TECHNICAL BULLETIN NO. 58 JULY 1963

Evaluation and Improvement of ANTHURIUM CLONES

H. KAMEMOTO
and
H. Y. NAKASONE

HAWAII AGRICULTURAL EXPERIMENT STATION, UNIVERSITY OF HAWAII

CONTENTS

THE AUTHORS

DR. H. KAMEMOTO is Horticulturist at the Hawaii Agricultural Experiment Station and Professor of Horticulture, University of Hawaii.

DR. H. Y. NAKASONE is Assistant Horticulturist at the Hawaii Agricultural Experiment Station and Assistant Professor of Horticulture, University of Hawaii.

Evaluation and Improvement of ANTHURIUM CLONES

H. KAMEMOTO and H. Y. NAKASONE

The culture of anthuriums, *Anthurium andraeanum,* in Hawaii has gradually evolved from a hobby status to an important cut-flower industry. Not only are anthuriums grown for local consumption, but a considerable proportion of the flowers are shipped to mainland markets. The major factors contributing to the success of anthuriums as an export crop are: (1) the flowers are long-lasting, often having a shelf life of 4 weeks, (2) they are exotic and of tropical origin, and (3) there is little competition outside of Hawaii. These factors, coupled with the ease of placing the flowers on the mainland market within a few hours, have greatly stimulated the expansion in cultivation of anthuriums in the Islands.

During the infancy of the anthurium industry, flowers were necessarily produced from heterogeneous plantings, due to the lack of stabilized varieties. Gradually, through selection and multiplication of certain superior seedling clones, commercial varieties were established. The majority of these varieties were restricted to those bearing red flowers. With the realization of the need for a systematic evaluation of available varieties and further improvement in flower color, size, shape, texture, and productivity, a breeding project on anthuriums was initiated in the spring of 1950 at the Hawaii Agricultural Experiment Station, University of Hawaii. Surveys of commercial establishments and private collections were immediately conducted to select and assemble the apparently outstanding commercial types as well as those possessing some characteristics of value in a breeding program. The selected plants were placed under surveillance for the purpose of evaluation, and, concurrently, a hybridization program was carried out with the major objective of producing improved commercial varieties. This paper summarizes the evaluation of the accessions and the results obtained to date in the breeding program.

EVALUATION OF ACCESSIONS

Yield

One of the most important factors in commercial anthurium production is yield per plant, particularly since anthuriums are grown in lath or saran

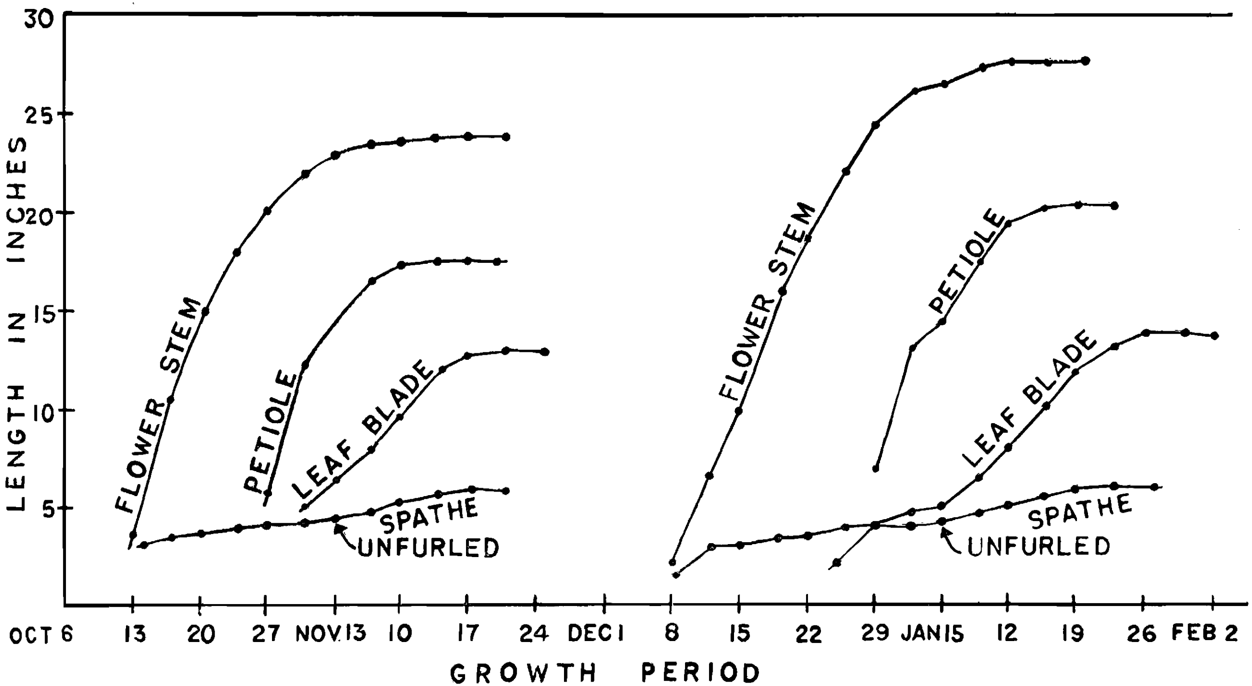

FIGURE 1. Sequence of leaf and flower production of variety Kaumana at two different periods.

houses often on valuable land, in which return per unit area assumes great significance. An understanding of the normal growth and flowering behavior of the anthurium is essential in evaluating accessions on their capacity to produce flowers or to breed for increased yields.

