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"Push-pull" Technology and Companion Planting: A Dual Strategy for Insect Pest Management in High Tunnel Vegetable Production and Organic Systems[1]

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Plastic-covered high tunnels (or "hoop houses") are protected crop production structures commonly used for extending the growing season of high-value specialty crops, such as vegetables and small fruits, and for possibly improving plant productivity and produce quality (Frey et al. 2020; Tian et al. 2023). High tunnels may be considered an intermediate between highly controlled greenhouses and open fields that offer a certain level of environmental modification, protecting crops from rain, high wind, and extreme temperatures. Depending on the crops and markets, high tunnels can be used to promote early production or late harvest for enhanced profitability. The use of high tunnel growing systems as a conservation practice has been supported by the Natural Resources Conservation Service for over a decade (USDA-NRCS 2023).

To manage pests in high tunnels, natural pest control strategies, such as cultural control by manipulating the habitat, conservation biological control, and companion planting, are often favored over chemical pesticides. Thus, high tunnel cropping often consists of polycultures utilizing companion crops to attract and sustain beneficial insects, while repelling and trapping insect pests—a pest management technique commonly referred to as "push-pull" technology (Cook, Khan, and Pickett 2007; Khan et al. 2016). Furthermore, beneficial predatory insects are attracted and sustained by using flowering plants such as marigold (*Tagetes erecta*) and sweet alyssum (*Lobularia maritima*) as companion crops (Lopez and Liburd 2022; Legaspi, Miller, Kanga, et al. 2020). Therefore, "push-pull" technology may be complemented by companion planting of flowering refuge plants to enhance the effectiveness of biological control agents. This publication aims to introduce "push-pull" technology and companion planting for pest management to high tunnel vegetable growers and organic farmers. It may also be of interest to other crop producers wishing to improve their IPM practices.

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"Push-pull" Technology and Companion Planting in High Tunnels in North Florida

At the Florida A&M University (FAMU) Research and Extension Center in Quincy, Florida, USDA-Agricultural Research Service (ARS) scientists and Extension faculty have been demonstrating the application of "push-pull" technology and companion planting in a high tunnel on tomato (*Solanum lycopersicum*) and leafy green crops. Based on preliminary studies, red giant mustard (*Brassica juncea*) plants are grown as the "push" factor around the inside perimeter of the high tunnel and interplanted with the lettuce (*Lactuca sativa*) or tomato (Legaspi 2010; Legaspi, Miller, Wolaver, et al. 2016; Legaspi and Simmons 2012). Trap crops may also be deployed as "pull" components to attract the pests where they may be controlled, preferably using biological methods such as biocontrol (Figure 1). Marigold and sweet alyssum may be planted as complementary natural refuge crops to nourish and shelter beneficial predatory insects (Figure 2).

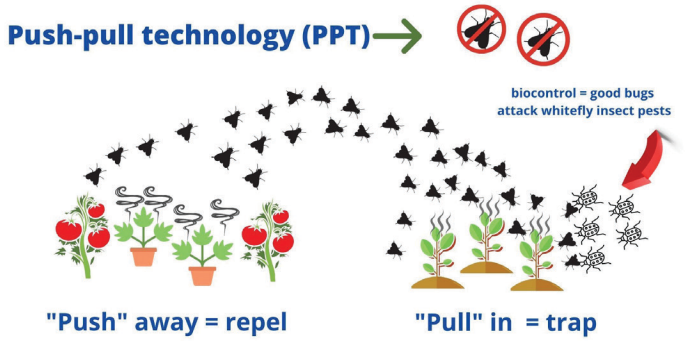

Figure 1. "Push-pull" technology and biological control of invasive whitefly insect pest.
Credits: Jesusa C. Legaspi, USDA-ARS

Figure 2. Companion plants in a leaf lettuce crop grown in a top-vented high tunnel at the Florida A&M University Research and Extension Center, Quincy, Florida. In the foreground, sweet alyssum (SA), followed by peppermint (P) and leaf lettuce (L) in the background.
Credits: Used with permission from Alejandro Bolques, Florida A & M University

