areas of the soil. Humic acid in the soil may also chelate soil Fe (Loeppert et al., 1994). Soil humic acid can also hold iron in exchangeable or complexed forms (Brady and Weil, 1996).

In conclusion, no beneficial plant growth effects from number of applications or rates of leonardite were found under the conditions outlined in this study.

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Flower Quality, Flower Number, and Western Flower Thrips Density on Transvaal Daisy Treated with Granular Insecticides

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SUMMARY. Greenhouse studies were conducted to determine the efficacy of two granular systemic insecticides, acephate (Pinpoint 15G) and imidacloprid (Marathon 1G), against western flower thrips (*Frankliniella occidentalis* Pergande) on Transvaal daisy (*Gerbera jamesonii* H. Bolus ex. Hook. f). These studies were arranged in a randomized complete-block design with four blocks and four treatments per block. Two rates of acephate (0.75 g/16.5-cm pot and 1.0 g/16.5-cm pot) and one rate of imidacloprid (1.3 g/16.5-cm pot) were used in two studies. Plants were artificially inoculated with five adult western flower thrips at the prebloom stage. Plants were evaluated each week for flower quality (1 = complete injury or flower distortion to 5 = no injury), thrips density per flower, and number of plants flowering in each plot. Both studies showed that the acephate treated plants had the best flower quality, lowest numbers of thrips, and greatest number of plants flowering compared to imidacloprid and the check. These studies demonstrate that granulated acephate exhibits some activity in flower tissue and may assist growers in managing western flower thrips in floricultural crops.

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Western flower thrips (*Frankliniella occidentalis* Pergande) is a major insect pest of greenhouse-grown floricultural crops because it feeds on leaves, buds, and flowers. Western flower thrips adults and immatures are predominantly found in flowers (Yudin et al., 1986) where they feed on pollen and can potentially reduce fertilization (Kirk, 1987). In addition, western flower thrips indirectly damage plants by transmitting the tospoviruses, tomato spotted wilt virus and impatiens necrotic spot virus (Allen and Broadbent, 1986; DeAngelis et al., 1993). Both of these viruses affect a wide range of floricultural crops such as gloxinia, New Guinea impatiens, chrysanthemum, and dahlia (MacDonald, 1993).

Growers have a low tolerance for western flower thrips, because it damages flowers and foliage. Control of western flower thrips in commercial greenhouses generally relies on multiple applications of conventional contact insecticides (Immaraju et al., 1992). This strategy is often ineffective because thrips populations can develop resistance to insecticides (Robb, 1988) and the active stages of thrips often feed in flowers and buds where contact with insecticides is extremely difficult (Immaraju et al., 1992; MacDonald, 1993). Eggs, which are laid in leaf tissue, are not affected by most insecticides. In addition, western flower thrips predominantly pupate in the soil where they are less likely to come in contact with insecticides (Helyer and Brobyn, 1992). As a result, insecticides must be applied frequently for effective control. A problem with the continued use of contact insecticides is the potential phytotoxicity to flowers (Nasruddin and Smitley, 1991).

In general, mixed results have been observed when using systemic insecticides against arthropods that feed in or on flowers. Systemic insecticides may be ineffective because the amount of active ingredient moving into flower parts is not sufficient to kill thrips (Lindquist, 1994). Differences between flower and leaf transpiration rates may make flowers poor sinks for systemics. In addition, it is possible that systemics degrade faster in flower parts (Cresswell et al., 1994).

Two new granular systemic insecticides are available for greenhouse use: imidacloprid (Marathon 1G; Olympac Horticultural Products Co., Bradenton, Fla.) and acephate (Pinpoint 15G; Valent

U.S.A. Corp., Walnut Creek, Calif.). Imidacloprid is a chloronicotinyl systemic insecticide effective against whiteflies and aphids. However, imidacloprid is reported to have minimal activity against western flower thrips feeding in flowers (Baker, 1995). This could be due to its low water solubility ($0.51 \text{ g} \cdot \text{L}^{-1}$ at 20°C), a characteristic trait that can play an important role in the movement of systemic insecticides into flower parts (Hale and Shorey, 1965; Tomlin, 1994). Because of the high water solubility of acephate ($790 \text{ g} \cdot \text{L}^{-1}$ at 20°C), it may be more likely to kill western flower thrips feeding in flowers (Heungens et al., 1989). This study was conducted to compare the efficacy of acephate and imidacloprid against western flower thrips in gerbera flowers.

