Pan Trap Designs for Monitoring Pollinators and Other Beneficial Insects in Conservation Gardens[1]

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Abstract Flowering ornamental plant species have the potential to support beneficial insect communities such as pollinating bees, wasps, and predatory plant bugs. We compared pan trap color, size, and placement height for sampling of insects in replicated conservation gardens planted with species selected to act as a conservation resource for pollinators and other beneficials. Of the 14 combinations of color, size, and height placement, yellow bowls (14.5-mm diam., 8.5 mm high) placed on the soil substrate captured the greatest numbers and diversity of pollinator and beneficial insect taxa. During the study, 16 species of bees were collected and identified, with *Lasioglossum* (*Dialictus*) *imitatum* Smith and *Halictus ligatus* Say (Hymenoptera: Halictidae) being the most abundant species collected, primarily in the yellow bowl pan traps at ground level.

Key Words pollinating arthropods, flowering ornamental plants, biodiversity conservation, ecosystem services, pan trap

Ornamental plants in gardens provide food resources as well as shelter and nesting areas that contribute to the survival and reproduction of bees (Frankie et al. 2005, Matteson et al. 2008, McIntyre and Hostetler 2001). Such plants and conservation gardens attract pollinators and beneficial insects, thus, conserving pollinator and natural enemy species through these ecosystem services. Monitoring pollinator and beneficial insect occurrence within habitat management sites allows for the evaluation of ornamental plant species for their arthropod attractiveness and their provision of arthropod-mediated ecosystem services, including pollination and biological control, in southeastern landscapes (Kremen et al. 2007). In the study reported herein, pan trapping was used to monitor pollinator and beneficial insects in conservation gardens. Pan trapping methods have been previously used in monitoring beneficial insects, including assessing the attractiveness of habitats to pollinators and butterflies following removal of invasive Chinese privet (*Ligustrum sinense* Lour.) (Hudson 2013). Westphal et al. (2008) found that pan traps can be used for surveying pollinator occurrence but that color and shape are important presumably because flower color and shape are highly important when attracting pollinating insects to a garden.

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Brødsgaard (1989) noted that different types of insects are attracted to different colors. Yellow has been successfully used to capture hymenopterans and dipterans; red is effective in attracting some coleopterans; and white attracts dipterans and grass-dwelling insects (Vrdoljak and Samways 2012). Our primary goal in the study reported herein was to identify an efficient pan trap for monitoring pollinator and beneficial insect occurrence in gardens by comparing pan trap color, size, and height placement. An additional goal was to characterize the potential pollinator and other beneficial insects inhabiting landscape beds installed in Georgia for the purposes of conservation and aesthetics.

Materials and Methods

This study was conducted in the University of Georgia's (UGA) Research and Education Garden on the UGA Griffin Campus (Spalding Co.; N 33°24′67″, W 84°26′40″). Butterfly and conservation theme gardens were established in October 2012 (soil type: sandy clay, pH: 5.1, Organic Matter: 3.25%, percentage C: 0.16%, percentage N: 0.04%) each with 75 commercially available perennial and annual, exotic and native plant species (Harris et al. 2016). In addition to their anecdotal attractiveness to pollinating insects, plants were selected based on horticultural attributes and superior adaptability to southeastern growing environments. Efforts were made to create aesthetically pleasing landscape designs in each garden, necessitating the use of various foliage textures and contrasts (e.g., fine versus coarse), as well as a variety of plant habits (e.g., groundcover versus upright). To this end, nonnative exotic species prized primarily for their colorful and/or bold foliage such as *Colocasia*, *Hibiscus*, *Stachys*, and gingers were planted. In addition, *Foeniculum*, *Petroselinum*, *Melissa*, and *Passiflora* also were incorporated in the planting to serve as food source for the larval stages of various insect species.

Annual plant species purchased from local vendors were planted in 15.2-cm-diam. pots, while herbaceous perennials were in 3.8-L containers and woody shrubs in 11.3-L containers. Irrigation consisted of MP Rotator heads on risers which provided 2.5 cm of water weekly. There were four replicate plots (total 1,705.2 m^2, 426.3 m^2 per plot) within the garden—three were contiguous and separated by buffer pathways, while the fourth was located in approximately 500 m away. Within each plot, each plant cultivar was sampled for insect occurrence and activity by direct visual observation, sweep net sampling, and pan trapping. Visual observations and sweep sampling data are reported in Harris (2015).

