Fragrance Quality, Emission, and Inheritance in *Anthurium* Species and Hybrids

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ABSTRACT

A total of 146 *Anthurium* species and hybrids from sections *Belolonchium, Calomystrium, Cardiolonchium, Chamaerepium, Dactylophyllum, Leptanthurium, Oxycarpium, Pachyneurium, Porphyrochitonium, Semaeophyllium, Tetraspermium* and *Urospadix* was evaluated for floral fragrance. Type of fragrance, time of emission, daily occurrence and developmental stage of scent emission were recorded along with the color of spathe and spadix and the environmental conditions. A majority of plants emitted scent: 68% of the species and 80% of the hybrids were fragrant. Fragrance was categorized as citrus, fishy, floral, foul, fruity, menthol, minty, pine, spicy, and sweet. There was no correlation between scent production or quality with flower color or botanical section. A plurality of plants emitted scent during the morning only (45%) and at the pistillate stage (77%). Detection of fragrance depended upon ambient temperature and relative humidity. Fragrance life of unharvested inflorescences varied from 3 days up to 4 weeks, whereas that of harvested inflorescences was short, only 1 or 2 days. First generation progeny analyses from 22 crosses between non-fragrant and fragrant parents indicated that multiple genes likely govern the presence of scent in *Anthurium*.

ABBREVIATION

RH, relative humidity

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KEY WORDS

Anthurium, fragrance, Araceae, genetic.

INTRODUCTION

Anthuriums are widely available as cut flowers and blooming potted plants. Evaluation criteria of hybrids have focussed on color, keeping quality, yield, leaf and canopy form, and disease resistance (Henley & Robinson, 1994; Kamemoto & Kuehnle, 1996). Flower fragrance, which is notably absent among anthuriums in the market, has been recently reintroduced for rose, carnation, and gladiolus to increase their popularity among consumers (Barletta, 1995). Addition of novelty, such as fragrance, may further enhance anthurium's market desirability. However, genetics of flower fragrance is documented only for *Gladiolus* (McLean 1933, 1938) and rice (Jodon, 1944).

Despite there being more than 1000 species of *Anthurium* (Croat, 1992), scent has been reported for only eleven, from the botanical sections *Belolonchium, Calomystrium, Pachyneurium,* and *Porphyrochitonium* (Bown, 1988; Croat, 1980). The quality of scent ranged from perfume-like, sweet, or evergreen to spoiled fruit or foul. Study of scent inheritance and a more extensive survey of *Anthurium* species and hybrids, including existing cultivars, is needed to determine the feasibility of breeding for fragrance and to assess the range of scents available, fragrance keeping quality, time and floral stage of scent emission, and its relationship, if any, to color and environmental conditions. Such knowledge will assist

Table 1. Survey of scent production, fragrance quality and inflorescence colors among *Anthurium* species in the University of Hawaii at Manoa and Missouri Botanical Garden germplasm collections.

Species (Accession no.)	Section	Type of fragrance[a]	Stage of emission[b]	Time of emission[c]	Spathe/ spadix color
A. amnicola (A417)	*Calomystrium*	minty	P	morning	lavender/purple
A. andraeanum (A221)	*Calomystrium*	floral	P	morning	pink/red
A. antioquiense (A490, A534)	*Porphyrochitonium*	NF	—	—	lavender/purple
A. aripoense (A193)	*Belolonchium*	fishy	P/S	all day	green/green
A. armeniense (A382)	*Calomystrium*	sweet	P	morning	white/red
A. atropurpureum var. *arenicolum* (53698)*	*Pachyneurium*	fruity (rotten)	S	morning	reddish green/ brown
A. bakeri (A116)	*Porphyrochitonium*	NF	—	—	green/green
A. barbadosense (A594)	*Porphyrochitonium*	foul	P/S	morning, night	green/green
A. barclayanum (50712)*	*Pachyneurium*	fruity (rotten)	S	all day	green/lavender green
A. bicollectivum (A237)	*Porphyrochitonium*	foul	P	morning	green/green
A. bonplandii (69761)*	*Pachyneurium*	foul	P	all day	green/green
A. brownii (A657)	*Belolonchium*	fishy	P	all day	green/brown
A. cerrobaulense (A332)	*Belolonchium*	fruity (rotten)	P	morning	green/brown
A. chiapasense ssp. *tlaxiacense* (46126)*	*Belolonchium*	foul	S	morning	green/brown
*A. cogolloanum**	unidentified	NF	—	—	green/pink
A. croatii (51656)*	*Dactylophyllum*	fruity (rotten)	P	day time	green/green
A. digitatum (54378)*	*Dactylophyllum*	fruity (rotten)	P	morning	green/lavender
A. fatoense (A659)	*Pachyneurium*	NF	—	—	green/green
A. ferrienense (57160)*	*Calomystrium*	sweet	P	morning	white/red
A. folsomii (A280)	*Porphyrochitonium*	fruity	P/S	all day	green/green
A. formosum (A291)	*Calomystrium*	minty	P	all day	pink/yellow

Table 1. Continued.