Materials and methods

Studies were conducted from 28 Sept. 1995 to 28 Feb. 1996 (Study 1) and 15 Mar. to 23 July 1996 (Study 2) at Purdue University Dept. of Horticulture and Landscape Architecture, West Lafayette, Ind. Study 1 was conducted over 12 weeks and study 2 was conducted over 9 weeks. Transvaal daisy (*Gerbera jamesonii* H. Bolus ex. Hook. f.) is commercially grown in greenhouses as a potted plant or for cut flowers. It was used for these studies because the flowers are born on stems arising from a rosette that can easily be inoculated with and examined for thrips. Study 1 used 'Improved Red Delight' gerbera and study 2 used 'Dark Eye Yellow' gerbera. Plants were potted into 16.5-cm plastic containers. The substrate consisted of 20% top soil, 40% perlite, and 40% sphagnum peat by volume. The substrate was supplemented with triple superphosphate (0-20-0) at 60 and 100 ppm nitrogen and potassium, and the pH was adjusted to 5.9 (± 0.1) with phosphoric acid.

Plants were placed into a glass greenhouse ($5.3 \times 4.1 \text{ m}$) on raised benches in a randomized complete-block design, with each of four treatments replicated four times. A block consisted of 4 plots of 5 plants each. The 4 treatments were check (no treatment), two rates of acephate ($0.75 \text{ g}/16.5\text{-cm}$ pot and $1.0 \text{ g}/16.5\text{-cm}$ pot), and imidacloprid ($1.3 \text{ g}/16.5\text{-cm}$ pot). Granules were preweighed and scattered evenly over the surface of the substrate. Insecticides were applied 5 d after the plants had been inoculated with adult western flower thrips. Plants

were 19 weeks old (from seed) when pesticide applications were made. After application of dry material, all pots were watered with $\approx 433 \text{ mL}$ of water to release the active ingredients. All plants were fertilized using a constant liquid feed program of 200 ppm nitrogen and potassium, and 80 ppm phosphorus. Water pH was maintained at $6.8 (\pm 0.1)$. Temperatures in the greenhouse ranged from 21 to 27°C ($\pm 4^\circ \text{C}$) with 60% to 80% relative humidity.

Western flower thrips used in this study were collected from a planting of carnation (*Dianthus caryophyllus* L.) and basil (*Ocimum basilicum* L.) in a different bay of the greenhouse. A sample of thrips ($n = 5$) from each greenhouse population were taken before infesting plants to determine that the populations were indeed western flower thrips. All individuals in the samples were verified as *Frankliniella occidentalis*. Adult thrips were collected into Petri dishes ($14.0 \times 2.5 \text{ cm}$) lined with filter paper. Five adult western flower thrips were transferred with a moistened camel hair soft brush to the unopened flower buds of each plant.

Weekly measurements recorded for each plant included thrips density per flower, flower quality, and number of flowers per plant. Measurements were taken only on fully opened flowers. Numbers of thrips (adults and immatures) in each flower were determined by placing a white sheet of paper ($21.6 \times 27.9 \text{ cm}$) $\approx 8 \text{ cm}$ below each open flower and tapping the stalk five times 8 to 10 cm below the flower with a pencil. Adult and immature thrips that fell on the white sheet of paper were counted. These thrips were then gently brushed back onto the flower.

Flower quality was determined for each flowering plant by rating flower injury from 1 to 5 [1 = complete injury or flower distortion, 2 = severe injury, 3 = moderate injury, 4 = slight injury, and 5 = no injury]. This measurement of flower aesthetic quality was an indicator of potential flower marketability. In addition, the number of flowers for each plant were counted. For this study to represent treatment effectiveness under commercial greenhouse conditions, thrips were able to move freely between plants. All treatments were analyzed for significance using multiple *t* tests ($P < 0.05$) for the independent samples with unequal variances (Steel et al., 1997).