The Flower—The inconspicuous botanical flower is hermaphroditic, with a two-carpelled ovary and four anthers. The rudimentary perianth consists of four scale-like leaves. When mature, the stigma appears as a rounded protuberance on the spadix. Pollen is often shed long after the stigma becomes receptive, thereby preventing self-pollination. At the juncture of the spadix and peduncle is found the colorful modified leaf called the spathe.

In common usage, however, the "anthurium flower" refers to the complex of the spadix and spathe and often includes the peduncle, and, hence, this usage will be retained hereinafter unless specified otherwise.

Normal Flowering Behavior—The anthurium produces flowers throughout the year, although there are differences in the rate of flowering depending upon the season. A flower emerges from each leaf axil. The sequence of leaf and flower production can be seen in figure 1. In the cases of the varieties Kaumana and Nitta, the flowers emerge about a month after the leaves appear and precede the new leaves by a few weeks. This sequence in emergence is maintained throughout their growth, although the intervals between leaf emergence are shortened or lengthened, depending upon the environmental conditions. Thus, during the summer months when conditions are favorable for growth, more flowers can be expected than during the winter months when temperatures are lower and daylengths are shorter.

Method of Determining Yield—Because only a few flowers are produced by a plant in a year and evaluation must often be based on the performance of a single plant, a suitable standard needs to be devised for the determination of yield. The following procedure has been adopted. At weekly intervals, the unfurling of the spathe of a new flower is recorded. The average interval in weeks between flowering is determined after 1 to 2 years of continuous observation. Then this average interval is divided into 52 weeks to arrive at the calculated number of flowers per plant per year. For example, if the first flower was recorded on January 15 and subsequent weekly intervals between flowering were 10, 9, 8, 7, 7, 8, and 9 weeks, the average week-interval is 8 and this average divided into 52 weeks will give 6.5 flowers per plant per year. There is an experimental error due to making the observations on a weekly rather than on a daily basis. However, this error becomes relatively small if observations are continued for more than a year. If, on the other hand, yield were to be expressed by the actual number of flowers appearing within a calendar year, the first flower of a plant might be recorded on January 2 and the last flower on December 28, thereby giving a distorted yielding capacity for a plant.

TABLE 1. Evaluation of anthurium accessions

ACCESSION NO.	RECOGNIZED VARIETAL NAME	SOURCE	SPATHE			
			Color	Size, Length × Width, Inches	Shape	Texture and Substance
4		E. Yamasaki	Red Obake	5 × 4½	Broad heart, large lobes	Smooth, thin
7		H. Otake	Bright red	7½ × 6	Heart	Medium
8		H. Otake	Dark pink	6½ × 5	Heart, overlapping lobes	Medium
10		H. Otake	Orange	6½ × 5	Heart, overlapping lobes	Medium
11		K. Asakura	Dark pink Obake	7¾ × 8½	Broad heart, fused lobes	Smooth, medium
12		K. Asakura	Creamish white Obake	8 × 6	Long heart, overlapping lobes	Smooth, medium
13	Haga White	K. Asakura	White	7 × 5½	Heart, overlapping lobes	Ridged, medium
15		K. Asakura	Orange	5¾ × 5	Broad heart, overlapping lobes	Medium
17		M. Saito	Orange	5½ × 4½	Heart, fused lobes	Smooth, medium
18		M. Saito	Red Obake	12 × 6¼	Long heart, fused lobes	Medium
23		T. Igarashi	Red	6¼ × 5¼	Heart	Smooth, medium
24		T. Igarashi	Orange	6 × 4	Heart	Medium
26	Kaumana	R. Someda	Dark red	5¼ × 4¼	Open heart	Ridged, heavy
33		H. Nakaoka	Red	4 × 4	Heart, overlapping lobes	Ridged, heavy
35		H. Nakaoka	Pink	6 × 5¼	Open heart, unequal lobes	Smooth, medium
38		Y. Matsunaga	Red	6 × 5	Heart, fused lobes	Medium

*The figure in parentheses denotes the number of weeks of observation that entered into the calculation of yield.

TABLE 1. (*Continued*)

ACCESSION NO.)	SPADIX			STEM		SUCKER PRODUCTIVITY	FLOWER YIELD, FLOWERS PER PLANT PER YEAR	EVALUATION
	Color	Length, Inches	Position	Length, Inches	Thickness			
4	Brown	2¾	Reclining	18	Thin	Poor	4.8 (131) *	Fair
7	Yellow	4	Reclining	34	Thin	Good	6.2 (148)	Fair
8	Red	4	Upright	28	Thin	Good	6.2 (59)	Fair
10	Yellow	3¾	Reclining	28	Medium	Fair	6.2 (59)	Fair
11	Greenish yellow	4	Reclining	28	Medium	Poor	5.4 (144)	Fair
12	Yellow	3¼	Straight	26	Medium	Fair	6.9 (136)	Excellent
13	Greenish yellow	4	Reclining	29	Thin	Good	6.9 (90)	Excellent
15	Yellow	3	Reclining	24	Thin	Good	6.2 (168)	Good
17	Yellow	2¾	Reclining	24	Thin	Good	6.0 (198)	Fair
18	Yellow	3¾	Reclining	28	Medium	Poor	5.9 (161)	Fair
23	Yellow	3¾	Reclining	31	Thick	Poor	5.3 (178)	Fair
24	Yellow	2¾	Reclining	30	Medium	Good	6.3 (74)	Fair
26	Red	3½	Reclining	30	Medium	Very good	6.4 (89)	Good
33	Yellow	3½	Reclining	20	Medium	Good	6.3 (115)	Fair
35	Yellow	4	Upcurved	30	Thick	Fair	5.5 (152)	Poor
38	Yellow	3	Reclining	30	Medium	Poor	6.5 (153)	Good