In a separate study on tomato production in summer 2019, the combined use of "push-pull" technology with companion planting of flowering plants was evaluated in a top-vented high tunnel. Potted plants of society garlic (*Tulbaghia violacea*), citronella (*Pelargonium citrosum*), and lemongrass (*Cymbopogon citratus*) as "push" components were placed within a tomato crop, and green leaf volatiles such as leaf acetate (cis-3-hexenal acetate) were used as the "pull" factor to attract whiteflies to yellow sticky card traps. To enhance natural enemy populations, the companion flowering plants grown in the high tunnel along the sides included marigold (cv. French Marigold) together with potted basil (*Ocimum basilicum* cv. African Blue) placed at the corners. Commercial packets of the beneficial insect volatile attractant PredaLure® were set up next to the basil plants. A relatively low population of the major insect pests such as the sweetpotato whiteflies (*Bemisia tabaci*), aphids (i.e., *Myzus persicae*), and thrips (i.e., *Frankliniella* spp.) were all recorded on yellow sticky cards that were placed weekly throughout the season (Figures 3 and 4). The "pull" component using green leaf volatiles to attract whiteflies to yellow sticky card traps was not feasible for testing due to the low numbers of sweetpotato whiteflies in the high tunnel. The recorded beneficial insects consisted mainly of the minute pirate bug (*Orius insidiosus*) and whitefly parasites, including *Encarsia* spp. and *Eretmocerus* spp. (Figure 4; Legaspi, Miller, Kanga, et al. 2020).

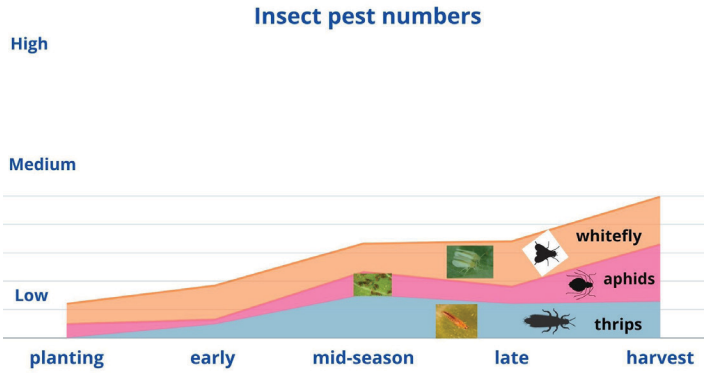

Figure 3. Insect population densities of major insect pests, sweetpotato whitefly, aphids, and thrips throughout the season in a tomato crop grown in a top-vented high tunnel in summer 2019 at the Florida A&M University Research and Extension Center, Quincy, Florida.
Credits: Jesusa C. Legaspi, USDA-ARS

Figure 4. Dual strategy of "push" technology and companion planting in a tomato crop grown in a top-vented high tunnel in summer 2019 at the Florida A&M University Research and Extension Center, Quincy, Florida.
Credits: Jesusa C. Legaspi and Ignacio Baez, USDA-ARS

Companion Planting in High Tunnels in North Central Florida

In an organically managed high tunnel system at the UF/IFAS Plant Science Research and Education Unit in Citra, Florida, sweet alyssum was planted as a companion crop at the center and the border of the leafy green beds in fall 2020. Sweet alyssum continued to grow and flower during the production season of the subsequent tomato crop (December 2020–June 2021) (Figure 5). Insect pest and beneficial monitoring (using yellow sticky cards and visual inspection) during the leafy green and tomato growing seasons showed that sweet alyssum could attract multiple types of beneficial insects, including lady beetles (Coccinellidae), soldier beetles (Cantharidae), drone flies (Syrphidae), paper wasps (Vespidae), mud dauber wasps (Sphecidae), various parasitoid wasps (Braconidae), and green lacewings (Chrysopidae), to promote biological control and help reduce the pest population.