Results and discussion

In both studies, acephate treated plants produced greater numbers of flowers per pot compared to imidacloprid treated plants and the check (Table 1). In study 1, both acephate treatments resulted in lower numbers of thrips than imidacloprid (Table 1). However, in study 2, pots treated with the acephate rate of 1.0 g/16.5-cm pot did not have significantly different numbers of thrips than imidacloprid (Table 1). The checks had fewer thrips per pot because they produced fewer flowers for thrips to infest. Acephate treated plants in both studies demonstrated the best flower quality rating compared to imidacloprid treated plants and the check (Table 1). Significant differences between flower quality of pots treated with different rates of acephate were not found for any of the variables measured.

Both our studies demonstrate that granulated acephate may protect flowers from early thrips injury. *Gerbera jamesonii* grown as a potted plant appeared to benefit from applications of acephate. An increased number of flowers on acephate treated plants is not likely the result of added nitrogen applied in the formulated product because nitrogen is associated with leaf growth, not flower production (Tjia and Rogers, 1982). Rather, more flowers and higher flower quality suggests that acephate is providing systemic protection to flower buds, allowing them to flower and remain free of noticeable injury during the study. This initial protection may prevent bud abortion, which was observed in the imidacloprid and control treatments, and reduce thrips injury to flowers.

It has been suggested that acephate acts as a fumigant in flower parts in addition to a systemic (Oetting and Beshear, 1980). Our observations of high numbers of thrips in flowers with no injury does not support the fumigant mode of action. Instead, thrips numbers on acephate treated plants could be the result of flowers attracting thrips from nearby plants that did not produce flowers. Despite the presence of thrips on acephate treated plants, flower quality was better than that of imidacloprid and check plants (Table 1). Imidacloprid treated plants had two times the number of thrips, and the check plants had similar numbers as acephate treated plants. Thrips were landing on and only feeding on acephate treated plants to the extent that injury was slight to moderate.

Water solubility may contribute to the activity of systemic insecticides moving into flower parts as well as other plant parts. Imidacloprid, which has a low water solubility (0.51 g·L⁻¹ at 20 °C), may be unable to protect flowers from thrips injury, because it cannot move into the floral parts of plants. Systemic chemicals with greater water solubility may be more mobile in the plant and able to reach the flower parts (Hale and Shorey, 1965). The water solubility of acephate (790 g·L⁻¹ at 20 °C) may allow for mobility into the floral parts of plants and provide protection from thrips injury.

Acephate has many desirable characteristics that make it useful as an insecticide against ornamental pests such as low mammalian toxicity, broad spectrum of activity, and systemic mode of action (Klocke and Myers, 1984). Granular formulations of acephate have

provided control of some greenhouse pests such as the green peach aphid (*Myzus persicae* Sulzer). Systemic activity of acephate against the green peach aphid on chrysanthemum was noticed within seven days of application. Activity was observed in buds and flowers. It was noted that 14 d following application there was a noticeable increase in aphids (Oetting, 1982). This is similar to what we observed in the last third of our studies. As flower quality decreased and thrips numbers increased the number of plants capable of producing flowers was reduced. It is possible that the high water solubility of this formulation may shorten the duration of its activity (Oetting et al., 1984). As a result, over time there is reduced systemic activity in the flowers and less protection from western flower thrips injury. For prolonged protection against thrips injury additional applications of acephate may be necessary, especially when Transvaal daisy is grown for cut flowers, which is a longer-term crop.

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Table 1. Mean flowers per pot, mean thrips per pot, and mean flower quality rating per flowering pot for each treatment for studies 1 and 2.

Treatment	Rate g/pot	Mean flowers	Mean thrips	Mean flower quality ^a
Study 1				
Acephate	0.75	0.63 a ^y	5.9 a	3.5 a
Acephate	1.0	0.50 a	3.8 a	3.7 a
Imidacloprid	1.3	0.20 b	12.9 b	1.4 b
Check		0.10 c	4.3 a	0.6 b
Study 2				
Acephate	0.75	0.73 a ^y	4.5 a	3.8 a
Acephate	1.0	0.71 a	6.6 ab	3.5 b
Imidacloprid	1.3	0.34 b	8.7 b	2.1 c
Check		0.16 b	5.3 b	1.3 c

^aFlower quality rating: 1 = complete injury or flower distortion, 2 = severe injury, 3 = moderate injury, 4 = slight injury, and 5 = no injury.

