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Development of Tetraploid Hybrid Passion Fruit Clones with Potential for the North Temperate Zone

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Abstract. **When *Passiflora incarnata* L. was crossed with *P. edulis* f. *flavicarpa* Degener, all plants of the diploid hybrid were pollen-sterile and nonfruitful. Doubling the chromosome number of emergent F_1 seedlings with colchicine restored fertility in some individuals, but all plants were strongly self-incompatible and many showed low pollen viability. Crossing colchicine-treated plants that had been converted to amphiploids produced a tetraploid hybrid group of four seedling progenies that had some degrees of cross-compatibility. Juice of the amphiploid hybrid is lighter in color than that of *P. edulis*, but is sweet, strongly aromatic, and may have use alone or, typically, as a blend with other juices.**

In 1971, a clone of maypop *(Passiflora incarnata)* collected in Tennessee was crossed with *P. Cincinnati* Masters (P.I. 98883), a passion vine from Argentina with spectacularly colorful flowers. The F, hybrid, named 'Incense', was released in 1973 (U.S. Dept. of Agriculture, 1976) and continues to be sold in the nursery trade. 'Incense' combines the ornamental value of its pollen parent with the ability of *P. incarnata* to survive temperate-zone winters in the vicinity of Washington, D.C. (Winters and Knight, 1975). As with its seed parent, all aboveground parts of 'Incense' die in the first freezing weather of late autumn, but the vine resumes growth in spring and begins to flower in early summer. Some interest exists now in producing passion fruit in the temperate zone as an annual crop (Dozier et al., 1991). The survival of 'Incense' for several years in the Washington, D, C., area suggested the possibility of using *P. incarnata* as a source of winter hardiness to combine with the fruit quality of *P. edulis* and *P. edulis* f. *flavicarpa* to obtain an edible passion fruit for use as a perennial crop in temperate-zone climates. The hybrid between *P. incarnata* and *P. edulis* f. *flavicarpa* was obtained, but like 'Incense', it proved to be pollen-sterile (Knight, 1974).

The objective of the work reported here was to develop a group of fertile plants of interspecific hybrid origin, using *P. edulis* and *P. incarnata* as the parents, that would be capable of functioning as perennial fruit crop cultivars in temperate-zone climates to which forms *of Passiflora edulis-the* purple and yellow passion fruits—are not adapted. Because of sterility of such diploid interspecific hybrids (2n = 18; Darlington and Wylie, 1955), an initial and essential aspect of the overall objective was to recover fertility by doubling the chromosome number of F_1 hybrids to produce a group of tetraploid plants capable of crossing among themselves even though they could not be backcrossed to either of the diploid parental species because of the difference in ploidies. The tetraploid hybrid group had to have a genetic base sufficiently broad to permit germplasm enhancement through the selection of horticulturally superior seedlings for asexual propagation as clonal cultivars. The highest degree of enhancement envisioned was the development of a group of cross-compatible cultivars combining the cold tolerance common in *P. incarnata* with fruit quality equal to the best now available in improved cultivars of *P. edulis*. This paper documents the progress to date toward the stated objective.

In Summer 1979, a clone of *P. incarnata* collected by H.F. Winters in Maryland was crossed with three introductions of *P. edulis:* P.I. 424813, a purple-fruited form collected wild in Brazil; *P. edulis* f. *flavicarpa* (M-17236, yellow-fruited); and an intraspecific hybrid (M-21471) derived from crossing a purple-fruited strain from Australia, 'Norfolk Island', with a clone of *P. edulis* f. *flavicarpa* (P. I. 243804) brought to Florida from Trinidad (Table 1). Seedlings from these crosses were treated upon emergence with a 0.2% aqueous solution of colchicine to double ploidy and thus restore fertility. When the vines began to flower in Spring 1980, I evaluated pollen fertility and tried to obtain successful pollinations because none of the treated plants proved to be self-compatible. Three of the colchicine-treated seedlings were successful seed parents and four succeeded as pollen parents (Table 1). The seven fertile colchiploids were intercrossed to produce four families of seedlings that were used in later work. One of these, M27461 (M26553A × M26654B), along with one of the original colchiploids, M26509A, was used to produce the progenies that were evaluated in

Table 1. Foundation clones and initial breeding of tetraploid *Passiflora* hybrids.