Species (Accession no.)	Section	Type of fragrance[a]	Stage of emission[b]	Time of emission[c]	Spathe/spadix color
A. formosum (A507)	*Calomystrium*	spicy	P	morning	pink/lavender
A. fragrantissimum (A662)	*Porphyrochitonium*	floral	P/S	midday	green/white
A. gladiifolium (A317)	*Urospadix*	fruity (rotten)	P/S	no data	maroon/maroon
A. gracile (A444)	*Leptanthurium*	floral	S	morning	green/white
A. grande (A373)	*Cardiolonchium*	NF	—	—	
A. harleyii (A575)	*Urospadix*	fruity (ripen)	P/S	all day	purple/purple
A. jefense (A324)	*Porphyrochitonium*	fruity (melon)	P	night	green/green
*A. lancetillense**	*Belolonchium*	fruity (rotten)	S	morning	green/purple
A. lindenianum (A220-2)	*Calomystrium*	minty	P/S	day time	white/white
A. nymphaefolium (A213)	*Calomystrium*	minty	P	morning	white/white
A. nymphaefolium (45022)*	*Calomystrium*	minty	P	morning	white/white
A. ochranthum (A670)	*Belolonchium*	pine	S	all day	green/yellow
A. ochranthum (69861)*	*Belolonchium*	pine	S	all day	green/yellow
A. pittieri (A269)	*Oxycarpium*	fishy	P/S	all day	green/green
A. plowmanii (53563)*	*Pachyneurium*	fruity (rotten)	S	day time	reddish green/brown green
A. prolatum (76532)*	*Pachyneurium*	NF	—	—	green/brown
A. radicans (76139)*	*Chamaerepium*	NF	—	—	green/maroon
A. ravenii (A224)	*Calomystrium*	fishy	P/S	all day	green/yellow
A. ravenii (A228)	*Calomystrium*	fishy	P/S	all day	green/yellow
A. salvadorense	*Pachyneurium*	NF	—	—	green/white
A. sanctifidense (A503)	*Porphyrochitonium*	menthol	P	morning	green/white
A. sanctifidense (A592)	*Porphyrochitonium*	NF	—	—	green/white
A. scherzerianum (A318)	*Porphyrochitonium*	NF	—	—	red/yellow
A. schlechtendalii (A411)	*Pachyneurium*	NF	—	—	green/brown
A. scolopendrinum	*Leptanthurium*	NF	—	—	brown/brown

Table 1. Continued.

Species (Accession no.)	Section	Type of fragrance[a]	Stage of emission[b]	Time of emission[c]	Spathe/ spadix color
A. solitarium (61798)*	*Pachyneurium*	foul	P	all day	green/lavender
A. subsignatum (49788)*	*Semaeophyllium*	floral (marigold)	P	all day	green/yellow
A. superbum (A488)	*Pachyneurium*	NF	—	—	green/brown
A. standleyi (A658)	*Pachyneurium*	NF	—	—	green/green
A. tarapotense (58115)*	*Pachyneurium*	NF	—	—	green purple/ purple
A. trinerve (A238)	*Tetraspermium*	NF	—	—	white/purple
A. warocqueanum (A101)	*Cardiolonchium*	NF	—	—	green/green
A. watermaliense (A322)	*Pachyneurium*	floral (marigold)	P/S	day time	black/black
A. willifordii (73936)*	*Pachyneurium*	NF	—	—	maroon/red
Unidentified (A596)	—	citrus (lemongrass)	P/S	no data	green/green
Unidentified (A607)	—	NF	—	—	green/yellow
Unidentified (74030, No. 1)*	—	minty	P	morning	white/lavender
Unidentified (74030, No. 2)*	—	minty	S	day time	white/lavender
Unidentified (75522)*	—	rotten fruit	S	all day	green/brown
Unidentified (76360)*	—	minty	P	morning	green/yellow

[a] NF = no detectable fragrance.
[b] P = pistillate; S = staminate.
[c] All day = scent detected at 8:00–9:30 A.M., 1:30–3:00 P.M. and 7:30–8:30 P.M.; day time = scent detected at 8:00–9:30 A.M. and 1:30–3:00 P.M.; morning = scent detected at 8:00–9:30 A.M.; midday = scent detected at 12:30–1:00 P.M.; night = scent detected at 7:30–8:30 P.M.
* Observed at Missouri Botanical Garden.

Table 2. Survey of scent production, fragrance quality and inflorescence colors for *Anthurium* cultivars.

Cultivar (University of Hawaii accession no.)	Type of fragrance[a]	Stage of emission[b]	Time of emission[c]	Spathe/spadix color
'Andraecola 1'	minty, floral	P	day time	light red/lavender
'ARCS'	minty	P	day time	lavender/purple
'Blush Tulip' (A568)	floral	P	day time	white/red
'Chamelian'	floral	P	morning	white green/green
'Congo' (A440)	minty	P	afternoon	white/light purple
'Fujii Light Pink' (A646)	fruity	P	day time	pink/yellow
'Hokulea'	minty	P	morning	pink/lavender
'Lady Beth' (A602)	sweet, floral	P	morning	pink/lavender
'Lady Jane' (A558-4)	floral	P	day time	light red/yellow
'Leilani' (A563)	minty	P	day time	lavender/lavender
'Manoa Mist'	floral	P	morning	white/yellow
'Mini Gem'	minty	P	morning	purple/purple
'Paradise Pink'	floral	P	morning	pink/yellow
'Pink Aristocrat' (A566)	minty	P	day time	pink/red
'Satan'	pine	P	all day	light purple/green
'Shipman Pink' (A601)	sweet, minty	P	day time	pink/yellow
'Shiroma's Splash' (A452)	floral	P	morning	pink obake/red
'Trinidad'	minty	P	afternoon	pink/purple
'Tropic Fire'	floral	P	day time	red/yellow

[a] NF = no detectable fragrance.
[b] P = pistillate; S = staminate.
[c] All day = scent detected at 8:00–9:30 A.M., 1:30–3:00 P.M. and 7:30–8:30 P.M.; day time = scent detected at 8:00–9:30 A.M. and 1:30–3:00 P.M.; morning = scent detected at 8:00–9:30 A.M.; midday = scent detected at 12:30–1:00 P.M.; night = scent detected at 7:30–8:30 P.M.

