Reducing Fertilization in Gerbera Production Enhances Host Plant Resistance to Western Flower Thrips©

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Western flower thrips (WFT) is one of the most damaging pests, world-wide, to ornamental crops. Plant nutrition can play a role in host plant resistance to WFT and in the possible reduction of pesticide usage. This study determined how gerbera host plant resistance is enhanced when nutrient availability is reduced, as determined by an increase in chemical defenses and a reduction in WFT feeding and abundance. We tested three fertility levels that consisted of 0X, 0.3X, or 1X (200 ppm N) the recommended fertilization rate for gerbera. Reducing fertilization increased the total phenolics, which are constitutive secondary metabolites that negatively affect insect feeding. In addition, the accumulation of jasmonic acid (JA), which is a plant hormone that regulates the induced defense response to insect feeding, was greater when fertilization was reduced. The enhanced chemical defenses in lower fertility plants resulted in reduced WFT abundance and feeding damage. Vegetative biomass was reduced in lower fertility plants, but flower production and the number of days to pollen shed were similar for gerberas receiving 1X and 0.3X fertilization. Thus, WFT-free plants that received 1X or 0.3X fertility were rated as marketable. Hence, reducing fertilization to a moderate level in gerbera production, which also increased flower peduncle length, can enhance resistance to WFT, while maintaining adequate plant quality.

INTRODUCTION

Gerbera jamesonii is an economically important floriculture crop that is sold as cut flowers, bedding plants, or as a potted flowering plant. Unfortunately, gerberas make excellent hosts for insect pests, especially western flower thrips [(WFT) *Frankliniella occidentalis* Pergande]. Gerberas have even been suggested for use as a "trap crop," to keep WFT off of other crops in greenhouse production (Blumthal et al., 2005). Western flower thrips are probably the most serious pest of floriculture crops in the world (Parrella, 1995). Western flower thrips damage plants directly by feeding and laying eggs on the plant, and indirectly by acting as vectors for tospoviruses such as tomato spotted wilt virus (TSWV) and impatiens necrotic spot virus (INSV). Western flower thrips are difficult to control because of their small size, ability to reproduce to high numbers, cryptic behavior, egg deposition inside plant tissue, and tendency to hide themselves in tight spaces (Morse and Hoddle, 2006). Also, WFT appear to have a propensity for becoming resistant to insecticides (Espinosa et al., 2002). A priority of the USDA Nursery and Floriculture Research Initiative is to develop and implement best management practices (BMPs).

As part of BMPs, growers are encouraged to decrease fertilizer and pesticide usage in order to reduce surface and ground water contamination. Reducing fertilization and subsequent nitrogen run-off may also facilitate in the control of WFT and cut insecticide applications.

Many insect herbivores are more prolific on plants treated with higher nitrogen (N) fertilization. High fertility has been shown to increase the productivity of WFT on chrysanthemum (Davies et al., 2005; Chau and Heinz, 2006) and tomato (Stavisky et al., 2002). The reduction in WFT abundance in response to lower fertility regimes has been attributed to the reduced availability of essential nutrients for WFT. However, the effect of fertilization on natural defense mechanisms (e.g., secondary metabolites) was not measured in any of these studies. Plants use constitutive (naturally occurring compounds that do not require a stimulus) and induced chemical defenses to aid in protection against phytophagous insects. Secondary metabolism is thought to provide compounds which are accumulated and stored, so that when attacked, the plant is already provided with the means to deter, or kill, herbivores. Toxic compounds, such as phenolics, can poison, or at least force insect pests to invest resources in detoxification mechanisms that in turn incur growth and development costs (Kessler and Baldwin, 2002). Jasmonic acid is a plant hormone that regulates the induced defense response, and is essential for defense against both chewing and cell-content feeding (e.g., WFT) herbivores.

The goals of this research were to determine the effects of fertilization on chemical defenses, and subsequent effects on WFT feeding and abundance. More importantly, the effects of fertilization and WFT feeding on plant growth, development, physiology, and quality were determined to assess the viability of optimizing fertilization in order to increase host plant resistance in gerbera.