(*Continued*)

TABLE 1. Evaluation of anthurium accessions (*Continued*)

ACCESSION NO.	RECOGNIZED VARIETAL NAME	SOURCE	SPATHE			
			Color	Size, Length × Width, Inches	Shape	Texture and Substance
40		J. Fujimoto	Light orange	6 × 5	Heart	Heavy
41		J. Fujimoto	Dark red Obake	7¼ × 6	Open heart, broad leaves	Smooth, medium
43		J. Fujimoto	Dark red	6 × 5¼	Broad heart	Medium
51		K. Izumi	Coral pink	6 × 4	Heart, overlapping lobes	Ridged, heavy
53		K. Izumi	White Obake	8 × 5	Open heart	Smooth, medium
55		K. Izumi	White	5½ × 5	Heart, overlapping lobes	Heavy
58		K. Izumi	Orange	4¾ × 3¾	Heart, overlapping lobes	Medium
65	Hayashi No. 2	K. Hayashi	Red	5½ × 4½	Heart, fused lobes	Medium
67	Izuno Orange	K. Hayashi	Orange	5½ × 4¼	Narrow heart, overlapping lobes	Medium
71	Asato Red	J. Kaneshiro	Red	7 × 5¾	Broad heart, overlapping lobes	Smooth, medium
72	Ozaki	J. Kaneshiro	Light red	6½ × 6¼	Broad heart, overlapping lobes	Medium
73		J. Kaneshiro	Dark red	5¼ × 4½	Heart	Smooth, medium
74		J. Kaneshiro	Red	6 × 4¾	Heart, overlapping lobes	Smooth, medium
75		J. Kaneshiro	Dark red	4¼ × 3¼	Heart, overlapping lobes	Smooth, medium
81		K. Kamemoto	White	5¼ × 4	Heart	Smooth, heavy

*The figure in parentheses denotes the number of weeks of observation that entered into the calculation of yield.

TABLE 1. (*Continued*)

(ACCESSION NO.)	SPADIX			STEM		SUCKER PRODUCTIVITY	FLOWER YIELD, FLOWERS PER PLANT PER YEAR	EVALUATION
	Color	Length, Inches	Position	Length, Inches	Thickness			
40	Yellow	3¾	Reclining	36	Medium	Very poor	5.6 (46) *	Fair
41	Yellow	3½	Reclining	28	Medium	Good	6.2 (157)	Fair
43	Yellow	3½	Reclining	25	Medium	Good	5.8 (152)	Fair
51	Greenish yellow	3½	Reclining	30	Thick	Good	5.1 (152)	Poor
53	Greenish yellow	3	Reclining	18	Thin	Good	6.6 (134)	Fair
55	Yellow	3¾	Upright	23	Medium	Fair	5.6 (159)	Fair
58	Greenish yellow	3¾	Reclining	24	Thin	Good	5.9 (123)	Fair
65	Red	3¾	Reclining	22	Medium	Good	4.7 (134)	Fair
67	Greenish yellow	3½	Reclining	30	Thin	Poor	4.4 (164)	Fair
71	Yellow	3¼	Straight	26	Medium	Good	5.5 (60)	Fair
72	Purple	3½	Reclining	28	Medium	Good	—	Good
73	Purple	3½	Reclining	21	Medium	Good	6.1 (60)	Fair
74	Red	3½	Reclining	24	Medium	Poor	5.2 (139)	Poor
75	Brown	2½	Reclining	20	Thin	Very good	—	Good
81	Yellow	3¼	Large, reclining	25	Medium	Good	4.2 (161)	Poor

(*Continued*)

TABLE 1. Evaluation of anthurium accessions (*Continued*)

ACCESSION NO.	RECOGNIZED VARIETAL NAME	SOURCE	SPATHE			
			Color	Size, Length × Width, Inches	Shape	Texture and Substance
84		J. Sanjume	Red	$5\frac{3}{4} \times 4\frac{1}{2}$	Heart, fused lobes	Smooth, thin
85		J. Sanjume	Dark red Obake	$10\frac{1}{2} \times 7$	Heart	Smooth, heavy
86			Red	$5\frac{1}{2} \times 4\frac{1}{4}$	Heart	Smooth, thin
87			Coral pink	$4\frac{3}{4} \times 4$	Heart	Medium
94		W. Yee	Red	$9\frac{3}{4} \times 4$	Double spathe	Heavy
95		W. Yee	Dark pink	$4\frac{3}{4} \times 3\frac{1}{2}$	Double or single spathe	Smooth, thin
97	Nitta	S. Kozohara	Orange	6×5	Broad heart, overlapping lobes	Smooth, medium
98	Kozohara Red	S. Kozohara	Dark red	$6\frac{1}{4} \times 5$	Heart, overlapping lobes	Smooth, medium
99	Fukano Red	S. Kozohara	Red	$6\frac{1}{4} \times 4\frac{3}{4}$	Heart, overlapping lobes	Smooth, medium
103		R. DeWeese	White	$3\frac{3}{4} \times 3\frac{3}{4}$	Open heart	Heavy
104		R. DeWeese	White	$4\frac{3}{4} \times 4\frac{3}{4}$	Open heart	Heavy
106	Hirose Red	Y. Hirose	Red	$6\frac{3}{4} \times 5\frac{1}{4}$	Heart, overlapping lobes	Ridged, heavy
109	Toyama No. 3	Toyama	Red	$6\frac{1}{4} \times 4\frac{3}{4}$	Heart, overlapping lobes	Smooth, heavy
110	Kansako No. 1	A. Kansako	Red	$5\frac{1}{2} \times 4\frac{1}{2}$	Heart, overlapping lobes	Ridged, medium
111	Kansako No. 2	A. Kansako	Light red	6×5	Heart, fused lobes	Smooth, medium
113	Kimura Red	P. Oka	Red	5×4	Heart, overlapping lobes	Ridged, medium

*The figure in parentheses denotes the number of weeks of observation that entered into the calculation of yield.

