primordium in some cultivars. A 5-lobed floral envelope was frequent in 'Caddo' and 'Chickasaw'. The 'Stuart' cultivar consistently had only 4 involucral primordia. There was thus a variation in the size and number of foliar structures of the flower. In cases with 2 adaxial bracteoles, considerable variation was evident in their connation from the onset of their development. This resulted, in many cases, with mature flowers having 4 distinct involucral projections, the adaxial one being bilobed. Usually, connation of the 3rd and 4th bracteoles is complete so that dehiscence of the involucre is 4-valved at fruit maturity. However, in some infrequent cases, connation does not occur and the involucre is 5-valved at maturity. In addition, 2 reduced foliar structures occasionally were observed interior to the 2 lateral bracteoles in 'Stuart' pistillate flowers. Hjelmqvist (8) has reported similar structures in *Carya tomentosa, C. ovata* and *C. cordiformis* and refers to them as perianth-leaves above the involucre.

The pecan pistillate inflorescence is a spike. Flowers are successively differentiated acropetally from the inflorescence apex. Shuhart (16) reported the initiation of a group of 5 lateral primordia, each of which develops as an individual flower. We found the number of floral primordia per inflorescence to be a variable within and among cultivars. This agrees with Woodroof and Woodroof (17) and confirms field observations of mature flower clusters.

Literature Cited

1. Abbe, E.C. 1974. Flowers and inflorescences of the "Amentiferae". Bot. Rev. 40:159–261.
2. Adriance, G.W. 1931. Factors influencing fruit setting in the pecan. Bot. Gaz. 91:144–166.
3. Amling, H.J. and K.A. Amling. 1983. Physiological differentiation of pistillate flowers of pecan and cold requirements for their initiation. J. Amer. Soc. Hort. Sci. 108:195–198.
4. Bailey, L.H. 1924. A manual of cultivated plants, New York.
5. De Candolle. 1862. Memoire sur la famille des Juglandees. Ann. Sci. Nat. Bot. IV Series: 18:5–48.
6. Eichler, A.W. 1878. Blüthendiagramme. Leipzig.
7. Goff, E.S. 1901. Investigation of flower-buds. Wis. Agr. Expt. Sta. Annu. Rpt. 18:304–316.
8. Hjelmqvist, H. 1948. Studies on the floral morphology and phylogeny of the Amentiferae. Bot. Not. (Suppl. 2), 1:1–171.
9. Holm, T. 1921. Morphological study of *Carya alba* and *Juglans nigra*. Bot. Gaz. 72:375–386.
10. Isbell, C.L. 1928. Growth studies on the pecan. Ala. Agr. Expt. Sta. Bul. 266.
11. Kramer, P.J. and T.T. Kozlowski. 1979. Physiology of Woody Plants. Academic Press, New York.
12. Matta, F.B., D.T. Sullivan, and F.B. Widmoyer. 1976. The relationship between pistillate flower development and air temperature in 'Western' pecan. HortScience 11:492–493.
13. Manning, W.E. 1940. The morphology of the flowers of the Juglandaceae. II. The pistillate flowers and fruit. Amer. J. Bot. 27:839–852.
14. Mullenax, R.H. and W.A. Young. 1972. Female flower development of the pecan. Proc. S. E. Pecan Growers Assn. 65:83–92.
15. Shuhart, D.V. 1927. The morphological differentiation of the pistillate flowers of the pecan. J. Agr. Res. 35:687–696.
16. Shuhart, D.V. 1932. Morphology and anatomy of the fruit of *Hicoria pecan*. Bot. Gaz. 93:1–20.
17. Woodroof, J.G. and N.C. Woodroof. 1926. Fruit-bud differentiation and subsequent development of the flowers of *Hicoria pecan*. J. Agr. Res. 33:677–685.