Anthurium varietal development and marketing programs.

MATERIALS AND METHODS

Survey of *Anthurium* Species and Hybrids

A total of 121 plants, comprised of 37 different species (40 samples) from 12 botanical sections, 19 cultivars, and 62 other hybrids, including interspecific crosses, breeding lines and selections under evaluation, was observed at the University of Hawaii at Manoa anthurium greenhouse facilities. Data were taken for the presence and nature of flower scent during a three and a half-year period (July 1993–Feb. 1997). Inflorescences were observed during the morning (8:00–9:30 A.M.), afternoon (1:30–3:00 P.M.) and night (7:30–8:30 P.M.) of clear days. Categories of scent were based on Calkin & Jellinek (1994) and Civille & Close (1994). More specific descriptors within a category were added when possible. Other data recorded were the floral stage (pistillate and/or staminate) of scent emission, the colors of spathe and spadix, temperature and humidity during observation, and fragrance intensity. The latter was rated on a relative scale of 1 to 3, with 1 being light scent and 3 being strong scent.

Single inflorescences of 22 species and 3 hybrids in the aroid collection at the Missouri Botanical Garden, St. Louis, Missouri, were also observed for scent presence and quality.

Fragrance Life

For potted plants, fragrance life of one to three unharvested inflorescences of *A. armeniense, A. lindenianum,* 'Lady Beth' and of the hybrid 'Ellison Onizuka' × *A. armeniense* was assessed in the greenhouse. Evaluations were made from the time the spathe was fully opened until anthesis of last flowers of the spadix. For harvested inflorescences, two to six cut flowers of the six hybrids 'Lady Beth,' *A. antioquiense* × 'Tatsuta Pink', (*A. lindenianum* × *A. amnicola*) × *A. lindenianum,* 'Manoa Mist' × *A. armeniense,* (*A. andraeanum* × *A. antioquiense*) × (*A. lindenianum* × *A. lindenianum*), and 'Ellison Onizuka' × *A. antioquiense* were observed. Inflorescences were harvested in the morning at the pistillate stage used during commercial harvest, i.e. the spadix is about ¾ mature with a receptive stigma (Kamemoto & Kuehnle, 1996), and stems were held in water in an air-conditioned room of 22–23°C. For unharvested and harvested inflorescences, the presence of fragrance was tested daily, three times a day (9:30 A.M., 1:30 P.M., and 4:00 P.M.) until no further fragrance was detected.

Genetic Study

Seeds from mature berries obtained from 22 controlled pollinations of non-fragrant by fragrant parents were germinated on a medium of shredded tree-fern fiber in 12.5-cm pots under 80% shade. Seedlings were transplanted to flats containing a mixture of composted redwood bark and size 2 perlite (1:1 ratio), then individually to 15-cm plastic pots in a medium of composted redwood bark and size 3 perlite (3:1 ratio). Evaluations commenced upon flowering 2–2.5 years after pollination.

Individual plants were examined in the morning, afternoon and night for the type and the presence or absence of flower scent. Each inflorescence was evaluated at its pistillate and staminate stages. Fragrance emission was detected by the first author's nose. Plants were scored as fragrant if at least one inflorescence produced detectable scent. Colors of the spadix and fully expanded spathe were also recorded. Each new inflorescence was evaluated during a 12- to 18-month period, with the number evaluated per progeny plant varying from one to 8 inflorescences. Chi-square analysis (Srb *et al.*, 1965) of progeny data tested the probability of fitted ratios.

RESULTS AND DISCUSSION

Species Survey

Among a total of 56 *Anthurium* species (61 accessions), a majority of 68% (38/56) produced fragrance (Table 1). Of these, 29% (16/56) released scent in the morning only, 23% (13/56) emitted scent morning, afternoon and night (all day), and 9% (5/56) produced scent in the morning and afternoon (day time). None of the species produced scent during the afternoon only. Three species emitted scent at other hours: midday (12:30–1:00 P.M.)—*A. fragrantissimum*; morning and night—*A. barbadosense*; and night—*A. jefense*. Fragrance was detected for 32% (18/56) of the scented species at the pistillate stage, for 16% (9/56) at the staminate stage, and for 20% (11/56) during both pistillate and staminate stages. Although a previous report noted fluctuation in *Anthurium* scent production (Croat, 1980), this study is the first to document the extensive variability of scent emission during the daily cycle and during spadix development.

Ten types of scent were observed among species. These were broadly classified as citrus, fishy, floral, foul, fruity, menthol, minty, pine, spicy, and sweet (Table 1). Some categories included more specific scents such as lemongrass (citrus), melon, ripe or rotten fruit (fruity) and marigold or green (floral). These results confirm the general fragrance descriptors used previously for *A. amnicola* (Bown, 1988), *A. armeniense,* (Croat, 1980; Kamemoto & Kuehnle, 1996), *A. fragrantissimum* (Bown, 1988; Croat, 1980) and *A. ochranthum* (Croat, 1980), and significantly expand the known scents in this genus.

Scents varied widely within botanical

Table 3. Survey of scent production, fragrance quality and inflorescence colors for *Anthurium* hybrids and breeding lines in the University of Hawaii at Manoa and Missouri Botanical Garden germplasm collections.