TABLE 1. (*Continued*)

(ACCESSION NO.)	SPADIX			STEM		SUCKER PRODUCTIVITY	FLOWER YIELD, FLOWERS PER PLANT PER YEAR	EVALUATION
	Color	Length, Inches	Position	Length, Inches	Thickness			
84	Red	3	Reclining	27	Thin	Good	5.5 (114) *	Fair
85	Red	3¼	Reclining	20	Thick	Fair	5.5 (143)	Excellent
86	Yellow	4	Long, reclining	26	Thin	Poor	7.5 (153)	Fair
87	Yellow	3¼	Reclining	23	Medium	Good	5.9 (70)	Fair
94	Red	3	Reclining	24	Medium	Good	5.5 (85)	Excellent
95	Purple	3	Upright	22	Medium	Good	4.8 (66)	Very poor
97	Red	3¾	Reclining	26	Medium	Good	5.9 (124)	Excellent
98	Red	3¾	Reclining	26	Medium	Fair	6.0 (87)	Good
99	Red	3¾	Reclining	21	Thin	Poor	4.7 (89)	Fair
103	Yellow	3¾	Reclining	20	Medium	Very good	5.3 (69)	Fair
104	Yellow	2¾	Reclining	20	Medium	Poor	5.6 (159)	Fair
106	Red	3¾	Reclining	26	Medium	Poor	5.9 (71)	Excellent
109	Red	4	Reclining	27	Medium	Poor	4.7 (143)	Fair
110	Red	3¾	Reclining	36	Thin	Good	6.1 (102)	Excellent
111	Red	3¼	Reclining	30	Medium	Good	6.1 (85)	Good
113	Red	3½	Reclining	25	Medium	Good	4.9 (75)	Fair

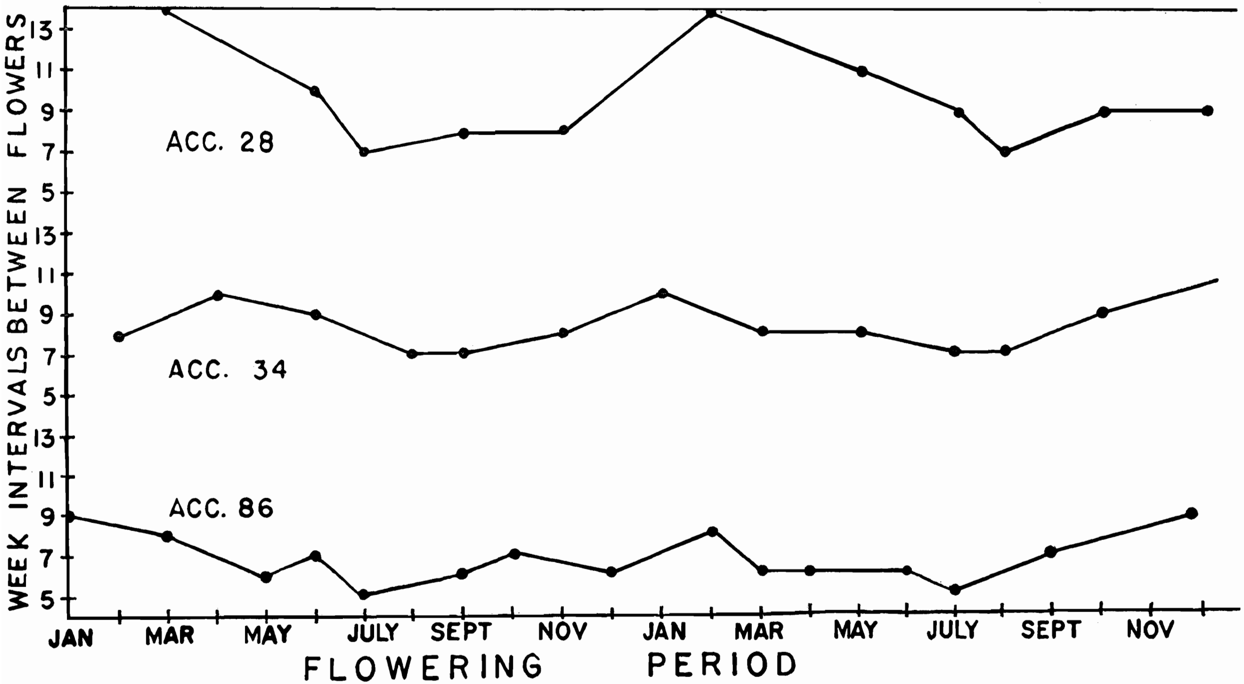

FIGURE 2. Fluctuations in week-intervals between flowerings of three varieties over a 2-year period.

