

# Greenhouse Production of Vegetable Crops Grown with a Closed-Loop Fertigation System in a Pesticide-Free Environment

D.J. Cantliffe, N.L. Shaw and E. Jovicich  
Horticultural Sciences Department  
University of Florida/Institute  
of Food and Agricultural Sciences  
P.O. Box 110690  
Gainesville, FL 32611  
USA

L.S. Osborne  
Mid-Florida Research  
and Education Center  
2725 Binion Rd. Apopka, FL 32703  
USA

P.J. Stoffella  
Indian River Research  
and Education Center  
2199 S. Rock Rd. Ft. Pierce, FL 34945  
USA

**Keywords:** biological control, integrated pest management (IPM), pepper (*Capsicum annuum* L.), cucumber (*Cucumis sativus*), muskmelon (*Cucumis melo*)

## Abstract

The primary arthropod pests associated with greenhouse vegetable production in Florida are: broadmites, spider mites, thrips, aphids, and whiteflies. The primary disease is powdery mildew. The objective of this research was to identify pesticide-free control measures of the most common arthropod pests of the Florida greenhouse vegetable industry and to recycle water and nutrients, safely without disease pressure. Broadmites and spider mites are controlled with the predatory mite *N. californicus* if released prior to or at transplanting. Aphids and whiteflies are controlled with the parasitic wasps *Aphidius colemani* and *Eretmoserus* sp. or *Encarsia* sp., respectively, which can be released and/or reared on banker plants. Thrips populations can be reduced with generalist predators such as *Orius* sp., but more recently a predatory mite, *Amblyseius swirskii* has been reported to be effective. Disease resistant cultivars are preferred, however, cultural controls such as isolation from disease pressure, anti-condensation coverings, fans and aeration and bio-friendly fungicides are necessary. Regular scouting and correct identification of pests is key to pest management and implementing biological control. Plants were fertigated in a hydroponic system using pine bark or perlite medium in nursery pots. Drainage water was collected, sanitized, adjusted for EC and pH when necessary, then recycled to the plants. A sustainable, pesticide-free environment is not only safer for the plants and produce being grown, but also, employee safety and efficiency can be increased since re-entry periods that delay worker production are eliminated.

## INTRODUCTION

Demand for fresh vegetables in the United States has increased dramatically over the last 20 years (Pollack, 2001) forcing vegetable producers to compete in a worldwide market on a year round basis. In Florida, not only is global competition pressuring growers to consider alternative cropping systems, but pressures from urban development are restricting traditional farm operations and management. Harvested vegetable acreage in Florida declined 12.5% from 2003 until 2006 while annual value of production increased nearly \$90 million to \$1.9 billion (U.S.D.A-N.A.S.S., 2007). Grower efficiency and improved technologies will be necessary for producers to gain profitable returns now and in the future (VanSickle, 2007).

Greenhouse structures can be located in areas less desirable for open-field vegetable production and away from urban encroachment or as evidenced in countries

such as Holland, Spain, and China, it can co-exist in an urban environment as well. The structures themselves can provide a barrier from pest intrusion and damage from wind, rain, and low temperatures. Especially in Florida, where production on sandy soil is prominent, water and fertilizers are frequently applied to open-field production with potential leaching into ground water. Improved irrigation and fertilizer technologies used in protected agriculture appropriately regulate water and fertilizer use to fulfill plant requirements and all excess is collected and recycled.

Pesticide use has become a large focus for growers trying to satisfy consumer demands for safe food and a clean environment. Pest management under greenhouse conditions is improved by using anti-virus exclusion screens, worker entry disinfection zones and UV-blocking polyethylene coverings. Furthermore, pest management is enhanced by using an integrated pest management (IPM) strategy that includes timed releases of beneficial organisms, banker plant habitats (Osborne and Barrett, 2005; banker plants in detail: [mrec.ifas.ufl.edu/lso/banker/banker.htm](http://mrec.ifas.ufl.edu/lso/banker/banker.htm)), and using pesticides with low residues which specifically target a pest species.