MATERIALS AND METHODS

Two separate studies were conducted with gerbera (*Gerbera* 'Festival Salmon') seedlings grown in growth chambers with Sunshine Mix #1 as potting media. Plants were fertilized as needed with 200 ml of Peters Professional Peat-lite special 15–16–17 at 0 (de-ionized water), 60, or 200 ppm N, which are respectively, 0 (0X), 30 (0.3X), or 100% (1X) the recommended rate. In the first experiment, one hundred WFT larvae were trapped on a single mature leaf of each sample plant, and allowed to feed for 72 h. Leaves were harvested and percent WFT feeding damage was determined. Jasmonic acid accumulation was determined using a gas chromatograph mass spectrophotometer.

In the second experiment, each pot was enclosed in a large acetate cylindrical cage and half of the plants were inoculated with five adult female WFT. The experiment was terminated after 53 days and WFT populations, plant biomass, net photosynthesis, stomatal conductance, leaf area, chlorophyll content, and flower production were determined. Total phenolics were determined using a spectrophotometer. The rate of flower development was determined by recording the number of days from transplanting to pollen shed of the most mature flower. The dry mass of peduncles per individual open flower was determined to demonstrate the phenotypic plasticity of plants under different fertilization regimes. Gerberas were rated for quality, based on the following scale: 1 = very poor, unsaleable; 2 = poor, unsaleable; 3 = average, saleable; 4 = good, saleable; 5 = excellent, saleable.

The experiments were arranged in a 3 fertility × 2 WFT factorial. There were five replications (n = 5) arranged in a completely randomized design. Data were compared using analysis of variance (ANOVA), with fertilization, WFT, and fertilization × WFT as main effects.

RESULTS

Experiment 1. The differences in the degree of WFT feeding among fertility treatments were visually apparent. The percent feeding damage (PFD) increased as fertilization increased. The PFD on WFT-inoculated 0.3X leaves ranged from 0.4% to 1.3%, whereas, the PFD on WFT-inoculated 1X leaves ranged from 2.0 to 7.0% (Fig. 1). WFT larvae were unable to survive on the 0X leaves and there was no detectable WFT feeding damage. The accumulation of jasmonic acid (JA) was significantly greater in response to WFT feeding. In both 1X and 0.3X plants, as WFT feeding damage (i.e., PFD) increased, JA accumulation increased (Fig. 1). Based on the slopes of the linear regressions, 0.3X plants accumulated JA at 47.7 $ng \cdot g^{-1}$ fresh weight (FW) each percent increase in WFT-induced PFD; whereas, 1X plants only accumulated JA at 7.7 $ng \cdot g^{-1}$ FW each percent increase in PFD. Hence, the moderately fertilized 0.3X plants were more sensitive to WFT feeding, and accumulated more JA in response. The nutrient deficient 0X plants did not have any detectable feeding damage; thus, correlations could not be made.

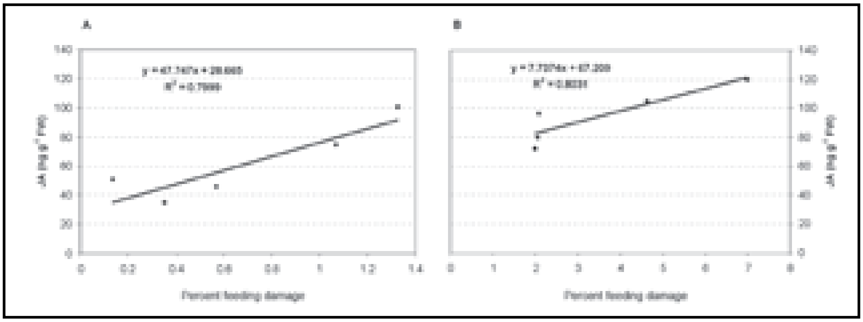

Fig. 1. A) The effect of WFT feeding damage on the accumulation of jasmonic acid (JA) in 0.3X fertilized *Gerbera* 'Festival Salmon'. **B**) The effect of WFT feeding damage on the accumulation of JA in 1X fertility *Gerbera* 'Festival Salmon'. Percent feeding damage (PFD) is the amount of western flower thrips feeding damage/total leaf area. Plants were fertilized with 200 ml of a 15–16–17 fertilizer (elemental analysis: 15N–7P–14K) at 0 (0X), 60 (0.3X), or 200 (1X) $mg \cdot L^{-1}$ N at each watering, as needed; n = 5. Western flower thrips did not cause detectable feeding damage on low fertility plants.