The yielding capacity expressed as flowers per plant per year has proved to be a very useful criterion for the evaluation of yield of accessions and seedlings, despite the fact that it is often based on the performance of a single plant, and environmental factors might affect the yield. It is clearly evident from the several culture tests on anthuriums involving plants of a single clone that the yield will vary with the treatments imposed (Kamemoto and Nakasone, 1953; Nakasone and Kamemoto, 1957, 1962), from no flowers, if the plant dies, to as high as the inherent capacity will allow. In the breeding program, the highest performance of an individual plant is of interest, for if a plant under favorable environmental conditions is able to produce 7 flowers per year, it can be concluded that, given optimum conditions, it could produce at least that many flowers or perhaps even more. Of course, if a plant were observed to give a low yield, one should assess the condition of the plant during the period of observation before an estimate of the yielding capacity of this plant is made.

Variation Among Clones—That inherent variation in yielding capacity exists among clones cannot be disputed. In table 1 is shown the observed number of flowers per plant per year for each accession. The yields recorded are from a low of 4.1 to a high of 7.5. The difference in yield between the two extremes is 83 percent, which is a sizable difference.

Except for clones grown for certain unique characteristics, a minimum of 6 flowers can be considered acceptable for commercial cut-flower production. Nitta, one of the best among the orange clones, produced only 5.9 flowers, while Kaumana, a red variety, yielded 6.4 flowers. It must be emphasized here that the yield per plant is restricted to flowers from the main growing shoot and does not include the flowers from suckers which are produced in abundance by the above two varieties. One might argue that the expression of yield should include flowers from the entire plant including the suckers. If this is done, spacing becomes a factor, and the maximum yield per unit area will still depend upon the best spacing and the maximum yield per shoot.

Accession 86 gave a phenomenal yield of 7.5 flowers per year. Its interval between flowerings during the summer months dropped to only 5 weeks (fig. 2). Unfortunately, this plant does not have desirable flower characteristics.

It might be of interest to note that a colchicine-induced tetraploid, Accession 51, yielded only 5.1 flowers.

Figure 2 shows the fluctuations in week-intervals between flowerings of a few representative accessions. The intervals between flowering are longer during the winter months than during the summer months. This means that flower yields are low during winter and high during summer. The conversion of these data into a production curve reveals that yield is strongly correlated with seasonal fluctuations in daylength and temperature. This fluctuation is of great significance since the demand for flowers during the winter months exceeds that during the summer.

Flower Color

Spathe color can be classified into five basic groups—red, orange, pink, coral, and white. These vary in shade and intensity. In addition to the basic colors, green may appear, usually accompanied by a change in shape of the spathe. Since the spathe is a modified leaf, the chlorophyll development along with the change in shape represents a reversion of the spathe to the primitive state. The term "Obake," derived from the Japanese word denoting a change or ghost, has been accepted for the bicolored flowers. A red Obake has a red-with-green spathe; a white Obake has a white-with-green spathe, etc.

The spadix color usually differs from the spathe. The most common color is yellow when the spadix is immature, changing to white when the botanical flowers are mature, as indicated by the protuberances on the spadix. Other spadix colors are red, purple, brown, gold, and green, in varying shades.

In evaluating flower color, therefore, all basic color groups must be considered independently. At one time, hobbyists were interested in very dark reds such as Pahoa Red, but the fact was soon established that for commercial acceptance and, more specifically, for the mainland export market, the light, bright red flowers were more desirable. Thus, Ozaki, having a light-red spathe, has become one of the leading commercial varieties.

Size, Shape, and Substance

For exhibition and judging purposes, the statement, "The larger the flower, the better," may hold, but for commercial cut-flower production, all sizes are needed, depending on the usage and, therefore, a grower will produce a variety of sizes from the miniatures to the large Obakes measuring 12 to 16 inches long. However, the highest consumer acceptance will probably be among the medium-sized flowers measuring about 5 to 6 inches in spathe length.

The standards developed for a desirable flower form are a heart-shaped spathe with symmetrical, overlapping or fused lobes and a reclining spadix, somewhat shorter than the length of the spathe as measured from the juncture of the spathe and spadix. A reclining spadix is considered to facilitate packaging of flowers for shipment and to also improve the appearance of the flower, although complete agreement among florists has not been reached on the latter point. Figure 3 (*A* and *B*) compares a desirable form and an undesirable primitive type with open lobes and a large, upturned spadix.

Generally, the heavier the substance, the better the quality. However, no relationship between substance and keeping quality or damage in shipment has been ascertained. Some feel that the smooth, thin, pliable spathe causes less bruising in transit.

Stem

Medium-to-heavy thickness of stem is necessary to adequately support the flower and present a better over-all appearance. Also, long and relatively