The primary arthropod pests associated with greenhouse vegetable production in a closed-system in Florida are: mites, western-flower thrips, aphids, and whiteflies. The primary disease is powdery mildew. The University of Florida Protected Agriculture Project (UFPAP, [www.hos.ufl.edu/protectedag](http://www.hos.ufl.edu/protectedag)) initiated hydroponic, vegetable research in a high-roof passively-ventilated greenhouse in spring 1999 (Gainesville, FL). During the first year, chemical pesticides were used to control both insect pests and disease. Several vegetable species were grown, subsequently, pest issues varied between the crops. Pesticide application was labor intensive, repetitive, and difficult to uniformly apply due to the dense planting system. Plants and fruit were damaged or burned by both the chemical and means of application (gasoline powered sprayer). Few chemical pesticides were registered for use in the greenhouse, therefore, rotation among chemical types was difficult and pest resistance was certain. Alternative pest control measures were necessary and IPM strategies were adopted. Releasing beneficial insects is user friendly, as personal protective equipment required for chemical application is not needed, re-entry times are eliminated, and employees can continue to work during the release. During the first few seasons of relying on natural enemies we learned many key lessons including 1) predators and parasitoids will not eliminate pests; 2) pest populations must be below threshold levels for beneficial arthropods to be effective; 3) chemical pesticides must be specifically selected in an IPM program as most chemicals which target pests will also kill natural enemies and bumble bee pollinators; 4) beneficial arthropods should be released at planting or prior to pest infestation; 5) scouting, record keeping, and proper identification of pests, disease, and biological agents are key to a successful IPM program. Since October 2003, research has been conducted in similar structures in Citra, FL where IPM strategies were implemented during the first growing season.

The objective of this research was to identify pesticide-free control measures of the most common insect pests of the Florida greenhouse vegetable industry, including the crops tomato (Rodriguez et al., 2001), pepper (Jovicich, 2007; Jovicich et al., 2004a, b), strawberry (Paranjpe et al., 2003; Rondon et al., 2004a, b), muskmelon (Mitchell et al., 2007; Shaw et al., 2001), squash (Shaw and Cantliffe, 2005) and cucumber (Shaw and Cantliffe, 2003) in a sustainable, recycled water and nutrient system.

## **GREENHOUSE STRUCTURE AND PEST PREVENTION**

The UFPAP located in Citra, FL, consists of two equal passively-ventilated 0.41-ha structures (Top Greenhouses Ltd., Barkan, Israel). Each sidewall was 4.2 m high. Each of five bays within both structures has a 1.5-m roof vent located at 4.2 m, for a total roof to floor peak of 5.7 m. The structure was covered with single layer, 8-mil polyethylene (PE) plastic (Sun Selector UVA, Ginegar Plastic Products, Ltd., Kibbutz Ginegar, Israel). The PE covering used was selected for its anti-fog additives as well as UV absorption qualities. The anti-fog plastic reduces damage to the plants from eliminating falling water droplets and also, the reduction of moisture in the greenhouse diminishes development of

leaf diseases. The UV absorption properties have been reported to distract and disrupt the behavior of insects, reducing the need for pesticides (Gonzales et al., 2004). These greenhouses were heated to temperatures to prevent freezing. The sidewall and roof vent openings are covered with anti-virus, 0.6-mm insect screen (Klaymen Meteor Ltd., Petah-Tikva, Israel). This net has been reported to completely eliminate entrance of whitefly in Israel ([www.meteor.co.il](http://www.meteor.co.il)). A newer insect screen is available at 0.26-mm mesh (SpiderNet) which is reported to significantly reduce thrips populations (Ministry of Agri. Israel, 2006).

Transplants were produced in an evaporative fan and pad-cooled glasshouse or a Conviron E15 (Controlled Environments Inc., Asheville, NC) growth chamber where they can be isolated from other plants and kept pest free. Transplants were produced in a soilless, sterile sphagnum peat and vermiculite mix.