J. Amer. Soc. Hort. Sci. 108(6):1003–1006. 1983.

Characteristics of Four Sets of Reciprocal Crosses in *Dendrobium* (Orchidaceae)

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Abstract. **Progenies of 4 sets of reciprocal crosses in *Dendrobium* were compared including an intraspecific cross, 2 interspecific crosses, and an amphidiploid cross. With the reciprocal crosses involving 2 accessions of *D. canaliculatum* (D173-2 and D129), offspring with cytoplasm of D173-2 (Papua, New Guinea accession) were taller, produced more pseudobulbs, and gave a higher flower yield than with D129. Offspring with the same *D. canaliculatum* cytoplasm also produced taller plants and more pseudobulbs in reciprocal crosses between *D. canaliculatum* and *D. strebloceras*. Reciprocal crosses of *D. schulleri* x *D.* X Sunset differed in chromosome number and flower quality. *D. schulleri* x *D.* X Sunset produced triploid offspring, while the reciprocal produced diploid offspring. Reciprocal matings of 2 amphidiploid *D.* X Jaquelyn Thomas selections did not differ in height, yield, number of pseudobulbs, or floral characteristics.**

Dendrobium orchids are grown commercially for cut and lei flowers in Hawaii. Intersectional hybrids involving *Dendrobium phalaenopsis* of the *Phalaenanthe* section and *D. gouldii* or *D. grantii* of the *Ceratobium* section have been particularly important for cut flower production because of their high yields, long flowering season, prolonged vase life, and low bud drop (2). These species hybrids generally exhibit low fertility due to lack of complete homology of the parental genomes, which reduces their usefulness for further breeding (6, 8, 11). However, by doubling the chromosome number fertile amphidiploids may result (8). Amphidiploids have been assuming considerable importance in the University of Hawaii's dendrobium breeding program (5). These newly formed amphidiploids can be expected to produce relatively uniform progenies.

Recently the University of Hawaii released a cultivar, *Dendrobium* X Jaquelyn Thomas 'Uniwai Supreme' (4). This is a

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Table 1. Mean values (±SD) of characters in the first set of reciprocal crosses of *D. canaliculatum* D173-2 and *D. canaliculatum* D129.

Cross	No. plants	Plant height (cm)	Yield[z]	Scape length (cm)	Raceme length (cm)	No. pseudobulbs	No. flowers per raceme
D173-2 x D129	10	10.9 ± 0.7	7.6 ± 1.5	14.3 ± 0.5	27.1 ± 1.7	16.1 ± 1.4	23.6 ± 1.4
D129 x D173-2	10	7.1 ± 1.0	4.0 ± 0.6	14.1 ± 0.6	23.7 ± 2.0	9.8 ± 0.6	18.5 ± 2.0
Significance		**	*	NS	NS	**	NS

[z]Mean no. racemes per plant over 16 months.
NS, *, **Nonsignificant (NS) or significant at 5% (*) or 1% (**) by *t* test.

seed-propagated amphidiploid hybrid produced from reciprocal crosses of 2 individual amphidiploid clones, K44-50 and 2085-4N.

Reciprocal crosses generally are assumed to produce similar progenies. However, differences have been found, especially in interspecific and intergeneric crosses. Kihara (9) reported that the cytoplasm of *Aegilops* spp. and *Triticum* spp. had specific effects on the expression of various genotypes. Irregular chromosome transmission in orchids was reported for reciprocal crosses involving diploid *D. phalaenopsis* 'Lyon's Light No. 1' (1, 7).

Preliminary observation of an intraspecific cross, *D. canaliculatum* D173-2 x *D. canaliculatum* D129, and the reciprocal, showed considerable differences in growth characteristics depending on which was used as the maternal parent. Progenies of another set of reciprocal crosses between *D. canaliculatum* D173-2 and *D. strebloceras* D38-3 appeared to show minor differences. Progenies from a third set of reciprocal crosses between *D.* X Sunset and *D. schulleri* showed marked differences in horticultural characteristics. These dissimilarities raised a concern whether or not reciprocal cross progenies of *D.* X Jaquelyn Thomas 'Uniwai Supreme' released earlier to the growers were uniform as expected. This study was initiated, therefore, to determine the cause of the differences between progenies of the above 3 sets of reciprocal crosses and the differences, if any, between the reciprocal crosses of *D.* X Jaquelyn Thomas 'Uniwai Supreme'.

Materials and Methods

Plant materials. The 4 sets of reciprocal crosses investigated were as follows:

1. *D. canaliculatum* D173-2 and *D. canaliculatum* D129. D173-2 and D129 are 2 accessions of *D. canaliculatum* (section *Eleutheroglossum*). Reciprocal crosses were made on July 14, 1975. After transplanting to 5-cm pots on January 24, 1977, differences in growth were noted. Ten plants of each cross were transplanted to 10-cm pots and were paired by similar size. Data obtained from January 1979 to May 1980 were analyzed by the paired Student's *t* test. Somatic chromosomes were counted to determine whether differences were due to changes in chromosome number.