Hybrids or breeding lines (University of Hawaii accession no.)	Type of fragrance[a]	Stage of emission[b]	Time of emission[c]	Spathe/spadix color
Hybrids				
A. andraeanum × *A. antioquiense* (A494)	NF	—	—	light red/yellow
[*A. andraeanum* Hort. (pink) × *A. antioquiense*] × 'Blushing Bride' (A631)	floral	P	morning	pink/red
{[*A. andraeanum* × *A. antioquiense*] × [*A. andraeanum* Hort. (pink) × *A. antio quiense*]} × 'Tagami' (A632)	floral	P	morning	white/red
[*A. andraeanum* Hort. (pink) × *A. antioquiense*] × *A. formosum* 'Hilo Hybrid' (A625)	minty	P	morning	pink/lavender
A. antioquiense × *A. armeniense* (A628)	sweet	P	day time	pink/lavender
A. crystallinum × *A. armeniense* (A624)	spicy	P	morning	white/purple
A. crystallinum × *A. papillilaminum**	NF	—	—	green/maroon
A. hookeri × 'Birdnest' (A630)	sweet	P	morning	white/lavender
A. papillilaminum × *A. crystallinum**	NF	—	—	green/green
A. radicans hybrid (75496)*	floral (green)	P	morning	green purple/ red purple
[*A. veitchii* × 'Bob Wilson Red'] × *A. formosum* 'Hilo Hybrid' (A629)	minty	P	morning	red/yellow
A. scherzerianum × *A. antrophyoides* (A535)	sweet	P	morning	pink/lavender
unnamed brown (A672)	floral	P	day time	brown/green
unnamed green (A675)	sweet, floral	P	afternoon	green/brown
unnamed pink (A626)	sweet, floral	P	day time	light pink/pink
unnamed red tulip (A680)	minty	P	morning	red/red
Open-pollinated *A. bakeri* (1081-1)	floral	P/S	all day	green/white
Open-pollinated *A. jefense* (1147)	fruity (melon)	P	morning	green/brown
Breeding lines				
A. amnicola × *A. formosum* (572-23)	minty	P	morning	purple/purple
A. antioquiense × *A. amnicola* (A491)	NF	—	—	lavender/purple

Table 3. Continued.

Hybrids or breeding lines (University of Hawaii accession no.)	Type of fragrance[a]	Stage of emission[b]	Time of emission[c]	Spathe/spadix color
A. antioquiense × 'Marian Seefurth' (768-7, -26, -27, -47)	sweet, floral	P	day time	pink/orange
(*A. lindenianum* × *A. amnicola*) × *A. lindenianum* (633-41)	minty	P	all day	white/white
'Manoa Mist' × *A. armeniense* (649-2, -7)	sweet, floral	P	morning	white/red
('Manoa Mist' × *A. armeniense*) × UH1095 (1061-4)	sweet	P	day time	white/red
('Manoa Mist' × *A. armeniense*) × UH1095 (1061-11)	floral, sweet	P	day time	white/lavender
('Manoa Mist' × *A. armeniense*) × *A. andraeanum* A481 (1131-7)	floral	P	day time	red/yellow

[a] NF = no detectable fragrance.
[b] P = pistillate; S = staminate.
[c] All day = scent detected at 8:00–9:30 A.M., 1:30–3:00 P.M. and 7:30–8:30 P.M.; day time = scent detected at 8:00–9:30 A.M. and 1:30–3:00 P.M.; morning = scent detected at 8:00–9:30 A.M.; midday = scent detected at 12:30–1:00 P.M.; night = scent detected at 7:30–8:30 P.M.
* Observed at Missouri Botanical Garden.

sections. For example, scents among member species of *Belolonchium* ranged from unpleasant, such as fishy or rotten fruit, to sweet pine (Table 1). Section *Calomystrium* produced generally very pleasant fragrance, such as sweet floral or minty, but included the fishy smell of *A. ravenii*. In section *Porphyrochitonium*, both pleasant and unpleasant types could also be found. While flowers may emit different scents to attract different pollinator group (Proctor *et al.*, 1996), pollinators for *Anthurium* are poorly described (T. B. Croat, pers. comm.). Only in *A. ochranthum* has fragrance and a pollinator (euglossine bee) been linked (Whitten *et al.*, 1988).

Scented *Anthurium* species displayed a wide variation in spathe colors, including black, brown, green, lavender, maroon, pink, purple, red and white. Specific scent types were not associated with particular spathe colors (Table 1). This contrasts with orchids whose white flowers emit floral scents whereas most reddish, greenish or yellowish-brown flowers release foul scents (Kaiser, 1993).

Two different plant accessions were observed for each of five species namely *A. formosum, A. nymphaefolium, A. ochranthum, A. ravenii* and *A. sanctifidense,* during similar stages of floral development (Table 1). Type of scent and time of emission were similar for each pair of *A. nymphaefolium, A. ochranthum* and *A. ravenii*. In contrast, *A. formosum* accessions A291 and A507 differed in type and time of fragrance, with A291 being minty all day long and A507 being spicy and emitting only in the morning. *A. sanctifidense,* A503, yielded menthol fragrance while no scent could be detected from A592. These discrepancies might be due to different chemotypes within the species, as de-

Table 4. Parental species of fragrant University of Hawaii-originated *Anthurium* hybrids, breeding lines and selections.

