trips. Os resultados são um ponto de partida para a integração de medidas de manejo de trips para o desenvolvimento da horticultura ornamental sustentável.

Palavras-chave: Associação com culturas agrícolas, *Gladiolus grandiflorus*, *Tagetes erecta*, trips (Thysanoptera: Thripidae).

Introduction

The gladiolus (*Gladiolus grandiflorus* L.) is appreciated worldwide as a cut flower due to its bright colors and distinctive morphology of its floral spike (Kumari et al., 2025). It is often used in religious celebrations and funerals in Mexico. Modern standards in variety of colors and shapes have helped transform this flower, once stereotyped as funereal, into a favorite, and it can be an important accent in floral arrangements (Reid, 2023). According to the Mexican Agricultural and Fisheries Information Service (SIAP) (2023a), it is the cut flower crop with the largest area under cultivation in Mexico, covering 3,926.80 ha. It is mainly grown in the central Mexican states of Mexico, Puebla, Morelos and Michoacan; this species ranks first in importance as a cut flower, with 4.58 thousand hectares planted, which surpasses the rose with 2.919 and the sunflower with 3.771 thousand ha (SIAP, 2023a). Mexico state contains around 31.67% of the national cultivated area. Gladiolus is the cut flower with the highest production and export and the third most sold flower in Mexico, after roses and chrysanthemums (SIAP, 2023b). It is grown in open field production systems that are labor-intensive year-round.

Thrips are one of the main insect pests for gladiolus production (Sridhar et al., 2022). Control has been based on synthetic insecticides and, rarely, biological alternatives such as *Trichoderma* spp., *Bacillus* spp. or *Pseudomonas* spp. In recent years, there has been an increasing push toward

more sustainable production systems for ornamentals in order to meet the 20/30 agenda. One of the possible alternatives to reduce damage and losses caused by insect pests is the use of crop associations or intercropping, but there are limited reports on its effectiveness in ornamentals.

Cempoalxochitl (*T. erecta*) is a promising option as an associated crop for thrip control. On one hand, this species is a strong attractant of natural enemies of thrips, including bugs of the genus *Orius* spp. and the predatory mite *Neoseiulus cucumeris* (Rodríguez and Coy-Barrera 2023). On the other hand, this plant has several uses that provide additional sources of income for producers. It is an ornamental flower of economic importance in the Mexican domestic market. It also contains thiophene compounds that have insecticidal, nematicidal, and fungicidal properties with applications in industries such as animal feed and nematode control (Mushtaq et al., 2024).

From an agronomic perspective, *Tagetes erecta* has been used in the management of insect pests as a repellent, either the plant (Qureshi et al. 2025) or its extracts (Valencia-Botin et al., 2024). Piña et al. (2023) indicate that *T. erecta* expresses the quality of being a natural host of thrips during all its phenological stages, its use as an associated crop with *Physalis philadelphica*, reduced the density of thrips, which allowed a higher yield of tomatillo. In this regard, Fabrick et al. (2020) concluded that the association of marigold with beans increased the mortality rate

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and there was less oviposition of the western tarnished plant bug (*Lygus hesperus*) and whitefly (*Bemisia tabaci*). In addition, its extracts have been reported to have insecticidal properties (Santos et al., 2022), and Hanim et al. (2023) mention that *Tagetes erecta* crop residue (MCR) should be used as a forage for its high nutritional value and abundantly available.

Despite the theoretical promise of intercropping with Cempoalxochitl, there are currently no data available on its effectiveness for thrip control in gladiolus crops in any of the areas where the flower is cultivated. Thus, the objective of the present study was to determine the effect of *T. erecta* on thrip density on gladiolus throughout the growing cycle as well as final flower quality.

Materials and Methods

The experiment was performed in the experimental field of the Agricultural Sciences Faculty, Autonomous State University of Mexico in Cerrillo Piedras Blancas, Toluca, Mexico state. The field is located at 19°24'.598'' North Latitude and 99°41'.418'' West Longitude, at an altitude of 2,606 m above sea level. We performed the experiment during the spring-summer gladiolus growing cycle. We used gladiolus corms of the Roja Borrega variety from the municipality of Tenancingo and cempoalxochitl seedlings native to the municipality of Calimaya. The corms were treated with Thiophanate-methyl (2 g L⁻¹) and an acidifying non-ionic surfactant (1 mL L⁻¹) (Surfacid, Quimía Agroinsumos, Los Mochis, Mexico) by immersion for 5 min prior to planting. The cempoalxochitl seedlings were obtained by germinating the seeds in 333-well polystyrene trays under greenhouse conditions.