The reciprocal crosses were remade in February 1979, and seedlings were transplanted into 5-cm pots in March 1981. Growth of seedlings was compared visually.

2. *D. canaliculatum* D173-2 and *D. strebloceras* D38-3. This is an intersectional hybrid involving the sections *Eleutheroglossum* (*D. canaliculatum*) and *Ceratobium* (*D. strebloceras*). The cross was registered as *D.* X Autumn Lace (10). Reciprocal crosses were made on August 8, 1975, germinated on November 11, 1975, planted in community pots on March 15, 1976, transplanted to 5-cm pots on May 23, 1977, and transplanted to 10-cm pots on September 8, 1978. Fourteen plants of each cross were completely randomized on a bench in a greenhouse. Data

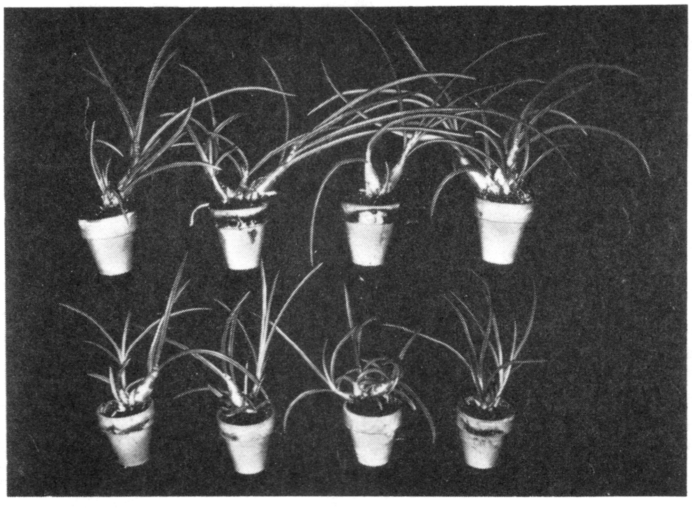

Fig. 1. Offspring of reciprocal crosses of 2 *Dendrobium canaliculatum* accessions. Top row: D173-2 x D129. Bottom row: D129 x D173-2.

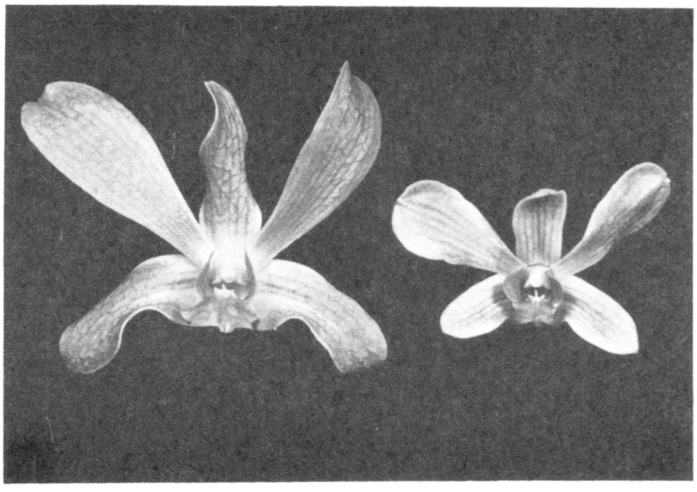

Fig. 2. Comparison of flowers of reciprocal crosses of *D. schulleri* and *D.* X Sunset. Left: *D. schulleri* x *D.* X Sunset. Right: *D.* X Sunset x *D. schulleri*.

Table 2. Mean values (±SD) of characters in reciprocal crosses of *D. strebloceras* D38-3 x *D. canaliculatum* D173-2.

Cross	No. plants	Plant height (cm)	Yield[z]	Scape lenth (cm)	Raceme length (cm)	No. pseudobulbs	No. flowers per raceme
D38-3 x D173-2	14	29.4 ± 1.8	9.9 ± 1.7	16.0 ± 0.6	33.6 ± 1.0	16.6 ± 1.3	18.7 ± 0.8
D173-2 x D38-3	14	38.9 ± 2.7	13.1 ± 1.8	15.1 ± 0.4	32.8 ± 1.1	22.4 ± 2.1	18.6 ± 0.5
Significance		**	NS	NS	NS	*	NS

[z]Mean no. racemes per plant over 16 months.
NS, *, **Nonsignificant (NS) or significant at 5% (*) or 1% (**) by *t* test.

obtained from January 1979 to May 1980 were analyzed using Student's *t* test.