Companion Planting in High Tunnels in South Georgia

In summer and fall of 2020 and 2021 in South Georgia, marigold and sweet alyssum were planted along the side-walls outside of the high tunnels to attract beneficial insects and to reduce the populations of sweetpotato whiteflies (Figure 6). Whiteflies cause enormous direct and indirect damage (as vectors of viral diseases) to field vegetable crops. One significant viral disease is Tomato Yellow Leaf Curl (TYLC). High tunnel tomatoes in 2019–2022 had 100% TYLC incidence on susceptible cultivars. Companion plants were planted in August 2020, but they were killed by a frost in January 2021. In October 2021, yellow sticky card samples indicated that the most abundant pests were sweetpotato whiteflies, followed by thrips, aphids, and leafhoppers (Cicadellidae). The beneficial insects were mainly parasitoid wasps (primarily Mymaridae, Encyrtidae, Scelionidae, Eulophidae, and Aphelinidae) followed by predatory flies (primarily Dolichopodidae and Syrphidae). Numerous beneficial insects (including pollinators) were observed to be attracted by the flowers (e.g., marigold) (Figure 7).

Figure 5. Sweet alyssum planted during the leafy green season in fall 2020 as a companion crop continued to thrive during the winter-spring tomato season (December 2020 to June 2021). This was in a high tunnel organic production system located at the UF/IFAS Plant Science Research and Education Unit, Citra, Florida. Pac choi (top left) was transplanted in mid-September with sweet alyssum direct-seeded three days later. Sweet alyssum plants continued to flower during the next production season of baby leaf lettuce (top right) that was directly seeded after the pac choi harvest and extended during the subsequent season for tomatoes (bottom left and right).
Credits: Shufang Tian, UF/IFAS

Figure 6. A tomato crop grown in an organically managed high tunnel with marigold and sweet alyssum planted outside along the sidewall of the high tunnel at the University of Georgia Horticulture Farm, Tifton, Georgia.
Credits: Used with permission from Juan C. Díaz-Pérez, University of Georgia

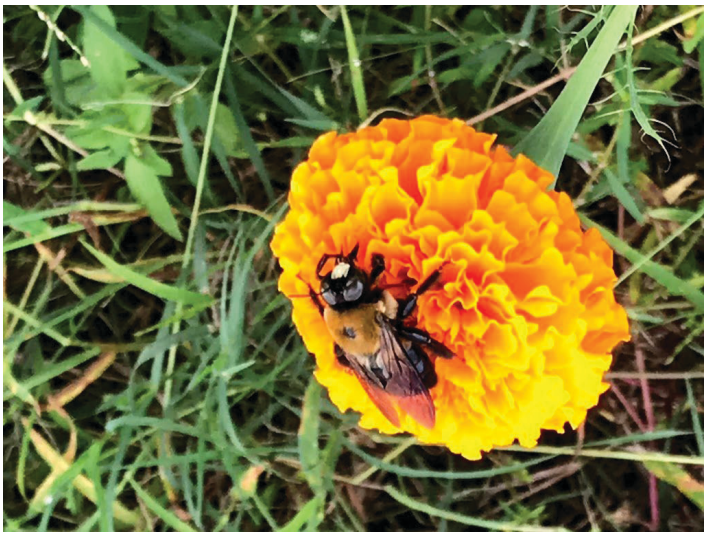

Figure 7. Native bee pollinator on a marigold flower planted along the sidewalls outside of an organically managed high tunnel at the University of Georgia Horticulture Farm, Tifton, Georgia.
Credits: Used with permission from Juan C. Díaz-Pérez, University of Georgia

Summary

Based on our observations as well as the findings of other studies, the dual strategy of the combined use of "push-pull" technology and companion planting may be a low-cost, environmentally friendly tool for insect pest management that can be included in an arsenal of pest control tactics for high tunnel vegetable crops. In particular, it can be conveniently integrated into organic production systems for improved IPM management.

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