Growth and Flowering Response of Container Grown Passion Flower Cultivars to Fertilizer and Paclobutrazo[1]

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Abstract

The effects of fertilizer and paclobutrazol applications on growth and flowering in four container grown passion flower cultivars (*Passiflora* 'Amethyst', *Passiflora* 'Blue Bouquet', *Passiflora* 'Fledermouse', and *Passiflora* 'Lady Margaret') were evaluated. A four month production system was used that included propagating cuttings in late winter, followed by greenhouse liner production in early spring, and finally by two months of outdoor container production. Shoot growth was increased by increasing fertilizer rates and the response was highly cultivar dependent. Fertilizer rates resulting in the highest levels of growth for each cultivar were generally higher than those required for most container grown nursery crops, ranging between 3.2 and 5.3 g/liter (0.44 and 0.73 oz/gal) of Osmocote 14N–6.0P–11.6K (14–14–14). Paclobutrazol reduced overall plant size without increasing the number of nodes or flowers. Cultivars were chosen based on cold tolerance and vigor and cultivar appeared to be the most significant independent variable. Of the cultivars evaluated 'Lady Margaret' was most suitable for the four month production system.

Index words: passion flower, container production, nutrition, plant growth regulation.

Species used in this study: *Passiflora* 'Amethyst', *Passiflora* 'Blue Bouquet' (*P. caerulea* x *P. 'Lavender Lady'*), *Passiflora* 'Fledermouse' *(P. biflora* x *P. perfoliata*), and *Passiflora* 'Lady Margaret' (*P. coccinea* x *P. incarnata*).

Growth regulator used in this study: Bonzi (Paclobutrazol), ß-((4-chlorophenyl)methyl)-α-(1,1-dimethyl)-1H-1,2,4-triazole-1-ethanol.

Significance to the Nursery Industry

Passion flowers are a high value crop and have good market potential as container-produced plants for patio or garden use. Although passion flower vines are fast growing and can make a sellable plant in approximately four months from sticking cuttings, there are very few cultural guidelines. The production plan in this study used a two month outdoor growing period, minimizing the total amount of time requiring a heated greenhouse and thereby maximizing the economic viability of the production system. To effectively use this system, techniques capable of optimizing growth and flowering are necessary to produce sellable plants in this condensed time course. Results from this study indicate that cultivar selection for cold temperature tolerance and early flowering, along with relatively high fertilizer rates are necessary to meet this single season schedule. Additionally this study determined that while paclobutrazol was capable of producing a more compact plant, it did not significantly increase the number of nodes or flowers per plant and is therefore unnecessary for this system.

Introduction

Flowering, tropical vines are becoming increasingly popular landscape plants. Vines offer an interesting variation in plant form and are valuable in the landscape for their practical and aesthetic qualities because they can be used in areas where trees and large shrubs are unsuitable. There are many novel ways these vines can be grown on trellises, arbors, and other overhead structures for their visual qualities and screening potential. The principle container-grown tropical flowering vines currently marketed for summer sales are *Allamanda* L., *Bougainvillea* Comm. ex Juss., and *Mandevilla* Lindl. These vines are typically produced in southern nurseries and shipped to other parts of the country. Although these species are well established in the market there is a potential for other tropical vines to have strong consumer acceptance.

Passion flowers (*Passiflora* spp.) include more than 450 species that, with rare exception, are tropical or sub-tropical flowering vines that climb using tendrils. There is much variation of the color and shape of the flowers and foliage in the many passion flower species and hybrids (19). Flowers are typically intricate with deep, rich colors and diameters ranging from approximately 1.5 cm (0.6 in) to 15 cm (5.9 in), and some species and hybrids have a very pleasant fragrance. Although there are many named cultivars, only a few are commonly available in U.S. garden centers.

Because passion flowers are easily propagated from cuttings (7), fast growing, and thrive in summer heat, they could easily fit into the summer container market. Additionally, these plants offer the potential for high economic returns and could therefore provide an excellent source of additional income to the nursery industry. One of the limitations to the expansion of passion flower production is that there is little information available to growers about the cultural practices necessary for successful container production.