Parental species (fragrance)	Section	Hybrid fragrance	Hybrids (cross no. or University of Hawaii selection no.)
A. amnicola (minty)	*Calomystrium*	minty	'ARCS', *A. amnicola* × *A. formosum* (572-23)
A. antioquiense (non-fragrant)	*Porphyrochitonium*	floral	'Tropic Fire', 'Paradise Pink' × (*A. antioquiense* × 'Marian Seefurth') (UH1311), 'Tropic Mist' × (*A. andraeanum* × *A. antioquiense*) (UH1332), (*A. andraeanum* × *A. antioquiense*) × UH507 (UH1402), (*A. antioquiense* × 'Marian Seefurth') × 'Alii' (UH1584), UH931 × 'Tropic Fire' (UH1679)
		minty	'Tropic Mist' × (*A. antioquiense* × 'Marian Seefurth') (UH1450)
		sweet	UH507 × (*A. andraeanum* × *A. antioquiense*) (UH1461), 'Momohara Orange' × (*A. andraeanum* × *A. antioquiense*) (UH1465)
		sweet, floral	*A. antioquiense* × 'Marian Seefurth' (768-7, 768-26, 768-27, 768-47), *A. antioquiense* × 'Tatsuta Pink' (UH1299)
A. armeniense (sweet)	*Calomystrium*	sweet, floral	'Manoa Mist' × *A. armeniense* (649-2, -7)
A. formosum (minty, spicy)	*Calomystrium*	minty	*A. amnicola* × *A. formosum* (572-23), [('Uniwai' × *A. kamemotoanum*) × *A. formosum*] × *A. amnicola* (UH1141)
A. lindenianum (minty)	*Calomystrium*	floral	'Tropic Mist' × (*A. antioquiense* × 'Marian Seefurth') (UH1450), (*A. andraeanum* × A. *antioquiense*) × 'Paradise pink' (UH1462)
		minty	'Trinidad', (*A. lindenianum* × *A. amnicola*) × *A. lindenianum* (633-41), [('Uniwai' × *A. lindenianum*) × *A. amnicola*] × (*A. andraeanum* × A. *antioquiense*) (UH1272)
		pine	'Satan'

scribed for sweet basil, *Ocimum basilicum* (Grayer *et al.*, 1996).

Hybrids Survey

A total of 84 hybrids was observed, with 80% producing scent (Tables 2 and 3; University of Hawaii selections not shown). Time of scent emission varied as follows: 46% of the plants were scented in the morning only, 37% were scented during the morning and afternoon, 11% were scented morning, afternoon and night, and 6% were scented in the afternoon only. Ninety seven percent of the fragrant hybrids emitted scent at the pistillate stage only and the remainders were fragrant

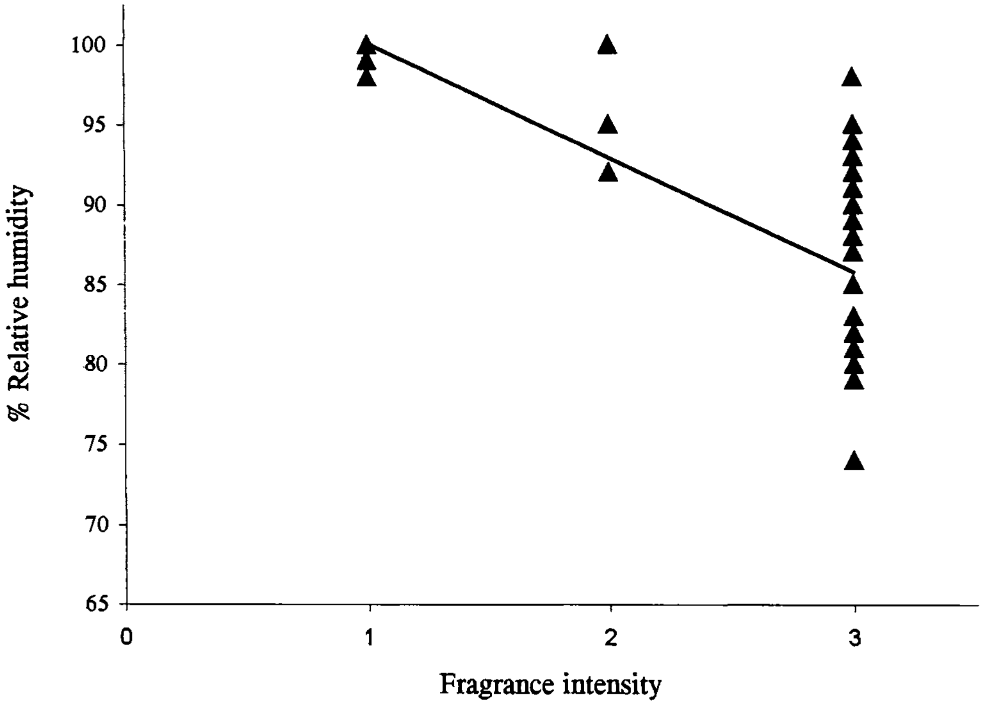

Fig. 1. Correlation between fragrance intensity and relative humidity for scented *Anthurium* species and hybrids, with correlation coefficient $r = -.786$.

during both pistillate and staminate stages, none released scent at only the staminate stage.

Most of the observed scented hybrids represent sections *Calomystrium* and *Porphyrochitonium* (Table 4). These two sections contribute valuable species for use in cut flower and potted plant breeding, including the fragrant *A. amnicola, A. armeniense* and *A. lindenianum*. The most common fragrances found amongst scented hybrids were floral (52%) and minty (33%). Some hybrids produced a mixture between floral and minty, described as sweet and floral or minty and sweet. Examples include 'Lady Beth', 'Shipman Pink', A626, A675, 'Manoa Mist' × *A. armeniense, A. antioquiense* × 'Marian Seefurth', ('Manoa Mist' × *A. armeniense*) × UH1095, [('Uniwai' × *A. kamemotoanum*) × *A. formosum*] × *A. amnicola,* and *A. antioquiense* × 'Tatsuda Pink' (Table 4). Combinations of scent might be due to the contribution of unique compounds from parental plants (Kuanprasert *et al.*, 1998). Although a few scented cultivars are currently available in the market, scent in *Anthurium* is not well known. This might be due to a lack of information on scented *Anthurium* and to environmental factors effecting volatility and production of scent.