The interior of the greenhouse was constructed to emphasize sustainable practices such as herbicide-free weed control and irrigation and fertilizer recycling. Plants were grown in individual containers such as 11-L plastic nursery pots (Lerio Co., Kissimmee, Florida) or bato buckets (Crop King Inc., Seville, Ohio) using locally available pine bark (Elixson Wood Products, Starke, Florida) or perlite (Airlite Processing Corp. of Florida, Vero Beach, Florida). To avoid soil pests and diseases, the greenhouse floor was covered with two layers of weed barrier matting. The bottom layer was a black, polypropylene weed barrier (B.11 Pak ground cover, Pak Unlimited, Inc., Cornelia, GA) and the top layer was a white, UV-stabilized polyethylene material (B.13 white ground cover, Pak Unlimited, Inc.) for increased light reflection through the plant canopy, which also aids in deterring insects from the underside of leaves. Pots were placed on top of troughs in order to collect drainage water and fertilizer (leachate). Troughs were made from sheets of insulating styrofoam (1.2 m w x 2.4 m l x 5 cm h) cut into 10-cm strips, two strips were fastened parallel to one another 10-cm apart using sod staples spaced approximately every 60 cm. The styrofoam was covered with white-on-black PE NFT-film (Agrodynamics, Coppel, TX) to create a continuous leachate collection trough the length of each row.

Excess leachate was recycled through the closed-loop fertigation system. The drainage was sanitized using a chlorine sanitizer and filtered for organic particulates (Eldar Shany, Yad-Mordechay, Israel). A computerized nutrient injector (Fertimix with Galileo controller, Netafim USA, Fresno, CA) was programmed to irrigate and fertilize plants based on measurements from the weather station and climate control sensors (temp., solar radiation, RH) to achieve plant need plus 10-20% daily leachate. Plants were then irrigated with recycled water or well water where either source was adjusted for desired EC and pH before final delivery. Total investment cost of the greenhouse structure with a projected life expectancy of 20 years, plus all components of production was \$104.67/m<sup>2</sup> (Jovicich et al., 2005).

The greenhouse was built with minimal openings to prevent points of entry for pests and included a disinfecting foot bath. Employees do not enter the greenhouse if they have been working in the open-field or a highly pest or disease infested area. Bright yellow or white colors of employee's clothing are limited to further discourage pest attraction. Employer provided uniforms, such as grey colored jumpsuits or overalls are recommended.

## **INTEGRATED PEST MANAGEMENT AND BIOLOGICAL CONTROL**

Regular plant scouting is the leading management tool for crop health, pest and disease control and growing pesticide-free in a protected agriculture system. Each greenhouse operation should use a common scouting record sheet (e.g. Fig. 1) among its personnel and follow similar routines (Lapchin and Shtienberg, 1999) using the proper monitoring tools, such as a 10-20X hand lens, insect traps, indicator plants, and yellow and/or blue sticky cards (Greer and Diver, 1999).

Broadmites (*Polyphagotarsonemus latus*), twospotted spider mites (TSM, *Tetranychus urticae*), western-flower thrips (*Frankliniella occidentalis*), cotton or melon aphids (*Aphis gossypii*), and whiteflies (*Bemisia tabaci*) are the most prevalent pests in

the Florida greenhouse vegetable industry. Of these five species, broadmites are the most difficult to detect because of their small size (body length is between 100-200 microns) and detection generally occurs once feeding has already damaged the apical growth (Jovicich et al., 2004a). Since infestation can easily occur during transplant production, it is recommended that plants commonly affected by broadmites be treated preventatively. Applications with pesticides, such as sulphur, may cause phytotoxicity to young transplants and is thus discouraged (Jovicich et al., 2004a). Preventative releases of the predatory mite (PdM) *Neoseiulus californicus*, have been shown to effectively control broadmites in pepper when released at a rate of 2 PdM per plant 6 days prior to transplanting or a rate of 4 PdM per plant at 6 days prior to, at, or 4 days after transplanting (Jovicich, 2007).