Growth and flowering of edible passion flower fruit (*P. edulis* Sims) are affected by fertilization rates (11). However, at higher fertilizer rates, vigorous growth could cause passion flower vines to become unmanageable during container production. Plant growth regulators have been successfully used to control height of container grown ornamental tropical vines such as glory bower (*Clerodendrum thomasoniae* Balf. [*C. Balfourii* Hort.]), producing more compact vines that were appropriate for trellised plants (16). However, there has been insufficient research on the use of growth regulators for container production of passion flower. Sanderson et al. (17) achieved significant height reduction in edible passion flower with several growth regulators, but

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the more vigorous ornamental species were not affected at the concentrations tested. Hale et al. (7) found that a paclobutrazol soil drench significantly reduced plant height in the vigorous blue passion flower (*P. caerulea* L.) at 25 and 50 ppm, with greater control at the higher concentration. Additionally, paclobutrazol has been shown to promote earlier flowering, and increase the number of flowers in some plants (1, 2).

Since there are only a few passion flower cultivars hardy in zone 6, winter production would require a temperature controlled environment. The additional cost of greenhouse production would limit the economic returns for this crop unless a production system was used that minimized the time that plants were in the greenhouse. We hypothesized that passion flowers could be grown using a 4-month production cycle where propagation and liner production occurs in the greenhouse for two months, followed by two months of outdoor container production, preferably beginning after the first frost-free date. For this condensed production system to be effective, it will be critical to use cold tolerant cultivars combined with cultural practices that maximize growth and flowering so that plants are finished and ready for summer sale.

The objectives of this study were to evaluate the feasibility of growing passion flowers with an early season four-month production scheme and to determine how fertilizer and paclobutrazol could be used to maximize growth and flowering in this condensed time course. Four cultivars were chosen based on their vigor and cold tolerance from a previous experiment (7), and these plants were treated with several rates of fertilizer and paclobutrazol to determine optimal cultural practices that could facilitate a more wide-spread use of passion flower in the nursery industry.

Materials and Methods

Experiments were conducted in 2001 and 2002. A single cultivar was used for the 2001 experiment and four cultivars with diverse genetic backgrounds were used in 2002. For both years, plants were propagated from two-node cuttings taken in early/mid March, treated with 1,000 ppm indole-3-butyric acid (IBA) and stuck in rooting cubes (Oasis 5015, Kent, OH). Cuttings were placed in an intermittent mist bed (6 sec every 12 min) with 21C (70F) bottom heat. After plants were well rooted, they were moved to 10 cm (4 in) square plastic containers (KL 40, Kord Products, Inc., Brampton, Ontario) with a peat/bark medium (Metro Mix 360, Scotts Company, Marysville, OH) and placed in a glass greenhouse with day/night temperatures of 25C/20C (77F/68F). Plants were fertigated at each watering with 100 ppm N from 20N–4.4P–16.6K (20–10–20) water soluble fertilizer (Peter's Peatlite Special, Scotts Company, Marysville, OH). On May 15, plants were pinched to two nodes and potted in 4.6 liter (4.8 qt) containers (Classic 500, Nursery Supplies, Inc., Columbus, OH) containing Barky Beaver Professional Grow Mix (pine bark, peat moss, sand, lime, Barky Beaver , Moss, TN). Plants were moved to an outdoor nursery and irrigated daily using one emitter per container delivering water to near container capacity. Ninety cm (35.4 in) tall bamboo hoop trellises were inserted into the containers and the plants were tied as needed for support.

In 2001, a completely randomized factorial experiment intended to evaluate the effects of fertilizer rates and paclobutrazol concentrations was conducted with the cultivar Blue Bouquet, with 20 replications per treatment. Plants were potted on May 15 and granular slow release fertilizer (Osmocote 14N–6.0P–11.6K (14–14–14), Scotts Co., Marysville, OH) was surface-applied at rates of 0.2, 1.1, 2.1, and 3.2 g/liter of potting medium (0.03, 1.1, 2.1, 3.2, and 0.44 oz/gal). These rates were based on those used in a previous cultivar trial (7). Paclobutrazol (Bonzi, Crompton (Uniroyal Chemical Co.) Middlebury, CT) was also applied at 0, 50 ppm or 100 ppm. The paclobutrazol solutions were prepared according to label specifications, and were applied as a soil drench in a volume 300 mL (10.1 oz) per container.