Experiment 2. Populations of WFT increased at higher fertility levels from 1.1 on 0X plants to 77.7 on 1X plants ($P < 0.0001$; Table 1). Many WFT were unable to survive on the 0X plants — three out of five 0X plants inoculated with WFT had no surviving WFT remaining and dead WFT were visible on the leaf surfaces. The 0X gerbera plants were noticeably stressed, which caused a shift in carbohydrates from primary metabolism to secondary metabolism, as determined by the lower plant biomass and higher phenolics, compared to higher fertility plants (Table 1). The 0.3X plants averaged 52.1 WFT, which is a 33% reduction in WFT abundance compared to 1X plants. The 0.3X gerberas had greater

Table 1. Effects of fertilization on western flower thrips abundance, total phenolics, various growth indices, and overall plant quality of *Gerbera* 'Festival Salmon'. Plants were fertilized with 200 ml of a 15–16–17 fertilizer (elemental analysis: 15N–7P–14K) at 0 (0X), 60 (0.3X), or 200 (1X) $mg \cdot L^{-1}$ N at each watering, as needed; n = 5.

Treatments		WFT[z] Abundance	Phenolics ($mg \cdot g^{-1}$ FW[y])	Vegetative DM[x] (g)	Flower DM (g)	Peduncle DM per flower (g)	Quality Rating (1-5)
0X	No WFT	---	5.5 a	1.7 c	0.0 b	0.08 c	1.4 d
	WFT	1.1[w] c	5.0 a	1.6 c	0.1 b	0.05 c	1.1 d
0.3X	No WFT	---	2.9 b	5.2 b	2.0 a	0.4 ab	3.5 b
	WFT	52.1 b	2.6 b	5.0 b	2.1 a	0.5 a	2.7 c
1X	No WFT	---	0.7 c	8.6 a	1.7 a	0.3 b	4.9 a
	WFT	77.7 a	0.9 c	8.4 a	2.0 a	0.3 b	2.8 c

[z]WFT = western flower thrips (*Frankliniella occidentalis* Pergande).
[y]FW = fresh weight.
[x]DM = dry mass.
[w]Values within column followed by a different letter are significant using Fisher's Least Significant Difference Test ($\alpha = 0.05$).

phenolic concentrations compared to 1X plants, but these plants were not visually stressed, and 0.3X plants without WFT were rated as marketable (Table 1). The 0.3X and 1X plants had similar flower dry mass (DM), flowered at approximately the same time, and flower stalks (peduncles) were actually taller in 0.3X plants (not previously reported) (Table 1).

DISCUSSION

Reducing fertilization increased total phenolics (constitutive defense) and WFT-induced JA accumulation in gerbera. This increase in chemical defenses reduced the prolificacy of WFT; as determined by less WFT feeding and abundance in lower fertility plants. Western flower thrips were often unable to survive on nutrient-deficient 0X fertility plants; however, these plants were noticeably stressed and not marketable. However, moderately fertilized (0.3X) gerberas had similar flower production compared to gerberas receiving recommended fertilization rates, and were rated as marketable. Hence, reducing fertilization may be a viable tool in commercial gerbera production that enhances host plant resistance to WFT, while maintaining acceptable quality.

Lowering fertilization by as much as 70% of the recommended rate may be more suited for cut flower production. In potted gerbera production, it is desirable for the foliage to cover the medium, for the leaves to be dark green, and for the flowers to be just above canopy level. Obviously in cut flower production, the foliage is not as much of a concern, and long flower stalks (peduncles) are desirable. Hence, in addition to increased host plant resistance, the longer peduncles in 0.3X gerberas would be an added benefit. Ideally, reducing fertilization would just be one strategy that is incorporated into a comprehensive IPM system. Gerbera cut flower IPM programs are already in use in some nurseries, in which a variety of insect predators are used for biological control in conjunction with biorational insecticides. Reducing fertilization may be another tool that can be used to keep pest populations low and reduce pesticide applications, while maintaining high quality. If fertilization is reduced to a level that increases host plant resistance and maintains plant quality — fertilizer run-off, pesticide usage, and associated phytotoxicity could also be reduced in gerbera crop production.

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