3. *D. schulleri* and *D* X Sunset. A commercial dendrobium breeder made a cross between 2 diploid plants, *D. schulleri* and *D.* X Sunset, which resulted in several award winning plants. The cross was repeated, but the parents were reversed. Two plants of the first cross and 10 plants of the 2nd cross were available for determining the somatic chromosome number. Offspring from reciprocal crosses were compared visually.

4. *D* X Jaquelyn Thomas K44-50 and *D.* X Jaquelyn Thomas 2085-4N. 'Uniwai Supreme' is a seed-propagated cultivar produced by crossing 2 amphidiploid *D.* X Jaquelyn Thomas, K44-50 and 2085-4N. K44-50 has white flowers with a lavendar tinge, while 2085-4N has 2-toned purple violet flowers. Reciprocal crosses were made on September 10, 1975, germinated on January 8, 1976, planted in community pots on March 4, 1977, and transplanted to 5-cm pots on August 8, 1978. A randomized complete-block design consisting of 4 crosses and 10 replications was used (2 crosses were omitted in this paper). The plants were grown in a greenhouse with data obtained from July 1978 to May 1980.

Somantic chromosome counts. Counts were made by sampling root tips between 9:00 and 10:00 AM. Root tips were pretreated for 4 hr in 0.002 M 8-hydroxyquinoline solution at about 18°C. Samples were fixed in modified Carnoy's solution (1:1:2, 95% ethanol, chloroform, glacial acetic acid) for 12 min. Root tips were hydrolyzed in 1N HCl for 10 min at 50°, washed in deionized water, stored in 45% acetic acid, and smears stained with 1% aceto-orcein.

Plant characteristics measured. Scape length was measured from the bottom of the raceme to the lowest flower. The total length of the raceme was measured from the base of the raceme to the tip. The percentage of bud drop was determined from the ratio of dropped buds to the total number of flowers at the time of harvest. Flower width was determined by measuring the broadest spread of the 3rd lowest flower of the raceme. The height of the plants was determined by measuring from the base to the shoot apex of the tallest growth as of May 1980. Yield was measured as the total number of racemes produced by the plant through May 1980. Keeping quality was defined as the number of days until a harvested raceme wilted or half of its flowers senesced. Keeping quality was evaluated only for the cut flower cultivar, 'Uniwai Supreme'.

Results and Discussion

D. canaliculatum D173-2 and D. canaliculatum D129. The progenies of the reciprocal crosses showed large differences in plant height, number of pseudobulbs, and yield (Table 1). The progeny with the higher values for the characters had D173-2 as the maternal parent. Chromosome counts of all offspring were $2n = 38$, the expected number for *Dendrobium* species.

The repeat set of reciprocal crosses showed no difference while the seedlings were in flasks. After the seedlings were planted in community pots, differences became apparent (Fig. 1). Since progenies from reciprocal crosses had the same chromosome number, the character differences of the reciprocal progenies probably can be attributed to the difference in cytoplasm.

D. canaliculatum D173-2 and D. strebloceras D38-3. The progenies of these reciprocal crosses differed only in height and number of pseudobulbs (Table 2). Offspring with *D. canaliculatum* cytoplasm (D173-2 x D38-3) were taller and produced more pseudobulbs. All offspring were diploid with $2n = 38$ chromosomes, and therefore the differences obtained in the reciprocal crosses again appear to be cytoplasmic-related. *D. canaliculatum* D173-2, when used as the maternal parent in this set of reciprocals as well as the previous set, produced offspring

Table 3. Mean values (±SD) of characters in reciprocal matings of amphidiploid *D.* X Jaquelyn Thomas K44-50 x *D.* X Jaquelyn Thomas 2085-4N.[z]

Cross	No. plants	Plant height (cm)	Yield[y]	Scape length (cm)	Raceme length (cm)	No. flowers per raceme	Flower width (cm)	Keeping quality (days)	Bud drop (%)
K44-50 x 2085-4N	10	121.4	7.2	19.1	50.1	14.2	6.2	13.8	0.2
2085-4N x K44-50	10	114.8	7.5	19.0	52.7	14.7	6.1	14.4	0.1

[z]Differences of character values between reciprocals are not statistically significant.
[y]Mean no. racemes per plant harvested over 22 months.

which were taller and had a larger number of pseudobulbs.