TSM appears to be present year-round in Florida. Under our conditions, preventative releases of *N. californicus* are performed at transplanting for melon (Mitchell et al., 2007), cucumber, squash, and pepper for TSM control at a rate of at least 1 PdM per plant as is also recommended for strawberry (Paranjpe et al., 2003; Rondon et al., 2005). A follow-up release is performed again within 3 weeks.

Western flower thrips become a significant problem when outside weed flower populations are high (March and April). Thrips feeding causes permanent damage to leaves and flower buds leading to an economic loss of yield. Thrips also vector tomato spotted wilt virus (TSWV) to which over 926 plant species are susceptible, including the Solanaceae family (Funderburk and Stavisky, 2004). TSWV has become a disease epidemic in several parts of the U.S. where some crops, such as tomato, can no longer be produced. Thrips can be controlled with the minute-pirate bug (*Orius* sp.), a generalist predator that appears to reproduce well in cucurbit crops (rate 1-5 predatory bugs/m<sup>2</sup>). *Orius* sp. has been observed feeding on TSM in cucumber and melon (data not reported) and strawberry (Rondon et al., 2004a). *Orius* sp. (Table 1) are still rather expensive in an IPM program and therefore, other management tools are highly recommended to prevent thrips infestation such as insect screen, traps, wearing proper colored clothing when entering the greenhouse, and removing weeds from inside and outside the greenhouse.

Aphids and whiteflies can be controlled with parasitic wasps. Parasitic wasps should be released at first sight of nymphs and larvae, and follow-up releases for at least three consecutive weeks (rate of 1-6 wasps/m<sup>2</sup>). Follow-up releases are important to target new immatures during wasp establishment (wasp reproductive cycle is minimally 21 days). Banker plant hosts work extremely well for parasitic wasp populations. More recently, *Amblyseius swirskij* PdM have been recommended for whitefly and thrips control (rate of 25 mites/m<sup>2</sup>), though they are not recommended in tomato (www.koppert.nl).

Many beneficial insects exist that work well for greenhouse vegetable pests (Osborne et al., 2004). However, some are not readily available through distributors and it may take 2-3 weeks before expected delivery. Those include lady bird beetles (variety of species), the big-eyed bug (*Geocoris punctipes*), lacewing (*Chrysoperla* sp.), and a variety of predatory bugs as well as native natural enemies.

The cost of using natural enemies in the greenhouse varies depending on the type of biological control used and release rates (Table 1). If preventative release rates are used and are effective, natural enemies per ha are about \$0.51/m<sup>2</sup> per season. For colored pepper, Jovicich et al. (2005) estimated \$0.46/m<sup>2</sup> for beneficials and \$0.11/m<sup>2</sup> for additional pesticide applications if and when needed. The cost of using chemical pesticides in the greenhouse varies with each crop and circumstance and difficult to estimate. However, the Univ. of Florida Center for Agribusiness publishes annual reports on the cost of production of field crops using chemical pesticides for pest and disease control (www.agbuscenter.ifas.ufl.edu). Pesticide application for green pepper, strawberry, and cucumber field-crops in Florida is approximately \$0.21/m<sup>2</sup>, 0.27/m<sup>2</sup>, and 0.09/m<sup>2</sup>, respectively. Not included in these calculations are the additional costs of both fumigants and herbicides; costs not associated with a greenhouse system. The expense of using an IPM program in the greenhouse can be justified via increased net returns from

greater yields of high-value product, greater price premiums received at market, and from the other issues previously mentioned regarding food, worker, and environmental safety.

The occurrence of many plant diseases promoted by rainfall or overhead irrigation can be reduced within a greenhouse while others can become more prevalent, especially powdery mildew (PM). Specialty crops, Galia muskmelon and Beit Alpha cucumber, were developed for open-field culture in dry-land farming regions of Israel where rainfall is minimal and disease pressure low (Shaw and Cantliffe, 2003) and are more susceptible to diseases which occur in greenhouse culture. Shaw and Cantliffe (2003) compared 13 mini- or Beit Alpha-type cucumber cultivars (cv) and reported that total fruit yields for several cv were not affected by high levels of PM, while other cv with a strong resistance to PM, produced low yields. Similar results were reported by Mitchell et al. (2007) for specialty melons.