Cross	Seedling progeny no.	Colchicine-treated plants successful as	
		Seed parent	Pollen parent
M25341B (wild *incarnata*, MD) x P.I. 424813 (wild purple *edulis*, Brazil)	M26509	M26509A[z] M26509C	M26509A
M25314B (wild *incarnata*, MD) x M21471 (purple *edulis* x yellow *edulis*)	M26553	M26553A	0
M17236 (yellow *edulis*) x M25314C (wild *incarnata*, MD)	M26654	0	M26654B M26654D M26654F

[z]Different letters following a progeny number indicate different seedlings within a population.

Table 2. Tetraploid passion fruit clones used in pollination tests in 1985 and 1986.

Parental cross	Clone	Used as	
		Seed parent	Pollen parent
M27461L x M26509A	M30173H	x	x
	M30173J	x	---
M27461M x M26509A	M30174B	x	---
	M30174C	x	x
	M30174M	x	---
	M30174N	x	---
	M30174O	x	---
M27461L x M27461H	M30176B	x	---
M27461 x self	M30177B	x	---
	M30177D	x	---
	M30177E	x	---
	M30177J	x	---

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Table 3. Response of tetraploid hybrid *Passiflora* clones to pollination by clone M30173H and/or M30174C.

Seed parent	Pollen parent	Fruit wt (g)	Seed/fruit (no.)	Juice/fruit (ml)	Juice/seed (ml)
M30176B	M30173H	76.0 a[z]	90.0 a	25.3 a	0.2984[NS]
M30174M		51.9 b	48.8 b	11.3 b	0.2299
M30174C		36.5 b	28.0 b	7.3 b	0.2570
M30176A		34.8 b	24.5 b	9.1 b	0.3508
M30174N	M30174C	73.8 a	67.3 ab	12.6 ab	0.1912
M30176B		72.8 a	90.8 a	19.4 a	0.2147
M30173H		41.1 b	38.8 bc	8.0 b	0.2057
M30177B		32.8 b	25.0 c	5.5 b	0.2077

[z]Mean separation by Wailer-Duncan K ratio *t* test, $P = 0.05$.
[NS]Nonsignificant.

Table 4. Fruit characters of 10 tetraploid passion fruit clones.

Clone	Peel color[z]	Wt (g) n	Wt (g) Mean (range)	Seed no. n	Seed no. Mean (range)	Juice (ml) n	Juice (ml) Mean (range)	Total acidity ($g \cdot liter^{-1}$)	Soluble solids content (%)
M30173H	RMT	14	36.2 (18.5–52.0)	14	35.4 (12–60)	14	8.0 (2.2–14.0)	2.5	16.2
M30173J	M	14	55.0 (25.0–97.8)	14	56.2 (11–13)	14	8.5 (1.4–17.0)	2.6	15.5
M30174B	M	14	32.4 (12.0–73.0)	14	32.6 (2–99)	14	6.7 (1.2–21.0)	3.1	15.5
M30174M	M	15	32.6 (0.5–80.0)	12	50.3 (18–85)	12	9.4 (5.0–20.0)	2.8	13.2
M30174N	M	25	43.4 (6.0–95.0)	24	47.0 (4–129)	23	9.0 (0.5–21.0)	2.0	14.0
M30174O	M	9	37.8 (2.0–58.0)	8	39.8 (6–59)	8	8.8 (1.5–13.0)	4.4	17.2
M30176B	G	16	59.5 (13.0–84.0)	16	70.0 (91–117)	16	19.0 (1.5–31.5)	2.7	15.9
M30177B	GRT	9	26.7 (5.5–46.0)	9	19.4 (2–47)	8	5.5 (1.0–12.0)	2.6	15.8
M30177D	GRT	14	56.5 (33.0–88.0)	14	53.4 (14–97)	14	15.8 (7.8–17.5)	2.2	14.4
M30177E	GRT	11	52.6 (5.0–93.0)	11	50.5 (2–104)	11	15.5 (0.5–30.0)	3.4	16.2
Population means			43.3 ± 11.8		45.5 ± 14.2		10.6 ± 14.2	2.8 ± 0.68	15.4 ± 1.2

[z]G = green, M = maroon, R = red, T = mottled.

1985 and 1986 for horticultural characters and responses to pollination (Table 2). Individual fruit were gathered as they ripened, and juice was extracted by hand, using cheesecloth, and stored in screw-top glass vials at -20C until all samples could be analyzed. Root tips of 16 newly emerged seedlings of M27461 were fixed in 3 acetic : 1 alcohol (v/v), stained with acetocarmine, and their chromosomes were counted in accordance with standard laboratory procedure. Fifteen of these consistently showed a somatic number of 36, whereas one, M264611, had cells that varied in chromosome number from 34 to 36. Thus, a functioning tetraploid population had been achieved.