Two experiments were conducted in 2002. The first experiment was designed to evaluate the effects of relatively high fertilizer rates (compared to what is normally used for container grown nursery crops) on four cultivars. The experimental design was a factorial arrangement between cultivar and fertilizer concentration. Four passion flower cultivars, Amethyst, Blue Bouquet, Fledermouse, and Lady Margaret, were used, with 18, 28, 21, and 15 replications of each cultivar used per fertilizer treatment, respectively.

Osmocote 14N–6.0P–11.6K (14–14–14) granular slow release fertilizer was applied to the surface of the containers on May 15 at 3.2, 4.3, or 5.3 g/liter of potting medium (0.44, 0.58, and 0.73 oz/gal). The second experiment evaluated the effects of paclobutrazol on two cultivars grown at these relatively high fertilizer rates. The experimental design was a factorial arrangement among cultivar, fertilizer, and paclobutrazol. The cultivars in this experiment were Blue Bouquet and Amethyst and 14 and 9 plants, respectively, of each cultivar were used per treatment. On May 15 Osmocote 14N–6.0P–11.6K (14–14–14) granular slow release fertilizer was surface-applied at 3.2, 4.3, and 5.3 g/liter of potting medium (0.44, 0.58, and 0.73 oz/gal), and 0 or 50 ppm paclobutrazol was applied as a drench as in 2001.

For both years data for growth and flowering were collected on July 15, two months after treatment application and outdoor growth. All data were subjected to analysis of variance, and means were separated using Duncan-Waller K ratio t-test.

Results and Discussion

During summer 2001, four levels of Osmocote fertilizer and two levels of paclobutrazol were applied to the *Passiflora* cultivar Blue Bouquet. Applications were made when plants were moved to the outdoor phase of the production cycle (two months after cutting propagation). Two months after these applications, plants were analyzed for number of shoots, total shoot length, mean shoot length, number of nodes, mean internode length, dry weight biomass, and number of flowers (Table 1). When data were analyzed by analysis of variance, the means square for fertilizer were highly significant ($P \leq 0.01$) for all measured parameters except for number of shoots, where it was significant ($P \leq 0.05$). Additionally, fertilizer response was highly significant, linear and positive for all response variables except mean shoot length, where the trend was still significant ($P \leq 0.05$). The large increase in shoot numbers as fertilizer was increased from 2.1 to 3.2 g/liter (0.29 to 0.44 oz/gal) resulted in a highly significant quadratic trend for mean shoot length (Table 1). The linear fertilizer effect was particularly evident in total shoot length and number of flowers per plant, with plants receiving 3.2 g/liter (0.44 oz/gal) of fertilizer showing 33 and 113% longer shoots and 93 and 145% more flowers than those receiving 2.1 and 1.1 g/liter, respectively.

Table 1. **Averages of shoot number, total shoot length, mean shoot length, number of nodes, mean internode length, dry weight, and number of flowers per plant of *Passiflora* 'Blue Bouquet' two months after application of Osmocote 14N–6.0P–11.6K (14–14–14) fertilizer and paclobutrazol.**