We established three treatments: Gladiolus monoculture (GM), cempoalxochitl monoculture (CM), associated planting with one row of cempoalxochitl and one row of gladiolus (1C-1G); and associated planting with one row of cempoalxochitl and two rows of gladiolus (1C-2G). No pesticides were used after planting to control insect pests or diseases.

We used a randomized complete block design with ten repetitions. The experimental unit consisted of six 5-m long rows spaced 0.80 m apart. Within rows, gladiolus corms were planted 10 cm apart and cempoalxochitl seedlings were planted 30 cm apart. In each block, we placed three yellow traps composed of a yellow 12 oz partyiscn® plastic cup. The traps were coated in vegetable oil to capture thrips and then tied with a string to a metal support that was buried in the soil. The traps were placed early in the day and collected in the afternoon for counting. The first sampling was performed seven days after the emergence of the gladiolus, which corresponded to 14 days after transplanting the cempoalxochitl (DAP). We trapped thrips weekly until the cutting phase of the gladiolus spike.

For each sampling, thrips captured in the yellow traps were placed in jars with 70% alcohol, labeled with the collection date, location, georeference point, altitude, collector name, and accession number. The samples were taken to the Laboratory of Entomology, Institute of Biology, National Autonomous University of Mexico where they were processed for mounting and identification. We prepared the samples by separating and counting the thrips from each jar, dehydrating them in 96% alcohol for 10 to 15 min, transferring them to absolute alcohol for 10 min, and finally treating them with xylene for 1 min. The thrips were mounted using a stereoscopic microscope and entomological pin to facilitate their manipulation in Canada Balsam. We determined the species of the thrips based on the morphological characters proposed by Lewis (1997)

and Cavalleri and Mound (2012). The specimens are catalogued at the Laboratory of Entomology, Institute of Biology, National Autonomous University of Mexico.

For each treatment, we evaluated the density of thrips captured on each sampling date. Using the number of thrips captured by date, we calculated the area under the incidence progress curve (AUIPC) of the insect over time (Madden et al., 2017) for each experimental unit using R software with the package agricolae. We used an analysis of variance (ANOVA) using PROC GLM (SAS System ver. 9.2 Cary, N. C. USA) to determine whether the AUIPC values differed among treatments. The separation of means was performed using a Tukey test with $\alpha = 0.05\%$. Finally, we determined the quality class of the floral spikes obtained from each treatment based on the criteria of the United Nations Economic Commission for Europe (UN/ECE, 1994). The length of the flower spike (cm) was measured with a tape measure from the base of the stem to the apex of the flower spike.

Results

Thrips were present throughout the whole gladiolus growing cycle under all treatments. The species present were *Frankliniella occidentalis* and *Thrips simplex* in a 60/40 ratio. The duration of the population cycles fluctuated between 13 and 16 days (Fig. 1). The highest thrip density occurred during the flowering stage, which was followed by a population decrease until the senescence of the plant.

In the gladiolus monoculture, the average thrip density across the full cycle was 32.09 specimens per trap, surpassing the economic threshold (Carrizo et al., 2008). In the associated plantings, the average thrip density was 20.9 thrips per trap in 1C-1G and 22.72 thrips per trap in 1C-2G; that is, 37.39% fewer thrips in 1C-1G and 29.19% fewer thrips in 1C-2G compared to the control. The cempoalxochitl monoculture (CM) had an average of 18.05 thrips/trap, 17.35% lower than when it was associated with gladiolus, which is evidence that the plant houses the thrip population rather than repelling them.

Thrip density fluctuated over the course of the growing cycle in all treatments. From 40 to 56 days after planting (DAP), there were no significant differences among the treatments for the variable thrip density. At 63 DAP, the ANOVA test (D.F.= 46 associated with the error) indicated a highly significant difference among treatments ($F = 4.95$; D.F. = 3; $p < 0.0026$); the separation of means indicated that GM (gladiolus monoculture) and 1C-2G had significantly higher thrip density than CM (cempoalxochitl monoculture). There continued to be highly significant differences among treatments at 71 ($F = 14.3$; D.F. = 3; $p < 0.0003$), 79 ($F = 9.34$; D.F. = 3; $p < 0.0018$), 92 ($F = 10.48$; D.F. = 3; $p < 0.0011$), 116 ($F = 13.16$; D.F. = 3; $p < 0.0004$), and 123 DAP ($F = 16.17$; D.F. = 3; $p < 0.0002$).