Efforts to use the seedlings of progeny M27461 in breeding began in Spring 1981 and continued through Summer 1983. At that time, accession numbers were assigned to 89 seeds from which the seedling clones examined in 1985 and 1986 were derived. One exceptional population, M30177, consisted of 17 seedlings resulting from a single self-pollination of M21471H, the only time self-pollination of a tetraploid passion fruit hybrid succeeded.

Without exception, all the amphiploid hybrids observed in 1985 and 1986 were strongly self-incompatible, indicating that a population of dependable pollinating insects will be needed wherever this crop is grown. Only a minority of the seedlings sampled were successful when their pollen was used in cross-pollinations, although all those that showed normal pollen were tried (Table 2). Means for fruit weight, number of seeds per fruit, juice per fruit, and juice per seed were separated by analysis of variance using the Duncan-Waller multiple range test (SAS Institute, 1985) for eight male-female combinations involving the two most successful pollinizers, M30173H and M30174C. The degree of fertility of various parental combinations involving these two pollinizers, as demonstrated by the number of seeds per fruit obtained, differed significantly (Table 3). One seed parent, M30176B, was highly successful with both pollen parents. M30176B yielded 90 seeds or more from either pollination and averaged 19.4 and 25.3 ml of juice/fruit, suggesting that, with adequate insect pollination, satisfactory yields can be expected in the field. When the two pollen parents were used in reciprocal cross-pollinations, both set fruit but neither demonstrated a high degree of cross-compatibility; the combination of M30173H x M30174C resulted in 39 seeds, whereas M30174C x M30173H yielded a mean of 28 seeds. Earlier observations that fruit weight and juice content of passion fruit *(P. edulis)* are directly related to the number of seeds matured are confirmed by the consistency of juice per seed in this tetraploid hybrid group.

In southern Florida, plants of the tetraploid hybrid group are similar to vines of *P. edulis* f. *flavicarpa* in that, after a normal winter, they start flowering in spring (from late April to May) and cease in late autumn (November or December). Thus, fruit ripening is scattered from summer to early winter.

Characteristics of 10 clones from the tetraploid hybrid group were compared for specific attributes. Peel color of ripe fruit varied from deep green (M30176B) to deep maroon (M30173J and all M30174 seedlings reported here) and, in some cases, was mottled-either dark red on a brown background (30173H) or dark red on a green background (all M30177 seedlings reported) (Table 4). Fruit weight varied from 0.5 to 97.8. The number of seeds per fruit in the plants observed ranged from one to 129. The amount of juice per fruit ranged from 0.5 to 31.5 ml. Total acidity of juice (expressed in grams per liter) ranged from 2.0 for M30174N to 4.4 for M301740. Total soluble solids content for the tetraploid ranged from 13.2% to 17.2%.

The initial observations of the tetraploid hybrid group suggest that the interspecific hybrids have promise as a new fruit crop for warm temperate-zone climates. Vines in field plantings at Miami and at the Southern Fruit and Tree Nut Research Lab., Byron, have survived temperatures below freezing, and field evaluations are continuing. External appearance of the solid maroon fruit has definite eye appeal. The peel has a velvety external texture that distinguishes it from the waxy surface of fruit of the purple passion fruit. Internal fruit color and juice color is lighter than that of *P. edulis*, a creamy-yellow suggestive of grapefruit pulp and juice, unlike the intense orange-yellow characteristics of *P. edulis* juice. As passion fruit juice is often blended with other juices in fruit drinks, its color is not of critical importance. Sufficient juice has not been available to permit extensive taste tests to compare acceptability of members of the tetraploid hybrid group with currently available cultivars of *P. edulis*. However, based on my subjective observations, the juice was pleasant in flavor, both acidic and sweet, as the analytical data indicate (Table 4), and also was strongly aromatic, resembling juice of *P. edulis* in this respect. Thus, there is reason to expect that juice of selections from the tetraploid hybrid group can be put to many of the same uses as is juice of the purple or yellow passion fruit.

The self-incompatibility of the hybrid plants puts potential growers at a definite disadvantage because it necessitates taking measures to ensure cross-pollination. Finding self-compatible plants in seedling populations is necessary. Cultivated forms of *P. edulis* are known to encompass self-compatible genotypes (Knight and Winters, 1963), but no self-compatible forms of *P. incarnata* have been confirmed to date. The maypop, however, has a wide distribution in the southern and central United States, ranging from Florida and Texas northward to Virginia, Illinois, and southeastern Kansas (Killip, 1960), and possesses considerable variability. Therefore, if self-compatible forms of this species can be found, it would appear desirable to use such material in resynthesizing the interspecific hybrid.

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