Source of variation	Shoots (no.)	Total shoot length (cm)	Mean shoot length (cm)	Nodes (no.)	Internode length (cm)	Biomass (g)	Flowers (no.)
Osmocote (g/L, oz/gal)							
0.2, 0.03	2.3b[z]	58.5d	30.4b	29.5d	2.0c	3.7d	0.1c
1.1, 0.15	3.6b	133.0c	44.3a	60.4c	2.5b	8.5c	1.1b
2.1, 0.29	5.2ab	214.0b	45.3a	81.1b	2.6b	13.8b	1.4b
3.2, 0.44	14.7a	284.0a	40.8a	97.7a	2.9a	16.3a	2.7a
Paclobutrazol (ppm)							
0	5.2a	207.0a	44.3a	67.4a	2.9a	13.9a	1.4a
50	9.4a	174.0b	45.0a	68.2a	2.5b	9.6b	1.4a
100	4.7a	135.0c	31.4b	65.2a	2.1c	8.2b	1.2a
Factorial treatments — analysis of variance — F-values							
Osmocote	3.3*	85.0**	5.2**	40.7**	19.9**	52.2**	13.4**
Linear	8.1**	253.0**	5.2*	117.0**	54.5**	150.5**	38.9**
Quadratic	1.5^{NS}	1.0^{NS}	9.8**	4.1*	1.1^{NS}	4.5*	0.2^{NS}
Paclobutrazol	1.1^{NS}	15.7**	8.7**	0.2^{NS}	27.8**	19.8**	0.3^{NS}
Linear	0^{NS}	31.1**	12.5**	0.2^{NS}	55.5**	37.1**	0.4^{NS}
Quadratic	0.1^{NS}	0.2^{NS}	5.0*	0.3^{NS}	0.0^{NS}	2.4^{NS}	0.3^{NS}
Osmocote × paclobutrazol	1.2^{NS}	5.2**	0.9^{NS}	2.1^{NS}	2.3*	4.4**	1.9^{NS}

[z]Means for each main effect in a column followed by the same letter(s) are not significantly different (Waller-Duncan K-ratio t-test $P = 0.05$).

^{NS},*,**, indicates non significant, significant at $P \leq 0.05$, and $P \leq 0.01$, respectively.

In the same analysis of variance, the means square for paclobutrazol were highly significant for total shoot length, mean shoot length, internode length, and biomass (Table 1). For each of these parameters paclobutrazol application resulted in a highly significant linear decrease. In particular paclobutrazol resulted in a significant reduction in total shoot length, and at the highest concentration (100 ppm) shoot length was decreased by 35% over the untreated plants (Table.1). Additionally, paclobutrazol had no significant effect on the number of flowers. In this experiment there was a significant interaction of fertilizer with paclobutrazol on total shoot length, mean internode length and biomass resulting from a decreased fertilizer response at the highest levels of paclobutrazol.

Results from the 2001 experiment indicated that it was possible to produce a sellable passion flower in four months, and that growth and flowering could be improved by increasing fertilizer application rates. During summer 2002 four passion flower cultivars were grown at even higher fertilizer rates to assess whether the effects of fertilizer were consistent among different cultivars and to further evaluate fertility optimization. In this experiment, fertilizer was again applied on the date that plants were moved into the outdoor phase of the production cycle, and data were collected after two additional months of growth. When all response variables measured in 2001 were assessed, cultivar effect was the most dramatic of all the independent variables and was highly significant ($P \leq 0.01$) for all response variables (Table 2). Most notable were the differences among cultivars for total shoot length, internode length, and flower number. For example, averaged over fertilizer concentrations, 'Blue Bouquet' and 'Fledermouse' had significantly longer (91 and 141%, respectively) total shoot length than 'Lady Margaret', which had the lowest values for that measurement. However, 'Lady Margaret', because it bloomed early in the production schedule, had more flowers per plant than any other cultivar, with 262% more flowers then the next highest flowering cultivar 'Amethyst.' In fact, in this study, 'Lady Margaret' was the only cultivar to produce a sizeable number of flowers during the four month production period. Although 'Lady Margaret' had the shortest stem length of all cultivars tested, it had the highest biomass relative to stem length for all cultivars. This cultivar had heavier stems and leaves in addition to increased flowering.

Fertilizer had a significant impact on all response variables measured except mean shoot length and number of flowers per plant (Table 2). For example, in 'Blue Bouquet', the cultivar with the highest number of nodes, increasing fertilizer application from 3.2 to 5.3 g/liter (0.44 to 0.73 oz/gal) caused a significant (37%) increase in the total number of nodes. Although there is a potential for increased flowering with increased nodes, 'Blue Bouquet' did not bloom until late in the production schedule, so the total number of flowers for this cultivar was low.