The separation of means indicated that in all of these periods, the gladiolus monoculture (GM) had significantly higher thrip density than the other treatments. At the same time, 1C-1G had lower thrip density than GM but similar density to the cempoalxochitl monoculture (CM). Between 79 and 85 DAP, the population density increased in all treatments. This increase was especially marked in the gladiolus monoculture, where it increased by 300%, while in the treatments where cempoalxochitl was present it increased by 200%. The 1C-2G treatment had significantly lower thrip density than GM at 92, 108 and 123 DAP (Fig. 1 and Table 1).

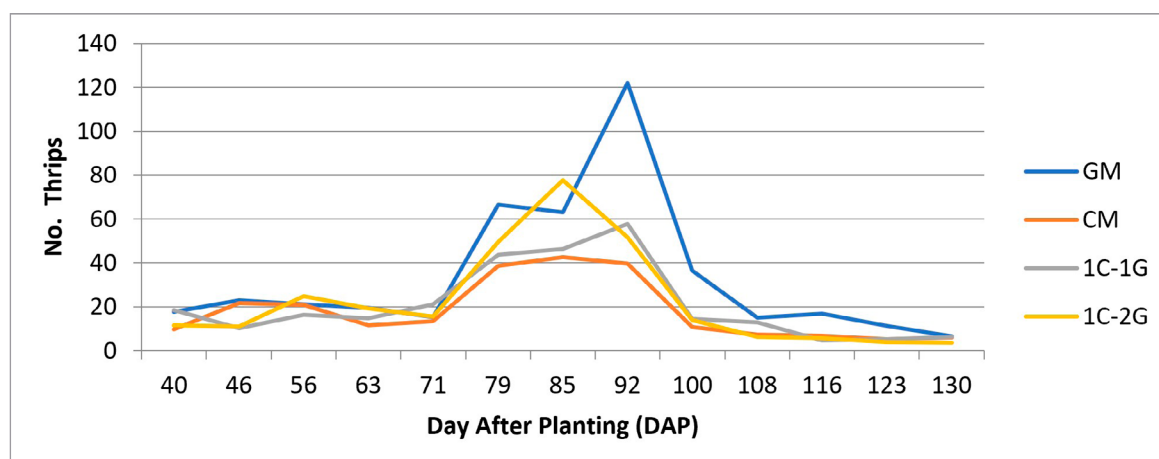


Fig. 1. Thrip density determined in the different treatments over time.

At 85 DAP, there was no statistically significant difference ($F = 2.33$; D.F. = 3; $p = < 0.0962$) in thrip density among the treatments evaluated, but this was the starting point of the largest increase in density among the associated treatments, although the cempoalxochitl monoculture (CM) was the treatment with the lowest density, while 1C-2G had the highest density. However, these results do not rule out potential thrips movement between adjacent treatment plots as a limitation on the counts, although this limitation occurred across all treatments over time. Peak thrip density occurred at 92 DAP in the gladiolus monoculture; this coincided with the flowering of the gladiolus. At 100 DAP, the density of thrips captured in all four treatments began to decrease. At 108 DAP the evaluated

treatments showed no significant differences among them, although 1C-2G had a lower number of captures and GM a higher density of the insect.

The analysis of variance of the area under the incidence progress curve (AUIPC) of the thrips captured showed significant differences among the different treatments ($F = 24.51$; D.F. = 3; $p = < 0.0001$). Treatment GM (gladiolus monoculture) had a significantly higher AUIPC than the remaining treatments, indicating higher overall capture over time; treatments CM (cempoalxochitl monoculture), 1C-1G and 1C-2G were statistically similar to each other. The fact of having cempoalxochitl alternating with gladiolus was able to reduce the insect populations over time (Fig. 1).

Table 1. Separation of means (Tukey, $\alpha = 0.05$) of the area under the incidence progress curve (AUIPC) over time and flower spike length by treatment.

Treatments	AUIPC by treatment	Flower spike length (cm)
GM	3206.3 a	111.8 a
CM	2044.3 b	-
1C-1G	2157.6 b	91.5 b
1C-2G	1598.1 b	116.8 a

*Values within columns that share a letter are not significantly different from each other.

Flower spike length was significantly affected by treatment ($F = 21.71$; D.F. = 2; $p = < 0.001$); in the gladiolus monoculture, spike length was statistically similar (though numerically lower) than that of 1C-2G, while 1C-1G had a lower spike length than the other treatments. This places both the GM and 1C-2G gladiolus flower spikes in quality 1 code 100 (between 100 and 120 cm) of the UNECE, indicating that it is adequate for sale as a sustainable ornamental.