Environmental Factors

Conditions of observation at the University of Hawaii were: morning—74% to 100% RH, 17° to 25°C; afternoon—65% to 80% RH, 28° to 30°C; and night—85% to 90% RH, 20° to 24°C. The most difficult time to detect scent was at 100% RH, especially at temperatures less than 18°C. This might be due to decreased volatilization of fragrance compounds under high water vapor pressure and to reduced production under cooler temperatures. There was a negative association between fragrance intensity and humidity (correlation coefficient $r = -0.786$, Fig. 1) and a pos-

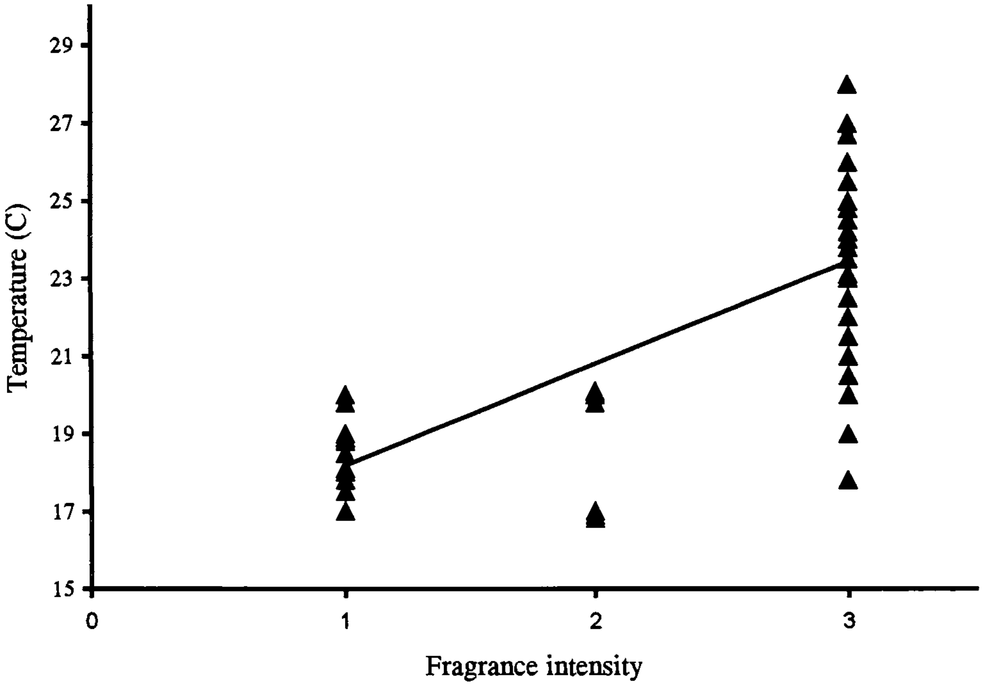

Fig. 2. Correlation between fragrance intensity and temperature for scented *Anthurium* species and hybrids, with correlation coefficient $r = -.75$.

itive association between fragrance intensity and temperature (correlation coefficient $r = 0.75$, Fig. 2).

Four species obtained by the University of Hawaii from Missouri Botanical Garden, *A. fatoense, A. salvadorense, A. schlechtendalii* and *A. standleyi,* were found scentless (Table 1), contrary to a previous report (Croat, 1980). Although this disparity may be due to different accessions, it also may be due to environmental factors in the Hawaii greenhouse affecting the amount of volatiles released. Indirect supporting evidence comes from a progeny of 'Ellison Onizuka' and *A. armeniense,* hybrid 1213-85, with light fragrance detected at 100% RH, 18°C and strong fragrance was detected at 80% RH, 22°C. Temperature influenced monoterpene emission in other crops such as slash pine (Tingey *et al.*, 1979) and peppermint (Burbott & Loomis, 1967) and anecdotal evidence in rose indicates that humidity and temperature are involved in fragrance emission (Allen, 1980; Bouquet, 1968; Carruth, 1992; Harkness, 1992). Based on the above, the effect of environmental conditions on *Anthurium* fragrance emission should be further examined.

Fragrance Life

Fragrance life for unharvested inflorescences ranged from 3 to 20 days (Table 5). The long fragrance life of *A. armeniense* and *A. lindenianum* makes them attractive for a breeding program. In this experiment, *A. armeniense* was a male parent for 'Ellison Onizuka' × *A. armeniense,* which also had long fragrance life.

Fragrance life of harvested inflorescences was short, only 1 to 2 days (Table 6). Harvesting decreased fragrance life for 'Lady Beth,' with unharvested inflorescences lasting for 3 to 5 days and harvested flowers lasting for less than one day.

Genetic study

Evaluation of first generation progenies from 22 crosses between non-fragrant ×

Table 5. Fragrance life of unharvested *Anthurium* inflorescences.