Among cultivars, Amethyst and Blue Bouquet showed the most significant increase in total shoot length (72 and 50%, respectively) and number of nodes (51 and 37%, respectively) when increasing fertilizer from 3.2 to 5.3 g/liter (0.44 to 0.73 oz/gal). However within cultivar, increasing concentrations of fertilizer had no significant effect on the number of flowers per plant for any of the cultivars tested with the exception of 'Amethyst', where there was a positive linear response ($P \leq 0.05$).

There was a significant interaction between cultivar and fertilizer only for number of shoots, total shoot length and biomass. For each variable the interaction likely resulted from the remarkable unresponsiveness of 'Fledermouse' to fertilizer, compared to the other cultivars.

An additional experiment was conducted in 2002 to further examine the effects of three relatively high fertilizer rates and paclobutrazol on two cultivars, Amethyst and Blue Bouquet. Two months after treatment application the same response variables measured in 2001 were assessed. Cultivar was again the most important source of variation, and was highly significant for all variables. 'Amethyst' plants had longer total and mean shoot lengths, and 19.5 times the number of flowers as 'Blue Bouquet'. Although 'Blue Bouquet' had more nodes, they did not result in appreciable flowering during the production cycle.

The means square for fertilizer were highly significant for all parameters except mean shoot length. For each significant parameter the response to fertilizer was linear and positive. The lack of response of mean shoot length was probably related to the tendency of these two cultivars to produce more shoots in response to fertilizer, as opposed to longer shoots, which resulted in a slight decrease in mean shoot length. The effects of fertilizer were particularly evident in total shoot length, biomass, and flowering. Increasing fertilizer from 3.2 to 5.3 g/liter (0.44 to 0.73 oz/gal) resulted in a 50% increase in total shoot length, a 36% increase in the number of nodes, and a 109% in crease in number of flowers. The increase in flowering was almost completely due to the increased flowering in 'Amethyst' (Table 3).

The means square for paclobutrazol were significant for total shoot length, mean internode length, plant dry weight, and number of flowers per plant (Table 3). For these parameters the response was negative. Although paclobutrazol treatment resulted in plants that were more compact, it had no effect on the number of nodes and decreased flowering. Additionally, both cultivars showed slight to moderate leaf distortion when treated with paclobutrazol; however, the leaves were not unattractive or necrotic and all plants grew out of the leaf distortion a few weeks after treatment.

The means square for cultivar × fertilizer were significant for shoot and flower numbers. For 'Blue Bouquet' shoot number but not flower number tended to increase in response to fertilizer; for 'Amethyst', shoot numbers were not affected by fertilizer rate, but increasing fertility tended to increase flower number (data not shown). There were only a few significant paclobutrazol interaction effects. The cultivar × paclobutrazol interaction was significant for shoot length, internode length and number of flowers (Table 3). As an example of this interaction, there was no paclobutrazol effect on reducing shoot length in 'Amethyst' unlike 'Blue Bouquet', while internode length was reduced in 'Blue Bouquet' but unaffected in 'Amethyst' (data not shown). The fertilizer × paclobutrazol interaction was only significant for biomass; plants grown at the lowest fertilizer rates tended to respond less or not at all to paclobutrazol (data not shown) and the significant cultivar × fertilizer × paclobutrazol interaction was significant only for mean internode length which mainly resulted from 'Blue Bouquet having a significant response to paclbutrazol at the lowest rate of fertilizer, unlike 'Amethyst' (data not shown).

'Blue Bouquet' was initially selected for the 2001 study based on a cultivar trial conducted at the University of Kentucky Arboretum in Lexington in the summer of 1999. Of the 50 species, hybrids and cultivars tested, 'Blue Bouquet' was among the best performers based on plant habit and number of flowers. For the summer 2002 experiment, three additional cultivars were added based on potential for growth and flowering.

Two of the cultivars used in these experiments, Amethyst and Blue Bouquet, are well known hybrids with similar ge-

Table 2. Mean number of shoots, total shoot length, mean shoot length, number of nodes, mean internode length, total dry weight, and number of flowers per plant of four *Passiflora* cultivars (Amethyst, Blue Bouquet, Fledermouse, and Lady Margaret), two months after application of Osmocote 14N–6.0P–11.6K (14–14–14) fertilizer.