^yMeans within each study not followed by a common letter are significantly different ($P = 0.05$) as determined by multiple t tests.

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Antitranspirants Do not Reduce Transplant Shock of Impatiens Seedlings in a Greenhouse

Marc van Iersel

ADDITIONAL INDEX WORDS. *Impatiens wallerana*, transplant shock, water relations, phytotoxicity

SUMMARY. Transplanting can result in root damage, thereby limiting the uptake of water and nutrients by plants. This can slow growth and sometimes cause plant death. Antitranspirants have been used to minimize transplant shock of vegetables. The objective of this research was to determine if antitranspirants are useful to reduce transplant shock of impatiens (*Impatiens wallerana* Hook.f.) seedlings in the greenhouse. Seedling foliage was dipped in or sprayed with antitranspirant (Vapor Gard or WiltPruf) and shoot dry mass was determined at weekly intervals. Antitranspirants reduced posttransplant growth of impatiens as compared to untreated plants, possibly because of a decrease in stomatal conductance, leading to a decrease in photosynthesis. The two dip treatments also caused phytotoxic effects (necrotic spots) on the leaves. In a second study, leaf water, osmotic and pressure potential were determined at 2, 9, and 16 days after transplant. Application of antitranspirants (as a dip or spray) decreased water and osmotic potential compared to control plants. The results of this study indicate that antitranspirants are not useful for minimizing transplant shock of impatiens under greenhouse conditions.

Plant growth following transplant can be slow because of transplant shock. Transplant shock usually is caused by

damage to the root system of plants. Fine roots are especially likely to be destroyed during transplanting (Kramer, 1983). Transplant shock can cause water stress (Berkowitz and Rabin, 1988), decrease nutrient uptake (Bloom and Sukrapanna, 1990), and make plants more susceptible to disease (Moss and Main, 1989). Water stress and decreased nutrient uptake may be a direct effect of root damage, while decreased vigor can make plants more vulnerable to diseases.

Transplant shock can result in a temporary water deficit, poor growth, and sometimes plant death (Berkowitz and Rabin, 1988; Nitzsche et al., 1991). Minimizing water loss from plants can reduce transplant shock and help maintain a favorable plant water status. Antitranspirants have been used successfully to minimize transplant shock. For example, abscisic acid has been used as an antitranspirant for transplanted bell peppers (*Capsicum annuum* L.) and has the potential to reduce transplant shock and increase yield (Berkowitz and Rabin, 1988). Applying wax emulsions to bell pepper foliage helps to maintain a favorable water status, decreases leaf abscission, and increases growth (Nitzsche et al., 1991). Antitranspirants can also decrease the transpiration rate and increase the xylem pressure potential of several woody and herbaceous ornamental plants in greenhouses (Hummel, 1990).

Because antitranspirants decrease leaf conductance, they not only reduce transpiration but increase resistance to CO₂ diffusion into leaves (Nitzsche et al., 1991). When leaf conductance is a limiting factor for photosynthesis, antitranspirants will reduce photosynthesis and subsequently growth. For example, Vapor Gard (Miller Chemical and Fertilizer Corp., Hanover, Pa.), a pinolene-based antitranspirant, can reduce the photosynthesis of young apple (*Malus × domestica* Borkh.) leaves (Weller and Ferree, 1978). Antitranspirants reduce stomatal conductance and transpiration, but also dry matter accumulation, of greenhouse-grown tomato (*Lycopersicon esculentum* Mill.) plants (Gu et al., 1996). The usefulness of antitranspirants in minimizing transplant shock thus depends on whether the benefits of reduced transpiration outweigh the disadvantage of reduced photosynthesis. The use of antitranspirants in greenhouses has not been very successful. Although

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