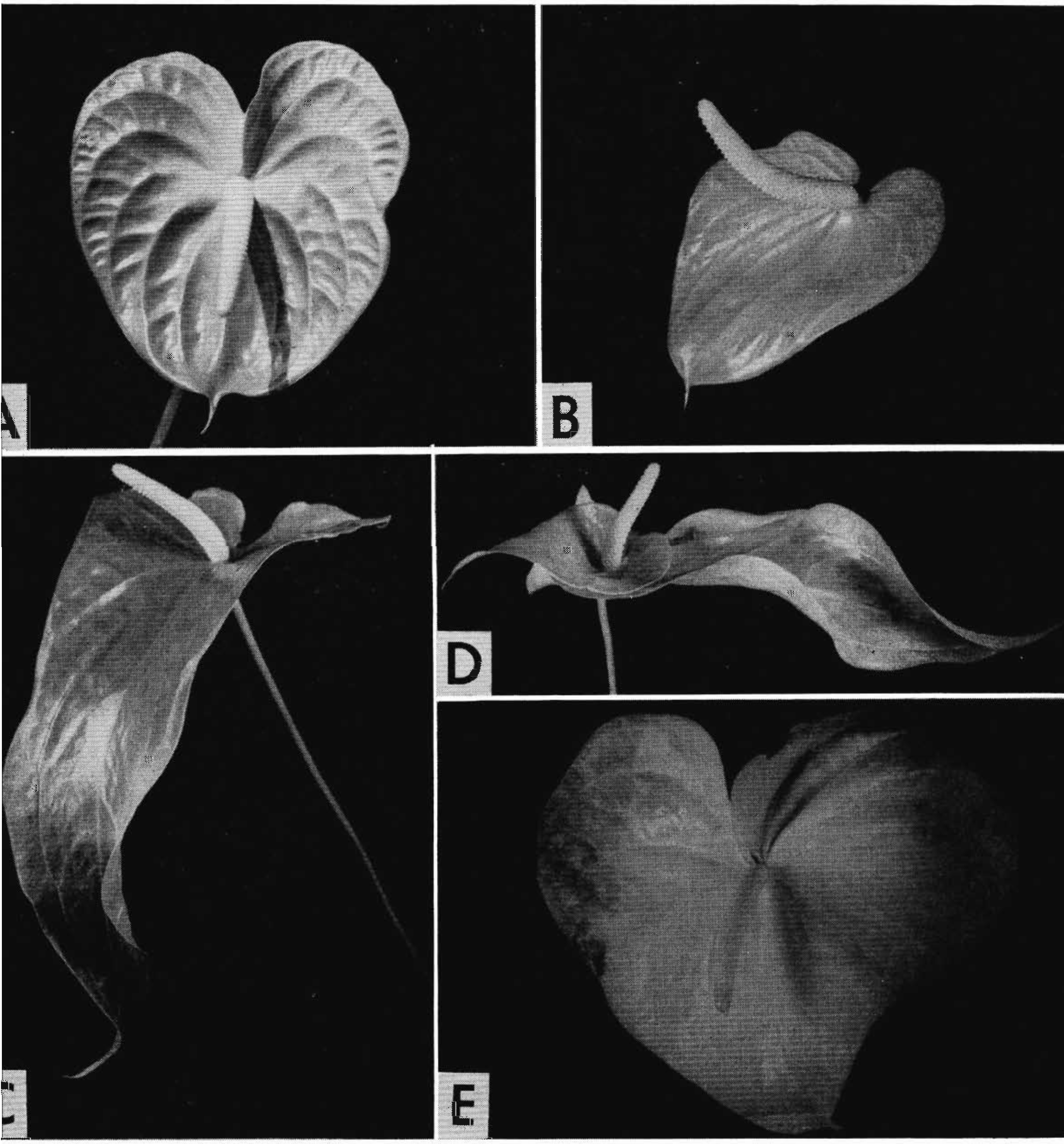

FIGURE 3. *A*, Selection H19, a desirable flower form with overlapping lobes and reclining spadix; *B*, an undesirable primitive type with open lobes and upturned spadix; *C*, Selection H17, a rose opal Obake with reddish spadix; *D*, Accession 94, a unique double-spathe variety; *E*, Selection H84, a broad, heart-shaped white Obake.

straight stems carrying the flowers above the foliage will prevent bruising during periods of strong winds.

Sucker Production

Differences in productivity of suckers are clearly evident among clones. Kaumana and Nitta are prolific producers of suckers. Because propagation from cuttings is very slow, a good commercial variety should produce suckers freely. However, an extreme proliferation of suckers may adversely affect flower production and become undesirable.

Explanation of the Evaluation Table

Table 1 lists the individual accessions with some pertinent information. The first column lists the accession numbers, and the third column the source. Most of these plants were generously donated at the outset of the research by the various people listed in column 3. The total number of accessions evaluated to date is 113, but many accessions were not included in the table for several reasons. Some plants were discarded due to virus infection. Others did not thrive under the conditions of the experiment. Still others exhibited mediocre or poor performance and were not worthy of inclusion.

The second column, "Recognized Varietal Name," lists only those clones that are commonly identified with horticultural names. For example, Kaumana, Nitta, Ozaki, and Kansako No. 1 are well known to practically all commercial growers.

Five basic spathe colors are recorded. The term "Obake," as explained earlier, refers to a spathe with green chlorophyll development. The color of the spadix usually changes with maturity as mentioned earlier, but the designation is restricted to the initial color prior to the change.

The measurements on spathe size, spadix length, and stem length are relative and only an approximation of the higher values obtained. Measurements will vary according to the size of plant, condition of plant, location, and season of year. The figures point out such information as the relatively small flowers of Kaumana, the long spadix of Accession 35, or the relatively long stems of Kansako No. 1.

The method of determining the yield in terms of number of flowers per plant per year was described earlier. In the second-from-the-last column, the yield is listed, together with a number in parentheses which is the number of weeks of continuous observations that entered into the calculation of the yield. The yield can be affected by cultural conditions and, therefore, these yield figures represent the highest yield obtained under the conditions of the experiment, and a yield that can be expected from the same clone in the future. It is highly possible that a clone with a low yield record listed in the table may, with improved cultural conditions, produce higher yields, but until such performance is actually recorded a higher yielding capacity is not proved.

The evaluation of a clone was based on all factors, although for commercial flower production, yield was weighted heavily. On the other hand, among the novelty types, Accession 94, possessing a double spathe, and Accession 85, an attractive dark-red Obake, were rated excellent, despite the relatively low yields of 5.5 flowers per plant per year recorded for both.

