PASSION FRUIT (*PASSIFLORA EDULIS*) TRANSPLANT PRODUCTION IS AFFECTED BY SELECTED BIOSTIMULANTS

J. Pablo Morales-Payan[1] and William Stall
University of Florida
Horticultural Sciences Department
P.O. Box 110690
Gainesville, FL 32611

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Abstract. **Research was conducted to determine the effects of foliar applications of the growth stimulators gibberellic acid 3 (GA; 0, 10, 20, 30, 40 mg L^{-1}), acetylthioproline (AP; 100, 200, 300, and 400 mg L^{-1}), benzyladenine (BA; 10, 20, 30, 40 mg L^{-1}), and a glycine-rich complex of amino acids and short-chain peptides (APC; 100, 200, 300, and 400 mg L^{-1}) on the growth of purple passion fruit (*Passiflora edulis* Sims.) seedlings for transplants. The growth stimulators were sprayed on the passion fruit leaves 15 days after emergence. Plant height and leaf and tendril number were determined weekly to establish the time between seedling emergence and the adequate transplanting stage. Adequate short transplants were defined as having at least four leaves, at least one tendril, and 25 cm in length. Adequate long transplants had at least four leaves, at least one tendril, and 50 in length. Regardless of rate, BA did not affect passion fruit seedling growth. In contrast, increasing APC, AP, and GA rates reduced the time from seedling emergence to the adequate transplanting stage. The best results were found when using APC at the rates of 300-400 mg.L^{-1}, which resulted in shortening the time for adequate transplant production by 26% as compared to untreated plants.**

The passion fruit (*Passiflora edulis* Sims.) is a plant species originated in South America grown commercially in many tropical and subtropical regions (Morton, 1987; Vanderplank, 1996). Worldwide commercial passion fruit production in 2001 was estimated at 600,000 t. The leading countries in passion fruit production are Brazil (300,000 t), Ecuador (125,000 t), Colombia (25,000 t), Peru (15,000 t), Indonesia (20,000 t), India/Java/Vietnam (10,000 t), Kenya/Uganda/South Africa (10,000 t), and Australia/New Zealand/Fiji (10,000 t) (Coppens d'Eeckenbrugge and Librados, 2000; Vanderplank, 1996). In 2000, an estimated 15,000 t of passion fruit juice concentrate were placed in the international market by producing countries, and approximately 92% was absorbed by the European Union (70%) and the US (22%) (Coppens d'Eeckenbrugge and Librados, 2000). In the US, commercial passion fruit production occurs in Hawaii, Florida, Puerto Rico, and the US Virgin Islands, but domestic production supplies a small percentage of the passion fruit juice demand. Rosson and Adcock (2000) estimated that in 1999 passion fruit juice represented 1-2% of all the fruit juice imported into the US, with 9 to 18 million gallons of passion fruit juice being imported annually in the 1990s. Most of the passion fruit juice was consumed blended with other tropical fruit juices, and the supply was dominated by the companies Snapple, Hydroline, Smucker's, Campbell's, and Shasta/Everfresh (Rosson and Adcock, 2000).

Commercial passion fruit is commonly established with transplants grown from seed (Morton, 1987). There are two major reasons for using transplants as opposed to direct seeding in the field: (1) Seedlings have a slow growth rate during the first 2-3 months after emergence (and hence have low competitive ability with weeds), and (2) while transplants are being produced in a nursery, growers can use the land for other crops. In regions where cold temperatures occur during parts of the year, an additional advantage of using transplants is to shorten the passion fruit growing season in the field by at least two months.

Stem cuttings, grafted or not, may be used to produce transplants. Cuttings ensure the plants will be true to the desired variety and may shorten the time from transplanting to harvest (Pio et al., 2001). However, asexual propagation is not advisable unless there is certainty that the propagation material is virus-free (Morton, 1987; Knight and Sauls, 1994). Thus, in areas prone to viral epidemics, transplants grown from seeds in protected nursery structures are preferred (Knight and Sauls, 1994).

Passion fruit transplants are considered adequate for transplanting to the field when the plants have at least four true leaves, at least one tendril, and a stem length of 25 to 50 cm, which takes approximately 60 to 120 d after seedling emergence (Chacón Arango, 1991; Coppens d'Eeckenbrugge and Librados, 2000; Knight and Sauls, 1994; Morton, 1987; Vandeplank, 1996). Since first harvest occurs approximately 270-300 d after transplanting (Coppens d'Eeckenbrugge and Librados, 2000; Morton, 1987), acceleration of growth and development at any stage of the crop is desirable, especially in areas where cold injury is likely to occur late in the crop season.