Cultivar	Osmocote (g/L, oz/gal)	Shoots (no.)	Total shoot length (cm)	Mean shoot length (cm)	Nodes (no.)	Internode length (cm)	Biomass (g)	Flowers (no.)
Amethyst	3.2, 0.44	2.5a^z	202.0b	91.3a	54.4b	3.6b	11.4b	2.5b
	4.2, 0.58	3.1a	296.0a	116.0a	72.1ab	4.2ab	19.8a	4.9ab
	5.3, 0.73	3.5a	354.0a	117.0a	83.9a	4.3a	21.8a	7.1a
Linear		3.8^{NS}	14.6**	1.4^{NS}	10.3**	4.8*	30.5**	5.8*
Quadratic		0.1^{NS}	0.3^{NS}	0.4^{NS}	0.1^{NS}	1.2^{NS}	4.0^{NS}	0.0^{NS}
Blue Bouquet	3.2, 0.44	7.3c	330.0b	48.0a	87.0b	3.8b	18.7c	0.2a
	4.2, 0.58	9.1b	378.0b	42.0b	100.0b	3.8b	23.0b	0.3a
	5.3, 0.73	11.7a	493.0a	42.1b	118.0a	4.2a	27.9a	0.2a
Linear		29.2**	21.8**	5.0*	12.6**	5.1*	26.4**	0.1^{NS}
Quadratic		0.3^{NS}	1.3^{NS}	2.0^{NS}	0.1^{NS}	3.0^{NS}	0.0^{NS}	0.4^{NS}
Fledermouse	3.2, 0.44	4.8a	432.0a	103.7a	75.5a	5.7a	13.6a	0.5a
	4.2, 0.58	5.2a	469.0a	97.3a	79.0a	5.9a	16.5a	0.6a
	5.3, 0.73	4.9a	445.0a	105.8a	76.2a	6.0a	14.4a	0.1a
Linear		0.0^{NS}	0.1^{NS}	0.0^{NS}	0.0^{NS}	1.0^{NS}	0.1^{NS}	0.5^{NS}
Quadratic		0.3^{NS}	0.6^{NS}	0.5^{NS}	0.3^{NS}	0.1^{NS}	1.6^{NS}	0.4^{NS}
Lady Margaret	3.2, 0.44	2.2b	166.0b	78.8a	47.9b	3.5a	18.7b	12.3a
	4.2, 0.58	2.5b	186.0ab	76.3a	53.3ab	3.6a	23.9a	15.2a
	5.3, 0.73	3.4a	208.0a	67.7a	60.2a	3.5a	23.0ab	14.9a
Linear		16.1**	9.2**	2.0^{NS}	5.5*	0.0^{NS}	4.2*	0.4^{NS}
Quadratic		0.8^{NS}	0.0^{NS}	0.2^{NS}	0.0^{NS}	0.1^{NS}	2.9^{NS}	0.2^{NS}
Factorial treatments — analysis of variance — F-values								
Cultivar		117.0**	47.3**	43.8**	33.1**	111.0**	23.7**	84.6**
Osmocote		10.0**	10.5**	0.1^{NS}	8.9**	3.8*	18.5**	1.8^{NS}
Culivar × Osmocote		4.7**	2.5*	1.1^{NS}	1.8^{NS}	0.9^{NS}	2.9**	1.0^{NS}

^{z}Means within each column for each cultivar followed by the same letter(s) are not significantly different (Waller-Duncan K-ratio t-test $P = 0.05$).

^{NS},*,**, indicates non significant, significant at $P \leq 0.05$, and $P \leq 0.01$, respectively.

Table 3. Averages of shoot number, total shoot length, mean shoot length, number of nodes, mean internode length, biomass (dry weight), and number of flowers per plant from two *Passiflora* cultivars (Amethyst and Blue Bouquet), two months after application of Osmocote 14N–6.0P–11.6K (14–14–14) fertilizer, and paclobutrazol.

