Field Performance and Phenotypic Variation of *Passiflora incarnata* L. in New York State

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Abstract. *Passiflora incarnata* L., a perennial vine native to southeastern North America, bears fruit containing an edible juice. I observed the growth, flowering, fruit yield, and fruit traits of *P. incarnata* plants grown in the field for one season in Ithaca, N.Y. Plants flowered throughout the summer and were pollinated by carpenter bees, but fruit set was low without additional hand-pollination. Fruits set before mid-August matured in 52 to 113 days, but fruits set after mid-August usually failed to mature. Following hand-pollination of some flowers, plants matured 0 to 14 fruits, and yield of edible juice was 5 to 10 mL per fruit. Vegetative growth, plant architecture, number of flowers produced, number of fruits matured, days from flower opening to fruit maturity, fruit size, the proportion of fruits filled with juice and seeds, and the size of juice-containing arils all varied greatly among plants. Part of this variation was probably genetic.

Passiflora incarnata L., the maypop, is occasionally cultivated for its large, colorful, and sweet-scented flowers as well as its edible fruits containing an aromatic juice (Vanderplank, 1996). Plant breeders have also used *P. incarnata* as a source of cold tolerance in breeding *P. edulis* Sims, the cultivated passionfruit (Knight, 1991; Otoni et al., 1995). *P. incarnata* is native to the southeastern United States from Virginia and Florida in the east to Kansas and Texas in the west (Killip, 1960). An herbaceous perennial vine, it overwinters via underground shoot initials (Wehtje et al., 1985). Large, showy flowers remain open for ≈24 hours and are produced during much of the growing season (May and Spears, 1988). The fruits, which abscise when mature, contain seeds individually surrounded by arils holding an edible juice. To assess *P. incarnata*'s horticultural potential, I evaluated its field performance and phenotypic variation, both of which are largely unknown, in Ithaca, N.Y., north of its native range. Although *P. incarnata* is not winter hardy in this area (C. McGuire, unpublished data), this research is still valuable in evaluating *P. incarnata*'s potential in warmer climates and its potential as a cold-climate annual crop.

Materials and Methods

In 1996, 43 live *P. incarnata* plants were obtained from commercial nurseries, and 73 seedlings were raised from seed saved from the author's previous plantings or obtained from collections made at Pine Mountain, Ga.; Muscogee Co., Ga.; and Auburn Univ., Ala. Seeds were sown in the greenhouse on 30 Mar. after soaking for 24 h in water to enhance germination (Wehtje et al., 1985); seedlings were maintained in 1-L pots of 4 peat : 1 perlite (by volume). Plants obtained from commercial nurseries were temporarily held in the greenhouse. All plants were hardened off outdoors for 1 week and then transplanted to the field in late May and early June. The field site was at Cornell Orchards, Ithaca, N.Y., in an Arkport fine sandy loam soil. Plants were planted 1 m apart along a 2.5-m-high wire fence. Weeds were removed in a 0.5-m strip on each side of the fence, and no irrigation or fertilizer was applied in the field. To ensure fruit set in this self-incompatible species (May and Spears, 1988), flowers were hand-pollinated

soon after opening every 2–3 d until 14 Aug.; flowers opening on other days were open-pollinated. For hand-pollinations, multiple pollen parents were used to pollinate each flower, and no attempt was made to exclude insects from flowers. Flowers were tagged with the date of opening to allow calculation of days to fruit maturity. When mature fruits abscised, their length and width were measured, and they were stored at 13 to 21 °C until they developed a conspicuous ripe aroma (<2 weeks); juice was then extracted by pressing the fruit interior through a fine wire mesh. Before juice extraction, fruits were scored for average aril size and fruit fill (proportion of the fruit interior filled with arils and developed seeds). Fruit fill was not recorded for fruits partially consumed by animals in the field. Because the growth of plants obtained from commercial nurseries was probably influenced by mode of propagation, only plants raised from seed are included in evaluations of vegetative growth and the number of flowers and fruits produced.

Results and Discussion

Passiflora incarnata seedlings emerged 2 to 4 weeks after sowing. Starting early in seedling development, and continuing through much of the summer, plants initiated new shoots from axillary meristems of leaves and cotyledons, from the hypocotyl, and from underground. The extent of new shoot initiation and final main stem length varied greatly among plants grown from seed (Table 1), and overall plant architecture ranged from dense and bushy to open and unbranched. This variation did not appear to be caused by herbivory or disease.