Documented research regarding the use of growth regulators and biostimulants in passion fruits is scarce, and most reports deal with post-harvest delay of fruit senescence (Pereira Da Silva et al., 1999) or micropropagation (Isutsa, 2003; Kantharajah and Dodd, 1990; McKenzie, 1990). In contrast, there is more abundant documented research on plant size manipulation in ornamental *Passiflora* spp. Sanderson et al. (1989) found that stem height of ornamental *P. edulis* was significantly shortened by the growth retardant ancymidol. However, those authors also found that neither ancymidol nor flurprimidol caused significant stem length reductions in *P. caerulea*, which has more vigorous vines than *P. edulis*. The use of indole butyric acid (IBA) to promote adventitious rooting in the ornamental *P. caerulea* × *P. amythestina* was reported by Geneve et al. (2001). Paclobutrazol soil drenches were found to restrain stem elongation in *P. caerulea* × *P. amythestina* (Geneve et al., 2001; Hale et al., 2001) and *P. caerulea* × *P. edulis*, but not in *P.* × *violacea*. (Hale et al., 2001). Moreover, multiple paclobutrazol soil drench applications were more effective than single applications to reduce stem height in *P. caerulea* × *P. amythestina* (Berberich et al., 2002).

The research by Hale et al. (2001), Geneve et al. (2001), Berberich et al. (2002), and Sanderson et al. (1989) showed

[1]Corresponding author.

that the growth of ornamental *Passiflora* spp. can be retarded using exogenous growth regulators. However, passion fruit growers would be interested in accelerating early growth to shorten the nursery stage and possibly the time from transplanting to first harvest. Research-based information is available about transplant growth regulation in other tropical fruit crops such as papaya (*Carica papaya* L.), Caribbean cherry (*Malpighia* spp.), Spanish lime or limoncillo (*Melicoccus bijugatus* Jacq.), sapodilla (*Achras sapota* L.), tamarind (*Tamarindus indica* L.), and golden apple (*Spondias dulcis* Parkinson). In papaya, transplant growth was accelerated by foliar applications of ethanol and gibberellic acid 3 (Morales-Payan et al., 1998), but not by soil-applied humic acid (Morales-Payan and Stall 2003). In sapodilla, tamarind, golden apple, Spanish lime, and Caribbean cherry, gibberellic acid increased plant height and reduced the time to produce adequate size transplants (Morales-Payan and Santos, 1997a, b). In purple passion fruit, two seaweed (*Ascophyllum nodosum*)-based biostimulants were found to accelerate transplant growth in an organic system (Morales-Payan, 2004). However, little is known regarding the influence of other physiological regulators and biostimulants on the growth of purple passion fruit during the nursery stage. For example, commercially available biostimulants based on amino acids and other natural compounds have been reported to accelerate plant growth and improve stress tolerance (Bueno Soto, 1985; Villacres Vallejo, 1992; Williams, 1984). The objective of this study was to determine the effects of the growth stimulants acetylthioproline, gibberellic acid 3, benzyladenine, and a glycine-rich mixture of amino acids and short-chain peptides on the growth of purple passion fruit transplants.

Materials and Methods

The research was conducted in a greenhouse in Gainesville, Fla. in 2003. Purple passion fruit seedlings were grown from seed in 0.5-L styrofoam containers filled with a commercial growing medium (30% sphagnum peat moss, 20% perlite, 50% vermiculite). Purple passion fruit seedlings were watered daily (100 mL per container) and fertilized with a total of 0.75 g of N, P, and K per container. During the experiment, maximum and minimum temperatures were 27.4 °C and 22.9 °C, respectively, and average photosynthetically active radiation (PAR) at noon was approximately 1650 µmol m^{-2} s^{-1}.

The treatments were foliar applications of the growth stimulators acetylthioproline (AP) (0, 100, 200, 300, and 400 mg L^{-1}), gibberellic acid 3 (GA) (10, 20, 30, and 40 mg L^{-1}), a glycine-rich mix of amino acids and short-chain peptides (APC) (100, 200, 300, and 400 mg L^{-1}), and benzyladenine (10, 20, 30, and 40 mg L^{-1}). The growth stimulators were sprayed on the passion fruit leaves 15 d after emergence. The treatments were established in a completely randomized design with 10 replications, in which one passion fruit seedling was an experimental unit.