Recommended Clones

The clones evaluated good to excellent and recommended for commercial cut-flower production are as follows:

Red:

1. Acc. 26, Kaumana. High yield (6.4 flowers), vigorous growth, and excellent sucker production. Small- to medium-sized, dark-red flowers of good keeping quality. An important commercial cut-flower variety, although the flower color might be considered too dark for general acceptance (see fig. 4*A*).
2. Acc. 38. High yield (6.4 flowers), light-red flowers of good form.
3. Acc. 72, Ozaki. The most popular commercial variety on the island of Hawaii. Yield appears to be high and sucker production good. Light-red spathe and a reddish-purple spadix.
4. Acc. 75. Dark-pink to light-red, small flowers measuring about $4\frac{1}{4} \times 3\frac{1}{4}$ inches. Suckers proliferate. May be desirable for the production of miniatures.
5. Acc. 85. Very attractive dark-red Obake, although yield is relatively low (5.5 flowers). An excellent Obake.
6. Acc. 94. Yield is rather low (5.5 flowers). However, the light-red double spathes make it unique (see fig. 3*D*).
7. Acc. 98, Kozohara. Satisfactory yield (6.0 flowers), good form and color (see fig. 4*D*).
8. Acc. 106, Hirose. Satisfactory yield (5.9 flowers), excellent shape, good color.
9. Acc. 110, Kansako No. 1. Satisfactory yield (6.1 flowers), prolific suckers, medium-sized, dark-red flowers with good shape, exceptionally long flower stems with flowers borne considerably above foliage (see fig. 4*B*).
10. Acc. 111, Kansako No. 2. Satisfactory yield (6.1 flowers), large, light-red flowers of good shape (see fig. 4*C*).

Orange:

1. Acc. 15. Satisfactory yield (6.2 flowers), long stems, and flowers carried considerably above foliage.
2. Acc. 97, Nitta. Satisfactory yield (5.9 flowers), excellent color and shape, prolific suckering, strong grower, very good keeping quality. One of the leading commercial orange varieties (see fig. 4*E*).

White:

1. Acc. 13, Haga White. Very high yield (6.9 flowers), glossy, paper-white spathe of good form and substance. Excessively large spadix with tendency toward fasciation (see fig. 4*F*).

HYBRIDIZATION AND SELECTION

While the accessions were under observation and before any evaluations could be made, hybridizations were initiated. Later, when yield and other information gradually accumulated, pollinations were carefully planned. However, it has not always been possible to perform the desired pollination for either lack of pollen, or the synchronization of pollen availability and stigma receptivity. The botanical flower is protogynous, the stigma becoming receptive soon after the unfurling of the spathe. The receptivity is generally correlated with a change in spadix color. The pollen, on the other hand, is often shed long after the opening of the spathe, although in small flowers from certain young seedlings the pollen is functional relatively early. The protogynous nature prevents selfing within a single spadix, and makes it necessary to have several plants of a clone to effect self-pollination.

Some clones do not produce any pollen and, therefore, can be used only as seed-bearing parents.

Young flowers with spathe still unfurled are covered with plastic bags to prevent contamination. Pollination is accomplished around 10 A.M. by grasping the pollen-ladened spadix with the fingers and then transferring the pollen to the stigmas of another flower by rubbing the spadix with the same fingers. If pollination and fertilization are consummated, the spadix gradually takes on a warty appearance, and finally after 6 to 7 months, mature two-carpelled, one- to two-seeded berries are obtained.

The berries are collected and pressed in water with the fingers to separate the pulp and seed, the pulp is decanted, and the cleaned seeds are scattered on a medium of finely shredded tree-fern fiber in gallon-size containers and kept under relatively heavy shade (75 percent lath). These seeds germinate immediately; as a matter of fact, some seeds are viviparous, having developed a long radicle within the fruit.

Four to 6 months after sowing, the seedlings are transplanted 2 to 3 inches apart in flats containing a 5:1 mixture of wood shavings and manure. Six to 8 months later, they are transplanted into 3-foot × 3-foot ground plots in five rows and five columns. As the seedlings come into flowering, flower color and other pertinent information are recorded. The seedlings can be expected to flower no sooner than 1½ years after seeding, and often 2½ to 3 years are required for the majority of seedlings to come into flowering.

Seedlings that show promising characteristics are singled out, given a selection number, planted in 3- to 5-gallon containers, and placed under critical observation. Often the shape of the flower changes with season and with increase in size and vigor of the plants, particularly those with a