Red, yellow, blue, and violet plastic cups (9.5-mm diam., 12 mm high) and red, blue, and yellow plastic bowls (14.5-mm diam., 8.5 mm high) served as the pan traps in the study. Each shape and color of trap was placed at two heights—soil substrate level or 91.5 cm above the substrate on a stand. Traps were placed 91.4 cm apart along the walking path in the center of each plot and arranged in a randomized complete block design with four replications. Each container was filled with a soapy solution (10 ml dishwashing detergent per 3.79 L water) to prevent captured insects from escaping. Insects were collected in the traps from 20 June to 25 June 2013. Collected specimens were transferred to alcohol and returned to the laboratory for identification.

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Only yellow bowls placed on the soil substrate were used as pan traps in order to monitor the occurrence and activity of small bee species in the garden plots. The traps were placed at both ends of each of the four replicated garden plots to yield a total of eight replicates. Insects were collected from the traps at 6- to 7-d intervals from 25 June to 4 August 2014. Bees collected in the pan traps in 2013 and 2014 were identified using appropriate keys. Reference collections are maintained in museums on the University of Georgia Griffin Campus and the University of Georgia Athens Campus.

Data were subjected to analysis of variance using the general linear model procedure. Data were transformed prior to analysis using the arcsin square root transformation for percentage data and square root transformation for count data. Back-transformed data are being reported. Main treatment means for pan trapping were separated using Tukey's Honestly Significant Difference Test (SAS Institute 2010).

Results

Potential pollinator insect taxa collected in pan traps in 2013 included: chalcid wasps (Chalcidoidea), fruit flies (Tephritidae), honey bees (Apidae), hover flies (Syrphidae), long-legged flies (Dolichopodidae), nonbiting midges (Chironomidae), other flies (Diptera), sawflies (Cephidae), small bees (i.e., *Lasioglossum* (*Dialictus*) *imitatum* Smith and *Halictus ligatus* Say, Hymenoptera: Halictidae), skipper butterflies (Hesperiidae), and tumbling flower beetles (Mordellidae). Occurrence of small bees (e.g., *L. imitatum* and *H. ligatus*) ($F_{13,135} = 3.92$, $P = <0.0001$), hover flies (Syrphidae) ($F_{13,136} = 3.95$, $P = <0.0001$), and other flies (Diptera) ($F_{13,136} = 2.46$, $P = 0.0054$) were significantly influenced by pan trap type (Table 1). Yellow bowls placed on the soil substrate were among trap designs most preferred by syrphid flies (1.25 ± 0.45) and other flies (1.25 ± 0.41). Traps commonly visited by small bees included the yellow bowls on the substrate (5.38 ± 1.69) and yellow bowls at 91.5 cm above the surface (7.13 ± 3.65). Trap type also significantly influenced tumbling flower beetles (Mordellidae), which were collected predominately in yellow bowls on the substrate (13.1 ± 6.68) and yellow bowls at 91.5 cm above the substrate (9.25 ± 4.11). Sawflies (0.25 ± 0.16), chalcid wasps (1.86 ± 0.77), and long-legged flies (33.9 ± 13.3) were most frequently captured in yellow bowls placed on the soil substrate, while skipper butterflies (0.25 ± 0.16) were collected in high numbers from yellow bowls placed 91.5 cm above the surface. Comparison of the total number of pollinators collected by each trap showed that pan traps of yellow bowls placed on the soil substrate were more efficient than all other trap designs (72.5 ± 19.1) (Table 2).

Other potential beneficial insect taxa collected in pan traps in 2013 included fireflies (Lampyridae), predaceous ground beetles (Carabidae), predatory ants (Formicidae), robber flies (Asilidae), and rove beetles (Staphylinidae). Pan traps of yellow bowls placed at 91.5 cm above the substrate were preferred by ground beetles and fireflies (Table 1). Comparison of trap types in efficiently capturing total numbers of all other beneficial insect species showed that the yellow bowl on the soil surface was a top performer (4.38 ± 1.22) but was significantly equivalent to the

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Table 1. Statistical analysis results from comparisons pan trap types in attracting pollinator and beneficial insect taxa 2013, UGA Research and Education Garden (Spalding Co., GA).