Adequate short transplants were defined as having at least four true leaves, at least one tendril, and 25 cm in height. Adequate long transplants were defined as having at least four true leaves, at least one tendril, and 50 cm in height. Transplant plant height, leaf number, and tendril number were determined weekly during 12 weeks, and the time from seedling emergence to adequate height, leaf and tendril number for shot and long transplants was determined for each treatment. Analysis of variance and regression (5% significance level) were conducted on the data (StatSoft, 1997).

Results and Discussion

The growth of purple passion fruit seedlings was affected by AP, APC, and GA treatments, but not by BA. In seedlings without growth stimulator treatment (control) and in those treated with BA, short transplants were ready (at least four leaves, at least one tendril, and 25 cm in length) approximately 53 d after emergence, whereas long transplants (at least four leaves, at least one tendril, and 50 cm in length) were ready approximately 76 d after emergence (Fig. 1).

The time to produce adequate purple passion fruit transplants was shortened exponentially as APC rates increased from 0 to 300 mg L^{-1}. At the rates of 300-400 mg L^{-1}, APC reduced the time necessary to produce short transplants from 53 d to 43 d, and long transplants from 76 d to 56 d (Fig. 1). The effect of APC may be attributed to its free amino acids (mainly glycine) and peptides, which are involved in mitochondrial activity, stress tolerance, nitrogen metabolism and new plant tissue production (Taylor et al., 2004; Wallsgrove, 1995). In other experiments, foliar applications of APC increased plant growth and yield in almond (*Prunus amygdalus* L.) (Viti and Bartolini, 1998), papaya (Morales-Payan and Stall, 2003), and olive (*Olea europea* L.) (Viti et al., 1989). Our results with APC are comparable to the effects of two seaweed (*Ascophyllum nodosum*)-based biostimulants on purple passion fruit seedling growth, which reduced the time from seedling emergence to adequate transplant stage by 20 d (Morales-Payan, 2004).

Increasing GA rates also reduced the time between passion fruit emergence and the adequate transplant stage. As GA rates increased from 0 to 40 mg L^{-1}, the time period between seedling emergence and adequate transplant stage decreased linearly from 76 d to 60 d (long transplant), and from 53 to 47 d (short transplant) (Fig. 2). GA is involved in cell growth and stem elongation (Phinney, 1983; Yabuta and Sumiki, 1938); the GA effect on stem elongation was evident in our experiments, since GA-treated passion fruit seedlings reached the desired plant height for the two transplant categories (25 or 50 cm) within one month from application (data not shown). Nevertheless, GA-treated seedlings did not reach the required number of true leaves (at least four leaves) to satisfy the adequate transplanting criteria until 47 d (short transplant) and 60 d after emergence (long transplant).
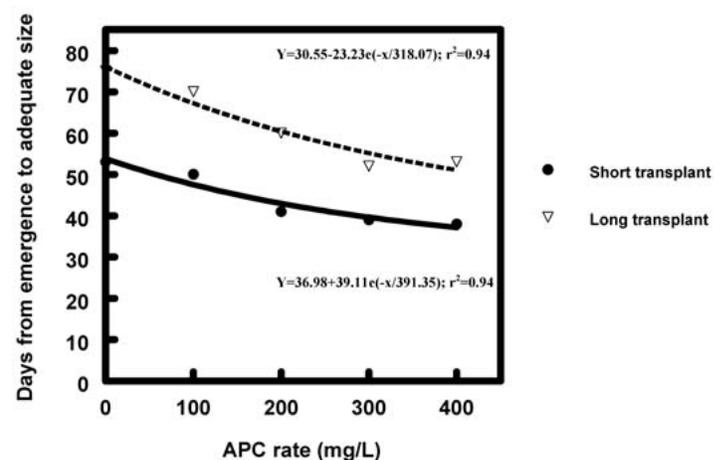