Common fungal and bacterial diseases within the greenhouse are: downy mildew, gummy stem blight, *Alternaria* spp., *Botrytis cinerea*, *Fusarium oxysporum*, and *Pythium* spp. Control strategies must rely less on chemicals and more on an integrated disease management approach including use of fungicides with a specific mode of action (Malathrakis and Goumas, 1999). Prophylactic measures should be taken to help prevent the onset of disease such as structural maintenance of plastic and insect screens, sanitation between crops, removing and properly disposing of diseased plants and maintaining plant health with proper fertigation and through controlling the greenhouse environment (temp., humidity, air movement, light, etc.) (Berlinger et al., 1999).

## DISCUSSION

In addition to the greenhouse structural components, other cultural controls may assist in achieving a pesticide-free environment. Disease-resistant cultivars should be used, but also, isolate the greenhouse crop from outside disease pressures originating in open-field crops. Air circulation from fans placed within the plant canopy or floor ventilation tubes (used for heating) may increase plant transpiration and thus lead to a more desirable climate for beneficial insect reproduction. Air circulation can also reduce excess plant moisture for prevention of diseases, such as *Botrytis* or gummy stem blight. Biorational pesticides are available that will compliment an IPM system when used properly such as potassium bicarbonate (Milstop, BioWorks Inc., Victor, NY) for PM and Spintor (Spinosad, DowAgrosciences, Indianapolis, IN) for thrips. Others include oil, soap, and neem products (be cautious of phytotoxicity), *Bacillus thuringiensis*, systemic fungicides (systemic pesticides are not recommended when bumble bees are required for pollination), and insect growth regulators.

Organic greenhouse vegetable production is still in its infancy, and currently it is unknown what price premium organic greenhouse vegetables would bring over conventionally produced greenhouse vegetables. No reports on eco-labelling, including 'pesticide-free', of vegetable commodities could be found. O'Dierno et al. (2006) published a marketing study within the seafood industry where consumers surveyed were 71% more likely to purchase an item labelled as 'eco-friendly', where only 54% would purchase an item labelled 'organic'. Organic labelling restrictions for produce are specific (U.S.D.A.-A.M.S., 2002) and though an organic product must be pesticide-free, a pesticide-free product does not necessarily have to be organic. The ability to produce a pesticide-free commodity using sustainable irrigation and fertilizer practices will advance the greenhouse vegetable industry in Florida and worldwide.

## Literature Cited

- Berlinger, M.J., Jarvis, W.R., Jewett, T.J. and Lebiush-Mordechi, S. 1999. Managing the greenhouse, crop and crop environment. In: R. Albajes, M. Lodovica Gullino, J.C. Van Lenteren and Y. Elad. (Eds). Integrated Pest and Disease Management in Greenhouse Crops. Kluwer Academic Publ. Dordrecht, The Netherlands. p. 97-123.
- Funderburk, J. and Stavisky, J. 2004. Biology and economic importance of flower thrips. Univ. of Fla., IFAS, Coop. Ext. Serv. Gainesville, FL. ENY 682. 6 p.