Flower production by seedling *P. incarnata* plants began in early June, increased through early September, then decreased, and usually ended before killing frosts in October. Seedling plants bore varying numbers of flowers (Table 1). Most individuals bore predominantly pink to lavender flowers, with varying tint and banding patterns, but one plant bore entirely white flowers. The only pollinators observed were carpenter bees (*Xylocopa* sp. or spp.), which did not become abundant at the site until mid-August. Fruit set on flowers opening before 15 Aug. was 55% for hand-pollinated flowers, but <10% for open-pollinated flowers. After 15 Aug., percent fruit set

Table 1. Variation among *P. incarnata* plants in growth, flower and fruit production, and fruit traits.

Plant characteristic	Mean ± SD among plants	Range among plants
Final main stem length (cm) ²	280.7 ± 60.5	150–390
Number of flowers opening 1 June–15 Aug. ²	33.4 ± 16.6	6–83
Number of fruit abscised at maturity during 1996 ²	5.0 ± 2.7	0–14
Mean days from flower opening to mature fruit abscission ²	76.6 ± 10.4	52.0–96.0
Mean fruit length (mm) ²	49.7 ± 5.9	31.0–65.3
Mean fruit width (mm) ²	41.5 ± 4.2	30.0–50.8
Mean fruit fill ^{2,3}	4.1 ± 0.9	1.0–5.0
Mean aril size ^{2,4}	3.1 ± 1.2	1.0–5.0

²Only plants raised from seed included. Data recorded from 73 plants.

³All fruiting plants included. Data recorded from 87 plants.

⁴Each matured fruit scored from 1–5: 1 = fruit poorly filled; 5 = fruit interior full.

⁵Each matured fruit scored from 1–5: 1 = arils only slightly larger than their enclosed seeds; 5 = arils much larger than their enclosed seeds.

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was not measured, but it appeared to increase for open-pollinated flowers.

Mature fruits abscised 52–113 d after flower opening, from early August until mid-November (data not shown). A data-suggested linear regression revealed that fruits developing from flowers opening later in the season took longer to mature ($r^2 = 0.257$; $P < 0.001$), possibly because of cooler weather in late summer and autumn. Fruits set after mid-August almost always failed to mature before shoots died in autumn. Both mean days from flower opening to mature fruit abscission and number of fruit matured varied between plants (Table 1).

At mature abscission, fruits were oblong to subglobose, sometimes tapering distally, and the rind exterior was thin, pliable, and yellow to green, sometimes with three maroon longitudinal stripes extending for part of the fruit's length and sometimes with three or six shallow longitudinal sutures. During storage, the rind sometimes became wrinkled and stiff. Individual plants differed in mean fruit dimensions (Table 1), shape, color, and rind thickness. Plants also differed in mean fruit fill and aril size (Table 1), which are likely the two main components of juice yield per fruit. Total juice yield of fruit batches was measured on several occasions, and mean juice yield per fruit was 5–10 mL, higher than the 1–6 mL

juice yield previously reported for fruits of wild, open-pollinated *P. incarnata* (Senter et al., 1993). The higher juice yield in this study may have been due to greater seed set and fruit fill resulting from hand-pollination. Fruits developed a pleasant aroma during storage, and juice flavor was slightly sweet, very aromatic, and delicious. Flavor varied between fruits, but there were no obvious consistent differences in fruit flavor between plants.

Herbivores, probably small mammals, severely damaged several plants in early summer, reducing their eventual growth, flowering, and fruiting. Japanese beetles (*Popillia japonica* Newman), and an unidentified true bug (order *Hemiptera*) fed on floral buds and flowers, occasionally causing flower abortion. Frugivores, likely mammals, sometimes consumed large portions of mature abscised fruit before they were collected.

The attractive flowers and delicious juice flavor observed here show that *P. incarnata* has horticultural potential. Despite its inability to overwinter in colder temperate regions, it can bear flowers and fruit as an annual crop. However, inadequate insect pollination and the failure of many fruits to ripen in autumn can hinder fruit production. The observed phenotypic variation in plant habit and flower and fruit traits suggests that proper cultural prac-

tices or human selection can improve these traits in *P. incarnata*.

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