Source of variation	Shoots (no.)	Total shoot length (cm)	Mean shoot length (cm)	Nodes (no.)	Internode length (cm)	Biomass (g)	Flowers (no.)
Cultivar							
'Amethyst'	3.3b[z]	357.0a	101.0a	70.0b	3.8a	14.4b	3.9a
'Blue Bouquet'	8.9a	270.0b	41.7b	97.5a	3.6b	18.8a	0.2b
Osmocote (g/L, oz/gal)							
3.2, 0.44	5.4c	262.0c	70.0a	74.3c	3.5b	13.6c	1.1b
4.2, 0.58	6.6b	317.0b	66.4a	86.2b	3.7b	17.5b	1.4ab
5.3, 0.73	8.4a	395.0a	64.6a	101.0a	4.0a	20.4a	2.3a
Paclobutrazol (ppm)							
0	7.1a	360.0a	67.8a	90.0a	4.0a	21.3a	2.0a
50	6.5a	288.0b	60.1a	84.0a	3.4b	13.0b	1.2b
Factorial treatments — analysis of variance — F-values							
Cultivar	247.0**	29.7**	136.0**	48.7**	7.0**	39.9**	98.8**
Osmocote	16.3**	21.9**	1.2NS	13.9**	9.2**	29.4**	6.0**
Linear	32.4**	43.6**	1.2NS	27.8**	18.4**	57.9**	11.3**
Quadratic	0.4NS	0.3NS	1.2NS	0.1NS	0.0NS	0.7NS	0.7NS
Cultivar × Osmocote	8.9**	0.2NS	2.9NS	0.4NS	0.9NS	0.2NS	6.0**
Paclobutrazol	0.6NS	13.7**	3.6NS	1.3NS	39.7**	129.0**	7.2**
Cultivar × paclobutrazol	4.4*	3.9NS	1.0NS	1.0NS	4.6*	3.3NS	54.6*
Osmocote × paclobutrazol	0.2NS	1.3NS	0.2NS	0.6NS	0.4NS	9.1**	1.8NS
Cultivar × Osmocote × paclobutrazol	0.1NS	0.9NS	0.2NS	0.3NS	3.5*	2.0NS	1.8NS

[z]Means for each main effect in a column followed by the same letter(s) are not significantly different (Waller-Duncan K-ratio t-test $P = 0.05$).
NS,*,**, indicates non significant, significant at $P \leq 0.05$, and $P \leq 0.01$, respectively.

netic backgrounds. 'Amethyst' may be a hybrid of blue passion flower (*P. caerulea*) and an unknown species and is tolerant of short periods with temperatures near freezing (19). Similarly, 'Blue Bouquet' *(P. caerulea* x *P.* 'Amethyst') can also withstand low temperatures. 'Fledermouse' *(P. biflora* x *P. perfoliata*) is a vigorous vine that produces two flowers at each node. 'Lady Margaret' (*P. coccinea* x *P. incarnata*) is a relatively new hybrid. One of its parents, may pops (*P. incarnata*), is native to parts of the United States and is the hardiest of all known passion flowers. The other parent, red granadilla (*P. coccinea*), is a very vigorous, large vine with heavy leaves and stems. 'Lady Margaret', because of its parentage, is a vigorous, free flowering vine that blooms early in the season and withstands cooler temperatures.

In the 2002 experiment all of the passion flower cultivars evaluated showed increased total shoot growth with increasing fertilizer concentration except 'Fledermouse', which did not respond to fertilizer at the rates tested (Table 2). The concentration of Osmocote that resulted in the greatest total shoot length was 5.3 g/liter (0.73 oz/gal) for all responsive cultivars. This is higher than the amount of Osmocote recommended by the manufacturer, which is between 1.3 and 4.7 g/liter (0.18 and 0.65 oz/gal) for container grown herbaceous and woody plants. It is clear that the levels of fertilizer that can be utilized by these aggressively growing tropical vines are relatively high compared typical container grown nursery plants. For example, Cabrera and Perdomo (3) determined that the optimal rate of Osmocote was 2.6 g/liter (0.36 oz/gal) for six container grown herbaceous perennials, while Graca and Hamilton (6) determined that 2.0 g/liter (0.27 oz/gal) was optimal for container grown spreading cotoneaster (*Cotoneaster divaricata* Rehd & Wils.). Joiner et al. (9) found that growth and flowering could be optimized in *Bougainvillea glabra* by applying 300 lb N/acre, which is equivalent to 1.5 g/liter (0.21 oz/gal) of Osmocote 14N–6.0P–11.6K (14–14–14). Also, with regard to shoot growth, because it did not appear to level off at higher rates, the three responsive cultivars might respond to even higher concentrations of fertilizer.