D. canaliculatum D173-2 was introduced from Lae, Papua, New Guinea, while *D. canaliculatum* D129 was obtained from a local orchidist and is probably of Australian origin. The differences encountered through cytoplasmic effects of D173-2 emphasize the need to consider the transmission of cytoplasm, especially with interspecific and intersectional hybridization in the genus *Dendrobium*.

D. schulleri and D. X Sunset. The reciprocal matings produced progenies with different ploidy levels. The 2 offspring of *D. schulleri* x *D.* X Sunset were determined to be triploid, while all the reciprocals were diploids. This indicates that one of the parents, *D.* X Sunset, produced functional, unreduced gametes when used as the pollen parent. The triploid offspring resulting from *D. schulleri* x *D.* X Sunset resembled *D.* X Sunset (Fig. 2), while the reciprocal, *D.* X Sunset x *D. schulleri* was about intermediate between the 2 parents. The triploid offspring must have received 2 sets of chromosomes from *D.* X Sunset and only one of *D. schulleri*. The reciprocal progeny received one set each from both parents.

The transmission of chromosomes similar to that observed in *D.* X Sunset was encountered earlier with *D. phalaenopsis* 'Lyon's Light No. 1' (1, 7). Unreduced gamete formation in 'Lyon's Light No. 1' was associated with irregular meiosis in pollen mother-cells. Thus, when 'Lyon's Light No. 1' was used as a pollen parent, the offspring were predominantly triploid, but when it was used as a female parent, the offspring were diploid.

It is interesting to note that *D. schulleri* x *D.* X Sunset produced several award-winning plants, while the reciprocal *D.* X Sunset x *D. schulleri* produced no award winners and only mediocre hybrids.

D. X Jaquelyn Thomas K44-50 and D. X Jaquelyn Thomas 2085-4N. No differences were observed between the progenies of the reciprocal crosses (Table 3). Thus, it can be concluded that seed of 'Uniwai Supreme' can be produced safely in either direction for commercial cut-flower production.

D. X Jaquelyn Thomas is a hybrid between *D. phalaenopsis* and *D. gouldii*. Although it is not known in which direction the original crosses were made, it is likely that both K44-50 and 2085-4N contain *D. phalaenopsis* cytoplasm. If the cytoplasm of one of the amphidiploids were from *D. gouldii*, perhaps some differences in the reciprocal progenies might have developed.

Literature Cited

1. Dorn, E.C. and H. Kamemoto. 1962. Chromosome transmission of *Dendrobium phalaenopsis* 'Lyon's Light No. 1'. Amer. Orchid Soc. Bul. 31:997–1006.
2. Kamemoto, H. 1976. Cytogenetics and breeding of dendrobium orchids. Sabrao J. 8:17–27.
3. Kamemoto, H. 1980. Breeding dendrobiums for commercial cut-flower production. Proc. 3rd ASEAN (Association of Southeast Asian Nations) Orchid Congr. p. 96–107.
4. Kamemoto, H. and J. Kunisaki. 1979. *Dendrobium* Jaquelyn Thomas UH232. Hort. Dig. 30:4.
5. Kamemoto, H., J. Kunisaki, and U. Charanasri. 1974. Breeding dendrobiums for commercial cut flowers. Proc. 7th World Orchid Conf. p. 205–209.
6. Kamemoto, H., K. Shindo, and K. Kosaki. 1964. Chromosome homology in *Ceratobium, Phalaenanthe*, and *Latourea* sections of the genus *Dendrobium*. Pacific Sci. 18:104–115.
7. Kamemoto, H. and M. Tara. 1968. Chromosome inheritance in reciprocal crosses of *Dendrobium phalaenopsis* 'Lyon's Light No. 1'. J. Amer. Soc. Hort. Sci. 92:665–671.
8. Kamemoto, H. and G.J. Wilfret. 1971. Genome breeding in *Dendrobium*. Proc. 6th World Orchid Conf. p. 245–248.
9. Kihara, H. 1979. Nucleo-cytoplasmic hybrids and nucleo-cytoplasmic heterosis. Seiken Ziho. 27–28:1–13.
10. Wilfret, G.J. and H. Kamemoto. 1979. Autumn Lace 'Florida Twist' *Dendrobium* hybrid. HortScience. 14:641–642.
11. Wilfret, G.J., T. Takeshita, and H. Kamemoto. 1979. Genome and karyotype relationships in *Dendrobium* (Orchidaceae). III. Meiotic behavior. J. Amer. Soc. Hort. Sci. 104:43–46.