Species, cultivar or hybrid	No. of flowers observed	Type of fragrance	Fragrance life (days)
A. armeniense (A613)	2	sweet	10–14
A. lindenianum (A220-2)	1	minty	20
'Lady Beth'	3	minty	3–5
'Ellison Onizuka' × *A. armeniense* (1213-85)	1	sweet, floral	18

fragrant parents showed none to be uniformly fragrant or non-fragrant, with segregation for presence of scent apparent in all populations (Table 7). Thus, no fragrant parents carried a single homozygous dominant or recessive gene-governing scent. Moreover, no parental genotypes appeared heterozygous for a single gene for scent, as the 1:1 ratio of non-fragrant and fragrant progenies was not observed. Only one cross, number 1185, gave the greatest possibility ($P > 0.95$) for goodness of fit but it had a small population size (n = 10). The fragrant parent in this cross, *A. lindenianum,* was used as a parental plant for 15 other crosses yet none showed segregation ratios with $P > 0.9$.

Both parents in cross numbers 1180 (Trinidad and *A. lindenianum*) and 1216 (*A. armeniense* and UH1131) were fragrant and produced a population of fragrant and non-fragrant plants (Table 7). Results from chi-square analysis, testing for the possibility that both parents were heterozygous for fragrance, was insignificant. The expected ratio for this cross was 3:1, fragrant : non-fragrant.

Taken together, chi-square analyses suggest that the number of genes controlling fragrance in *Anthurium* should be more than one. These results were similar to those in *Gladiolus* (McLean, 1933) and are not unexpected given that at least three major compounds contribute to detectable fragrance in *Anthurium* (Kuanprasert *et al.*, 1998). Interestingly, genetics of fragrance in some popular commercial crops such as rose has not been reported.

Table 6. Fragrance life of harvested *Anthurium* inflorescences.

Cultivar or hybrid	No. flowers observed	Type of fragrance	Fragrance life after harvest (days)
'Lady Beth'	3	minty	1[a]
(*A. andraeanum* × *A. antioquiense*) × (*A. lindenianum* × *A. lindenianum*)	1	minty	1[a]
'Manoa Mist' × *A. armeniense*	2	sweet, floral	2
(*A. lindenianum* × *A. amnicola*) × *A. lindenianum*	1	minty	1[b]
'Ellison Onizuka' × *A. armeniense*	1	floral	2
UH1299	6	sweet, floral	2

[a] Fragrance lasted until early afternoon.
[b] Fragrance lasted only for the morning.

Table 7. Chi-square analysis for goodness of fit for determining fragrant inheritance in segregating progeny of crosses between non-fragrant × fragrant *Anthurium* plants.

Cross	Female		Male		Flowered		Ratio 1:1	
no.	Plant[a]	Color	Plant[a]	Color	F	NF	χ^2	P
1172	UH585	orange	A220-2	white	11	6	1.47	0.25–0.10
1180[b]	'Trinidad'	pink	A220-2	white	67	14	—	—
1182	UH566	dark pink	A220-2	white	17	2	11.84	<0.00
1183	A38	red	A220-2	white	4	1	1.80	0.25–0.10
1184	692-48	white	A220-2	white	4	5	0.20	0.75–0.50
1185	UH818	pink	A220-2	white	5	5	0.00	>0.95
1188	A558		A220-2	white	54	23	12.48	<0.00
1195	A494	pink	RS1361-1	white	31	55	6.70	0.01–0.005
1196	UH585	orange	A220-2	white	27	19	1.39	0.25–0.10
1197	UH186	pink	A220-2	white	4	7	0.82	0.75–0.50
1198	UH185	red	A220-2	white	20	5	9.00	<0.00
1200	383	red	A220-2	white	14	7	2.33	0.25–0.10
1201	A99	red	A212-2	white	2	22	16.67	<0.00
1202	'Kozohara'	red	A220-2	white	8	5	0.69	0.5–0.2
1203	'Paradise Pink'	pink	A170	white	27	12	5.77	0.05–0.01
1204	'Fujii Light Pink'	pink	RS1316-1	white	46	32	5.12	0.05–0.01
1205	A38	red	A220-2	white	17	18	0.03	0.90–0.75
1206	A167	orange	A212	white	15	34	7.37	0.01–0.005
1207	A67	red	A220-2	white	24	14	2.63	0.25–0.10
1208	A99	red	A212	white	8	13	1.19	0.50–0.25
1210	'Marian Seefurth'	pink	A220-2	white	10	19	2.79	0.05–0.01
1212	A167-2	red	A220-2	white	26	34	1.07	0.75–0.50
1213	'Ellison Onizuka'	white	A382	white	60	25	14.41	<0.00
1216[c]	649-7	white	UH1131	red	5	17	—	—

[a] A212-2 = *A. hoffmanii*; A213-2 = *A. nymphaefolium*; A220-2 = *A. lindenianum*; A382 = *A. armeniense*; RS1361-1 = *A. lindenianum* (A170) × *A. lindenianum* (A220); 649-7 = 'Manoa Mist' × *A. armeniense* (A382).

[b] Both parents are fragrant. For a ratio of 3:1, F:NF, fragrance is produced in Fragrant (Ff) × Fragrant (Ff); χ^2 = 3.09, P = 0.10–0.05.

[c] Both parents are fragrant. For a ratio of 3:1, F:NF, fragrance is produced in Fragrant (Ff) × Fragrant (Ff); χ^2 = 32.06, P < 0.01.

In rose, inheritance of fragrance is also believed to be complex; crosses among non-fragrant roses yielded fragrant progenies whereas those among fragrant roses yielded non-fragrant progenies (K. Zary, Jackson & Perkins, pers. comm.). In *Anthurium,* a hypothesis of a quantitative basis for fragrance inheritance should be tested.