The increase in growth with increasing concentrations of fertilizer is consistent with studies with field and container grown edible passion flower (11, 18). It has also been shown that a young edible passion flower plants, developing large amounts of vegetative and root growth, will have nutrient uptake that is nearly double that of mature plants (8).

In this study, in addition to data presented in the tables, data for all parameters measured non-destructively were collected one month after treatment application. At this earlier assessment date cultivar appeared to have the most significant effect of all possible sources of variance (data not shown). From these results it was apparent that at higher fertilizer rates, the greater response to fertilizer concentration was seen in the second month of growth. This may be due to the lower temperatures experienced by these plants during the first month of outdoor production, which may have limited growth in these tropical plants. The three cultivars selected for their relative tolerance to cold temperatures produced between 28 and 31% of their overall shoot growth during the first month, while the least chilling tolerant cultivar ('Fledermouse') produced less than 20%.

The colder growing conditions may also have limited fertilizer availability. Controlled release fertilizers such as Osmocote can increase nutrient release by as much as 30% for every 10C (50F) increase in temperature (10). An additional compounding effect is that low temperatures have been shown to inhibit mineral nutrient uptake in edible passion flower (12, 13). Although nutrient uptake at cool temperatures was considered marginally adequate for plant growth, nutrient uptake and growth was increased at higher temperatures. In edible passion flower, growth was negatively affected when substrate temperatures remained below 18C for any extended period of time (14).

Paclobutrazol and other plant growth regulators are widely used on a commercial basis to control vegetative growth (15). In both years of this study paclobutrazol application resulted in reduced total shoot length, internode length, and biomass (Tables 1 and 3), thereby producing more compact plants. Paclobutrazol has also been shown to promote precocious flowering, and increase the number of flowers in some plants. However, plant response to these products is not consistent, and in some cases flowering is delayed. Banko and Bir (1) found that paclobutrazol promoted a moderate increase in flower number in some cultivars of mountain laurel (*Kalmia latifolia* L.), and in yarrow (*Achillea* x 'Coronation Gold') flowering was accelerated by 3–6 days (2). Similarly, paclobutrazol increased the quantity and consistency of flowers on *Eucalyptus nitens* and this response was enhanced by increasing fertilizer (20). In contrast, Deneke et al (4) determined that uniconazole reduced plant height but increased the time to flower for the vigorous tropical vine, mandevilla (*Mandevilla* x *amoena* 'Alice du Pont'), while there was no impact on flowering time of flower number on paclobutazol-treated carnations (*Dianthus caryophyllus* L.) (5). Although paclobutrazol application had a significant negative impact on flowering in the 2002 experiment, the response was mainly due to cultivar differences, with 'Blue Bouquet' performing poorly compared to 'Amethyst'. When examined over both years, the most important conclusion of the effects of paclobutrazol on flowering was that it did not increase the number of nodes or flowers.

This study demonstrates that selected passion flower cultivars can be successfully grown to a salable size as a single season crop. For this four month production cycle, cultivar choice is critical, and it appears that cultural practices, particularly fertility management need to be optimized for each cultivar and growing location. Results from this study revealed that 'Lady Margaret' and 'Amethyst' produced the highest number of flowers and were considered more appropriate cultivar selections compared to 'Fledermouse' and 'Blue Bouquet'. Fertilizer impacted both plant size and flowering and should be applied at relatively high rates compared to typical container grown nursery crops. Paclobutrazol was effective at reducing plant height, but did not increase node production or flowering. Since these plants can be trellised in the container, reducing growth is unnecessary if flowering is not increased. Therefore the use of paclobutrazol would not be recommended for this production system.

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