- Gonzalez, A., Garcia-Alonso, Y., Espi, E., Fontecha, A. and Salmeron, A. 2004. Viral diseases control with UV-blocking films in greenhouses of Southern Spain. *Acta Hort.* 659:331-338.
- Greer, L. and Diver, S. 1999. Integrated pest management for greenhouse crops. *Natl. Sust. Agri. Pub. Serv. ATTRA publ. # IP144.* 34 p.
- Jovicich, E. 2007. Management of early broad mite [*Polyphagotarsonemus latus* (Banks) (Acari: Tarsonemidae)] infestations in greenhouse-grown bell peppers (*Capsicum annuum* L.) with the predacious mite *Neoseiulus californicus* McGregor (Acari: Phytoseiidae). University of Florida, PhD dissertation. 180 p.
- Jovicich, E., VanSickle, J.J. and Cantliffe, D.J. 2005. Greenhouse-grown colored peppers: a profitable alternative for vegetable production in Florida? *Hort Technology* 15(2):355-369.
- Jovicich, E., Cantliffe, D.J., Osborne, L.S. and Stoffella, P.J. 2004a. Mite population and damage caused by broad mites (*Polyphagotarsonemus latus* [Banks]) infesting bell pepper at different seedling development stages. *Acta Hort.* 659:339-344.
- Jovicich, E., Cantliffe, D.J. and Stoffella, P.J. 2004b. Fruit yield and quality of greenhouse-grown bell pepper as influenced by density, container, and trellis system. *HortTechnology* 14: 507-513.
- Lapchin, L. and Shtienberg, D. 1999. Sampling and monitoring pests and diseases. p. 82-96. In: R. Albajes, M. Lodovica Gullino, J.C. Van Lenteren and Y. Elad (eds), *Integrated Pest and Disease Management in Greenhouse Crops.* Kluwer Academic Publ. Dordrecht, The Netherlands.
- Malathrakis, N.E. and Goumas, D.E. 1999. Fungal and bacterial diseases. p. 34-47. In: R. Albajes, M. Lodovica Gullino, J.C. Van Lenteren and Y. Elad (eds), *Integrated Pest and Disease Management in Greenhouse Crops.* Kluwer Academic Publ. Dordrecht, The Netherlands.
- Ministry of Agri. Israel. 2006. SpiderNet+. [www.meteor.co.il](http://www.meteor.co.il)
- Mitchell, J.M., Cantliffe, D.J., Sargent, S.A., Datnoff, L.E. and Stoffella, P.J. 2007. Fruit yield, quality variables, and powdery mildew (*Podosphaera xanthii*) susceptibility of Galia melon (*Cucumis melo* L.) cultivars grown in a passively ventilated greenhouse. *Proc. Fla. State Hort. Soc. Vol. 120.* (In press).
- O'Dierno, L.J., Islam, S., Govindasamy, R., Myers, J.J. and Puduri, V. 2006. Identification and evaluation of viable market opportunities for organically-grown aquatic products. *U.S.D.A. Agri. Marketing Ser.* 102 p.
- Osborne, L.S. and Barrett, J.E. 2005. You can bank on it, banker plants can be used to rear natural enemies to help control greenhouse pests. *Ornamental Outlook.* Sept. 2005. p. 26-27.
- Osborne, L.S., Bolckmans, Z. Landa and Pena, J. 2004. Kinds of natural enemies. p.95-127. In: Heinz, K.M, R.G. Van Driesche and M.P. Parrella (eds.). *Biocontrol in protected culture.* Ball Publishing, Batavia, IL.
- Paranjpe, A., Cantliffe, D., Lamb, E., Stoffella, P. and Powell, C. 2003. Winter strawberry production in greenhouses using soilless substrates: An alternative to methyl bromide soil fumigation. *Proc. Fla. State Hort. Soc.* 116:98-105.
- Pollack, S.L. 2001. Consumer demand for fruit and vegetables: the U.S. example. In: A. Regmi (ed), *Changing structure of global food consumption and trade.* WRS-01-1. Econ. Res. Serv., USDA. 111 p.
- Rodriguez, J.C., Cantliffe, D.J. and Shaw, N. 2001. Performance of greenhouse tomato cultivars grown in soilless culture in North Central Florida. *Proc. Fla. State Hort. Soc.* 114:303-306.
- Rondon, S.I., Price, J.F., Liburd, O.E., Francis, R. and Cantliffe, D.J. 2005. *Neoseiulus californicus* McGregor: A predatory mite species for controlling two-spotted spider mites in strawberries. Univ. of Fla., IFAS, Coop. Ext. Serv. Gainesville, FL. EDIS HS245. 5 p.
- Rondon, S.I., Cantliffe, D.J. and Price, J.F. 2004a. The feeding behavior of the bigeyed bug, minute pirate bug, and pink spotted lady beetle relative to main strawberry pests.