Although all the fragrant parental plants were white, spathes of fragrant progenies were coral, orange, pink or red. This indicates absence of linkage between the presence of flower fragrance and spathe color. Several types of fragrance, including non-parental types, were found among progenies within the shared parents (data not shown). Parental plants *A. lindenianum, A. nymphaefolium* and RS1361-1 emit minty fragrance yet their progenies from cross number 1185, 1195, 1200, 1202, 1203, 1204, 1210 and 1212 had minty as well as other scents. It would be valuable to examine the ratio between different type of fragrances using chemical component analysis as done in *Ocimum basillicum* var. *glabratum* (Gupta, 1994), to determine the number of genes that control fragrance production in *Anthurium.*

In summary, no other species belonging to the Araceae is known to possess such a great variation in scent. Within the single genus *Anthurium,* ten categories of scent were identified here from a sampling of only 5% of the known member species. Only those species or hybrids that release pleasant fragrances, for example *A. armeniense,* are desirable in a breeding program. More observations, especially in the crossable sections such as *Calomystrium* and *Porphyrochitonium,* will enhance the potential of producing commercial fragrant anthuriums with an array of desirable scents. However, this study emphasizes that floral stage of scent emission and the evaluation environment must be considered when observing flowers for scent during a breeding program. Moreover, results of the fragrance life study with unharvested and harvested inflorescences suggest that breeding for fragrance should focus on potted plants. To our knowledge, this is the first report on fragrance life of a scented ornamental.

Documentation on the presence of scent and its quality in existing cultivars provides a basis for future marketing promotion. As the major chemical components of *Anthurium* fragrance have recently been identified (Kuanprasert *et al.*, 1998), more specific descriptors for *Anthurium* scents may become available to aid breeding and marketing. This study showed that fragrance is transmissible with a complex inheritance, as first suggested by Kamemoto & Kuehnle (1996). In some cases, breeding by genetic engineering (Kuehnle & Chen, 1994), using a fragrance gene such as *Lis,* encoding S-linalool synthase (Dudareva *et al.*, 1996), may improve fragrance in an existing cultivar. Lastingly, further study on the effect of the environment on fragrance emission is needed in order to develop recommendations for cultural practice and marketing of quality fragrant plants.

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LITERATURE CITED

Allen, E. F. 1980. Rose scent—a quantitative study. *The Rose Annual* 58–61.

Barletta, A. 1995. Scent makes a come back. *FloraCulture International* 23–25.

Bouquet, A. 1968. Perfumes of the rose. *Amer. Rose Ann.* 53:107–111.

Bown, D. 1988. *Aroids.* Timber Press, Portland, OR.

Burbott, A. J. & W. D. Loomis. 1967. Effects of light and temperature on the monoterpenes of peppermint. *Plant Physiol.* 42:20–28.

Carruth, T. 1992. The fickle finger of fragrance. *Amer. Rose Ann.* 77:24–25.

Croat, T. B. 1980. Flowering behavior of the neotropical genus *Anthurium* (Araceae). *Amer. J. Bot.* 67:888–904.

Croat, T. B. 1992. Species diversity of Araceae in Colombia: a preliminary survey. *Ann. Miss. Bot. Gard.* 79:17–28.

Dudareva, N., L. Cseke, V. M. Blance & E. Pichersky. 1996. Evolution of floral scent in *Clarkia*: novel patterns of s-linalool synthase gene expression in the *C. breweri* flower. *The Plant Cell* 8:1137–1148.

Grayer, R. J., G. C. Kite, F. J. Goldstone, S. E. Bryan, A. Paton & E. Putievsky.

1996. Infraspecific taxonomy and essential oil chemotypes in sweet basil, *Ocimum basilicum*. *Phytochemistry* 43:1033–1039.

Henley, R. W. & C. A. Robinson. 1994. Evaluation of twenty-one potted anthurium cultivars grown for interior use. *Proc. Florida State Hort. Soc.* 107:179–181.

Harkness, P. 1992. Roses for noses. *Amer. Rose Ann.* 77:15–17.

Jodon, N. E. 1944. The inheritance of flower fragrace and other characters in rice. *J. Amer. Soc. Agron.* 36:844–848.

Kamemoto, H. & A. R. Kuehnle. 1996. *Breeding Anthuriums in Hawaii.* University of Hawaii Press, Honolulu.

Kuanprasert, N., A. R. Kuehnle & C. S. Tang. 1998. Floral fragrance compounds of some *Anthurium* (Araceae) species and hybrids. *Phytochemistry* 49:521–528.

Kuehnle, A. R. & F. C. Chen. 1994. Genetic transformation in *Anthurium*, pp. 217–225 in Y. P. S. Bajaj (ed.), *Biotechnology in Agriculture and Forestry.* Springer-Verlag, Berlin.

McLean, F. T. 1933. The inheritance of fragrance in gladiolus species crosses. *The New York Bot. Gar.* 34:73–80.

McLean, F. T. 1938. A genetic analysis of the inheritance of fragrance in gladiolus. *Bull. Torr. Bot. Club* 65:181–197.

Proctor, M., P. Yeo & A. Lack. 1996. *The Natural History of Pollination.* Timber Press, Portland, OR.

Srb, A. M., R. D. Owen & R. S. Edgar. 1965. *General Genetics.* W. H. Freeman and Company, San Francisco, CA.

Tingey, D. T., M. Manning, L. C. Grothaus & W. F. Burns. 1979. The influence of light and temperature on isoprene emission rates from live oak. *Physiol. Plant* 47:112–118.

Whitten, W. M., H. G. Hills & N. H. Williams. 1988. Occurrence of ipsdienol in floral fragrance. *Phytochemistry* 27: 2759–2760.