Insect Taxa	df	*P*-Value	*F*-Value
Apidae	13, 136	0.0787	1.66
Cephidae	13, 136	0.0009***	2.98
Chalcidoidea	13, 136	<0.0001***	4.50
Chironomidae	13, 136	0.6845	0.78
Dolichopodidae	13, 136	<0.0001***	7.56
Hesperiidae	13, 136	0.0011**	2.91
Mordellidae	13, 136	<0.0001***	4.21
Other flies	13, 136	0.0054**	2.46
Small bees	13, 135	<0.0001***	3.92
Syrphidae	13, 136	<0.0001***	3.95
Tephritidae	13, 136	0.0013**	2.87
All pollinators	13, 135	<0.0001***	13.18
Asilidae	13, 136	0.3747	1.61
Carabidae	13, 136	0.0275*	1.99
Formicidae	13, 136	0.0027**	2.66
Lampyridae	13, 136	0.0091**	2.31
Staphylinidae	13, 136	0.0074**	2.37
All beneficial insects	13, 136	<0.0001***	3.64

* Significant at the $P < 0.05$ level.
** Significant at the $P < 0.01$ level.
*** Significant at the $P < 0.001$ level.

yellow cup placed on the soil surface (4.72 ± 1.48) and the blue bowl placed on the soil surface (4.18 ± 1.05) (Table 2).

A total of 214 small bees, representing 16 species, were collected in pan traps in 2013 and 2014. These consisted of *Agapostemon virescens* F., *Augochlora pura pura* Say, *Bombus griseocollis* DeGeer, *Bombus impatiens* Cresson, *Halictus ligatus* Say, *Halictus parrallelus* Say, *Holcopasites calliopsidis* Linsley, *Lasioglossum* (*Dialictus*) *coreopsis* Robertson, *Lasioglossum* (*Dialictus*) *disparile* Cresson, *Lasioglossum* (*Dialictus*) *illnoensis* Robertson, *Lasioglossum* (*Dialictus*) *imitatum* Smith, *Lasioglossum* (*Dialictus*) *mitchelli* Gibbs, *Lasioglossum* (*Dialictus*) *tegulare* Robertson, *Lasioglossum* (*hemihalictus*) *lustrans* Cockerell, *Melissodes comptoides* Robertson, and *Ptilothrix bombiformis* Cresson. Of these species, *L.* (*Dialictus*) *imitatum* was the most frequently collected (116), captured primarily in

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Table 2. Mean (± SE) number of all pollinators and all beneficial insects collected from selected pan trap types in 2013, UGA Research and Education Garden (Spalding Co., GA).*

Pan Trap Type	All Pollinators	All Beneficial Insects
Blue, bowl, soil level	4.82 ± 1.26b	4.18 ± 1.05abc
Red, cup, soil level	7.10 ± 3.70b	2.40 ± 0.62abc
Yellow, bowl, stand	35.3 ± 10.7b	1.13 ± 0.35abc
Yellow, bowl, soil level	72.5 ± 19.1a	4.38 ± 1.22ab
Yellow, cup, stand	7.20 ± 1.95b	0.60 ± 0.22c
Yellow, cup, soil level	8.45 ± 1.62b	4.72 ± 1.48a

* Means in same column bearing different letters are significantly different ($\alpha = 0.05$).

yellow bowls on the soil substrate (Table 2). *Halictus ligatus* was also found in high numbers (54), captured in the yellow bowls placed on the soil substrate in 2013 and 2014.

Discussion

Based on our search of available literature on this subject, our current study is one of the first to report the response of pollinators and natural enemies to traps deployed in replicated plantings of ornamental plants suitable for southeastern landscapes. One of the first steps toward conservation of bees, pollinators, and other beneficial insects in our landscapes is to determine which plants will provide adequate resources at different times in the growing season and can be implemented in landscapes by land managers, landscape professionals, and homeowners (Tuell et al. 2008). We used pan traps in this study to help characterize visitation to gardens planted with a wide selection of ornamental floral resources for pollinators, natural enemies, and plant-feeding insects. Woltz et al. (2012) affirms complex landscapes with flowering plants provide overwintering refuges, alternative hosts and prey, and nectar and pollen resources for pollinating and beneficial arthropods. If pollinator and natural enemy populations are supported throughout the season by floral resources, growers and homeowners may receive increased pollination and biological control services by planting appropriate plants in their landscapes.

Pan trapping is a traditional method that can be used to survey bees and other beneficial insects over multiple sites (Hudson 2013). Insect groups collected through pan trapping in this study included members of the taxonomic families Apidae, Asilidae, Carabidae, Dolichopodidae, Formicidae, Mordellidae, Staphylinidae, Syrphidae, and small bees (e.g., *L.* (*Dialictus*) *imitatum* and *H. ligatus*). Our findings further conclude a very simply constructed pan trap consisting of placement of plastic yellow bowl on the soil surface or at a height of 91.5 cm above the surface can be successfully used to survey beneficial hymenopteran, coleopteran, dipteran, and lepidopteran insects in the landscape and garden settings.

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