Environ. Ent. 33:1014-1019.

Rondon, S.I., Price, J.F. and Cantliffe, D.J. 2004b. An integrated pest management approach: monitoring strawberry pests grown under protected structures. *Acta Hort.* 659:351-356.

Shaw, N.L. and Cantliffe, D.J. 2005. Hydroponic greenhouse production of "baby" squash: selection of suitable types and cultivars. *HortTechnology* 15:722-728.

Shaw, N. and Cantliffe, D.J. 2003. Hydroponically produced mini-cucumber with improved powdery mildew resistance. *Proc. Fla. State Hort. Soc.* 116:58-62.

Shaw, N., Cantliffe, D.J. and Taylor, B.S. 2001. Hydroponically produced 'Galia' muskmelon – What's the secret? *Proc. Fla. State Hort. Soc.* 114:288-293.

U.S.D.A.-A.M.S. 2002. National organic program standards. U.S.D.A. Agri. Marketing Serv. [www.ams.usda.gov](http://www.ams.usda.gov)

U.S.D.A.-N.A.S.S. 2007. Quick stats – Florida data - vegetables. U.S. Dept. Agr. Natl. Agr. Stat. Serv. [www.nass.usda.gov](http://www.nass.usda.gov)

VanSickle, J.J. 2007. Vegetable outlook – 2007. Fla. Coop. Ext. Serv., Univ. of Fla., IFAS, Coop. Ext. Serv. Gainesville, FL. FE681. 4 p.

**Tables**

Table 1. Cost and rate of release for various beneficial insects used on strawberry, pepper, and cucurbit crops produced in a 1 ha passively-ventilated high-roof greenhouse.

Beneficial insect	Target pest	Releases rate	Cost
<i>Neosieulus californicus</i>	Mites	10 mites/m <sup>2</sup>	\$0.06/m <sup>2</sup> / release
<i>Hippodamia convergens</i>	Aphids, soft bodied insects	10-20 beetles/m <sup>2</sup>	\$0.03/m <sup>2</sup> /month
<i>Aphidius colemani</i>	Aphids	0.15 wasps/m <sup>2</sup>	\$0.02/ m <sup>2</sup> /crop
<i>Amblyseius swirskii</i>	Whitefly, thrips	25 mites/m <sup>2</sup>	\$0.0/ m <sup>2</sup> /release
<i>Orius insidiosus</i>	Thrips, others	1 bug/m <sup>2</sup>	\$0.10/ m <sup>2</sup> /release
<i>Eretmoserus eremicus</i> *	Whitefly	3 wasps/m <sup>2</sup>	\$0.04/m <sup>2</sup> /release
<i>Eretmoserus mundus</i> *	Tobacco whitefly	3 wasps/m <sup>2</sup>	\$0.05/m <sup>2</sup> /release
<i>Encarsia formosa</i> *	Glasshouse whitefly	3 wasps/m <sup>2</sup>	\$0.02/m <sup>2</sup> /release

\* Whiteflies should be properly identified prior to ordering parasitic wasps as certain wasp species prefer certain whitefly species as well as respond differently to climate.

**Figures**

**Scouting Record Sheet**

Date \_\_\_\_\_ Crop \_\_\_\_\_

Scout Name \_\_\_\_\_ Crop Age \_\_\_\_\_

Time In \_\_\_\_\_ Time Out \_\_\_\_\_ Air Temp. \_\_\_\_\_

Additional Comments:

Plant Location	Leaf node w/ Adult Pests	Leaf node w/ Immature Pests	Leaf node# Type and # of Pests Present			Leaf node# Type and # of Beneficials Pres.			% Pests Parasitized	Other (disease, wilt, etc.)
			node #	pest type	pest #	node#	benf type	benf #		
1										
2										

Fig. 1. An example of a partial scouting record sheet used to monitor insect populations and disease in greenhouse vegetable crops.