Fig. 1. Effect of a glycine-rich mixture of amino acids and short-chain peptides (APC) rates on the time to produce adequate short (25 cm in length) and long (50 cm in length) passion fruit transplants.
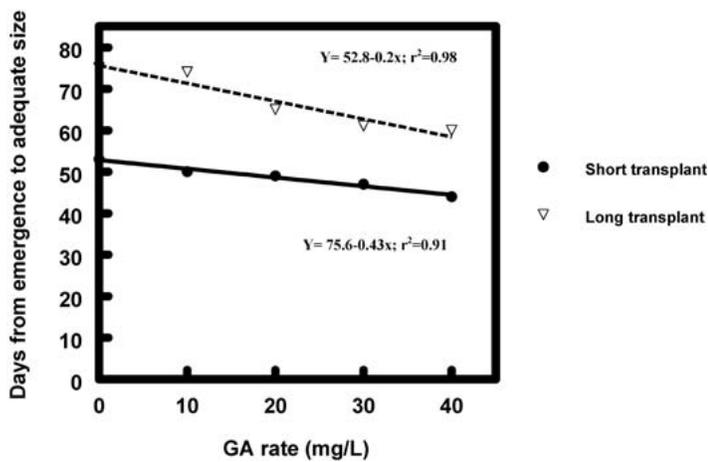
Fig. 2. Effect of gibberellic acid 3 (GA) rates on the time to produce adequate short (25 cm in length) and long (50 cm in length) passion fruit transplants.

In AP-treated passion fruit seedlings, the time from emergence to adequate transplant stage as a function of AP rates followed a pattern similar to that of GA-treated transplants (Figs. 2 and 3). As AP rates increased from 0 to 400 mg L^{-1}, the period of time necessary for passion fruit seedlings to reach the adequate transplanting stage decreased linearly from 76 to 60 d (long transplants) and from 53 to 46 d after emergence (short transplants). However, GA-treated seedlings attained the required plant height before they reached the required number of leaves for adequate transplant stage, whereas in AP-treated passion fruit seedlings reached the adequate leaf number before they attained the necessary plant height (data not shown). AP has been associated with increased nutrient uptake, increased mitochondrial activity, and increased anti-oxidant activity in some enzymatic systems. Also, AP has been shown to be involved in the metabolism of amino acids, glutathione, and sulfur in plants, which may be associated with the accelerated growth rate exhibited by some plant species when treated with AP (Oeriu et al., 1969; Schmidt and Jäger, 1992; Wallsgrove, 1995).

From the horticultural perspective, our results show that AP, APC and GA may be useful in shortening the nursery
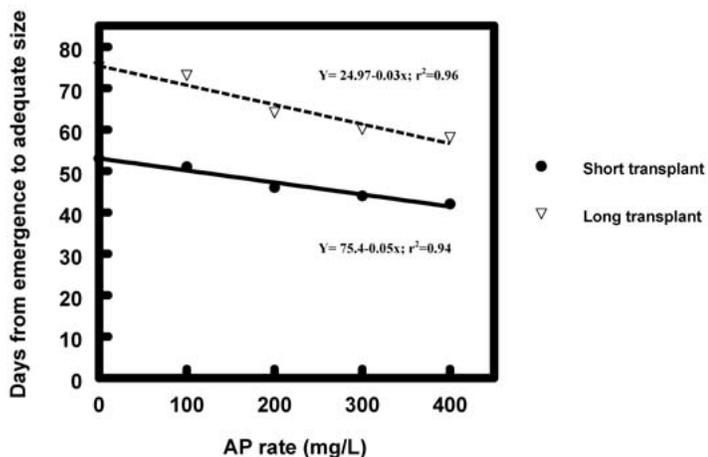

Fig. 3. Effect of acetylthioproline (AP) rates on the time to produce adequate short (25 cm in length) and long (50 cm in length) passion fruit transplants.

stage in purple passion fruit, particularly when producing long transplants. In our experiments, the best results were found when using APC at the rates of 300-400 mg L^{-1}, which reduced the time from emergence to transplanting stage by nearly three weeks (or approximately 26%) for long transplants. While the effects of GA on the time required from emergence to the adequate transplanting stage were less dramatic than those of APC, by the time that all the transplanting requirements had been met, GA-treated transplants were taller than APC- and APC-treated transplants. In a vine crop such as passion fruit, establishing the crop with taller transplants may be advantageous, since those plants are more likely to climb and cover the trellis system faster than shorter plants, thus avoiding early competition for light from weeds and developing a high canopy that will in turn cast shade on the weeds. Future research will study the effects of other growth stimulators individually and in combination, and their possible interactions with fertilizers on the growth and quality of purple passion fruit transplants.

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