Discussion

Although thrips were present and fluctuated over the course of the growing cycle in all treatments, associated planting with cempoalxochitl led to significant reductions in thrip density at a key point in the production cycle (flowering), lower area under the incidence progress curve (i.e., lighter overall infestation), and flower spikes that were of suitable size for export markets in the gladiolus crop. Taken together, these results show that cempoalxochitl-associated planting is a highly promising alternative management strategy for the production of gladiolus. This technique decreases the need for synthetic pesticides and therefore decreases the environmental contamination and carbon footprint of ornamental production, making it an excellent candidate for sustainable production of ornamentals.

The lower thrip density in gladiolus associated with cempoalxochitl (*Tagetes erecta*) suggests that thrips utilize cempoalxochitl and may prefer it over gladiolus, reducing direct feeding and its resulting damage on gladiolus plants. This is consistent with findings by Swain et al. (2026), where cempoalxochitl had beneficial effects on tomato and chile production, potentially due to the fungicidal, nematocidal, and

insecticidal properties of the terthianyl compounds it contains. The fact that cempoalxochitl harbors thrips rather than repelling them means that having cempoalxochitl in association with gladiolus provides a source of food for thrips' natural enemies (Santos et al., 2022), which may then disperse into the gladiolus crop and perform biological control functions. The cempoalxochitl could even serve as a substrate for the intentional release of natural predators such as *Orius* spp. to reduce thrip population density (Atakan, 2024) and strengthen biological control of thrips. In addition, cempoalxochitl is a commercially important plant in its own right. Cempoalxochitl production could be especially lucrative during the summer-fall cycle, as there is a high demand for this flower for Day of the Dead festivities (in which it is emblematic). It could also correspond with times of high demand for use in other agricultural cycles, such as for livestock feed (Hanim et al., 2023).

Associated planting did not decrease gladiolus flower quality. The flower spikes in the associated treatments reached an average of 1.16m, placing them in the Code100 category of the UNECE. This is also within the 1.1-1.2 m size that is considered appropriate for the export market (Baruah and Bora, 2022). In addition to length, flower appearance is also important, though the criteria are less well-defined. Although we did not quantify aspects of flower appearance, we noted that the flowers in the associated treatments seemed adequate. Meanwhile, the flowers from the gladiolus monoculture had damage such as silver patches and color changes. This corresponds with the descriptions of thrip damage by Sridhar et al. (2022) who report the presence of silver spots that change to brown on the flower spikes, reduced size and loss of the distinctive pointed shape of the apex, and malformed, discolored, and wilting flowers.

Our finding of reduced incidence of thrips in gladiolus crops when associated with cempoalxochitl leads us to propose cempoalxochitl as a biological barrier, trap crop for the release of biological controls, focused spraying of chemical control, or as a gladiolus associated crop. Zhang et al. (2021) also indicated that since it is attractive to thrips, cempoalxochitl could be used as a “bank” or host plant system to allow the maintenance and conservation of predators and as an alternative food source for thrips. An additional advantage is that this plant is easy to cultivate in the field or greenhouse and its flower can be harvested for use in the production of livestock feed (Hanim et al., 2023) or colorings (Kar and Patra, 2022), uses which do not depend on the aesthetic qualities of the plants and would therefore not be affected by thrip damage. This method of control represents a cultural management alternative that is ecologically feasible and decreases the indiscriminate use of synthetic pesticides as the main method for combatting this pest insect. At the same time, it provides a second crop that is itself valuable and could help to supplement and diversify the income of gladiolus producers. The results obtained with this proposed thrips management strategy suggest the need for replicate trials at other locations and across different gladiolus growing cycles, as well as the evaluation of potential edge effects and thrips movement between adjacent treatments. Furthermore, the presence of natural enemies and the volatile compounds associated with the effect observed in *Tagetes erecta* should be quantified.

Conclusions

The incorporation of cempoalxochitl as an associated crop with gladiolus reduced thrip population density, and the quality of the gladiolus flower was not affected in terms of the length of the flower spike. As such, cempoalxochitl-associated planting is a viable alternative for increasing the sustainability of ornamental gladiolus production.

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Author Contribution

JRC: Investigation, Methodology. **ADHM:** Investigation. **MAGB:** Methodology, Data Collection. **JRSP:** Funding Acquisition, Project Administration, Writing – Original Draft. **ACV:** Writing – Review & Editing. **OFM:** Writing – Review & Editing.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability Statement

Data will be made available upon request to the authors.

Declaration of generative AI and AI-assisted technologies in the writing process

The authors declare that the use of AI and AI-assisted technologies was not applied in the writing process.

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