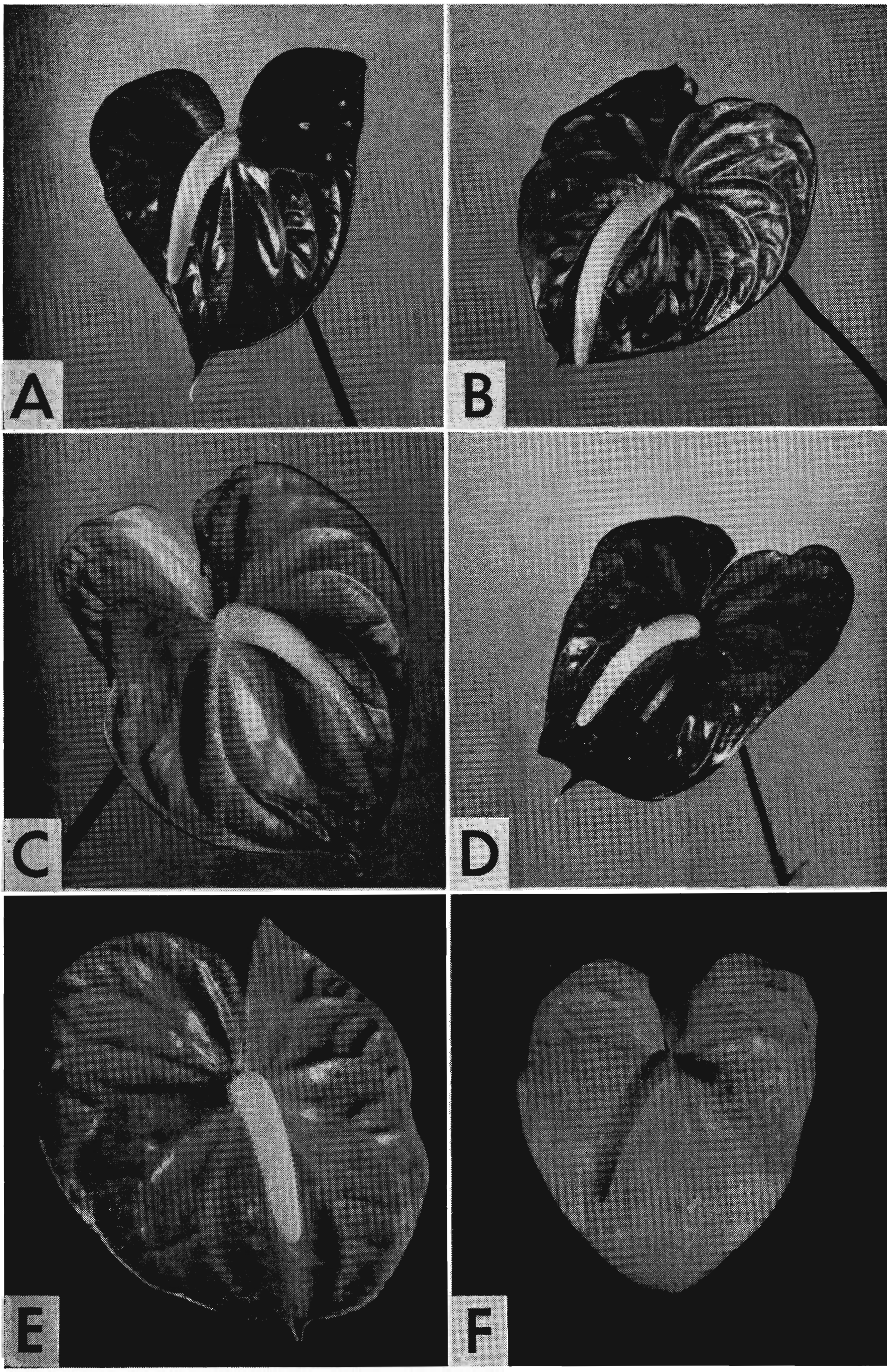

FIGURE 4. *A*, Kaumana; *B*, Kansako No. 1; *C*, Kansako No. 2; *D*, Kozohara; *E*, Nitta; and *F*, Haga White.

tendency to produce Obake flowers. For this reason, many selections are eliminated during the course of observation and evaluation.

Seedlings that have performed well are increased either in ground plots or in pots for further observations.

GENETIC STUDIES

Spathe Color

One of the major objectives of the breeding program is to develop improved white- and pastel-colored varieties since these types are not readily available to the trade. Because breeding is greatly facilitated if the mode of inheritance is known, attempts to analyze the genetics of flower color were concurrently made with the breeding program.

It requires 3 to 4 years to obtain a single generation and also, due to the limitations of facilities, only a limited number of progenies could be carried through at any period. Thus, the accumulation of genetic information has been slow.

Red vs. Orange—In table 1 are presented the results obtained by selfing or crossing reds and/or oranges. A progeny of red × red gave all reds, although the population was very small. A red plant (Acc. 38) selfed, on the other hand, resulted in 44 red to 20 orange, which did not deviate significantly from a 3:1 ratio. An orange plant selfed gave all orange flowers, although here again the population was very small. Two progenies of red × orange gave different results. Only reds arose from Acc. 15 × Acc. 41, while both reds and oranges were recovered from Acc. 97 × Acc. 98.

From the above data the following conclusions might be drawn: (1) red is dominant to orange; (2) orange breeds true for orange, while red may give rise to either all red progeny or a mixed progeny of red and orange, depending upon whether the parent plant is homozygous or heterozygous; (3) crosses between red and orange can be expected to produce all red offspring if the red parent is homozygous, or a 1:1 segregation of red and orange if the red plant is heterozygous.

R^r has been designated as the gene necessary for the production of red pigment and R^o, for the orange pigment.

The dominance of red over orange explains the preponderance of reds in a heterogenous group of seedlings.

Red vs. White—When two whites were crossed, only whites were obtained, indicating that white is pure-breeding. Crossed to red, the offspring of three progenies segregated equally into red and coral pink (table 2). Since the red parent can be heterozygous for red and orange, as noted above, the 1:1 segregation of red and coral pink is easily explained. Assuming that white is the rr genotype, the cross $R^rR^o \times rr$ will give R^rr and R^or, the former responsible for the red spathe and the latter for the coral pink spathe.

It has not been possible to rule out the presence of two factors responsible for the colors, instead of a multiple-allele system. However, the results obtained to date strongly favor the multiple-allele system. It is proposed to clarify this by performing test crosses.

It was postulated earlier (Kamemoto and Nakasone, 1955) on the basis of preliminary observations on flower color segregations that a cross between a red and a white should give pinks. It is now apparent that if the red parent is heterozygous, reds and coral pinks arise instead of rose pinks.

TABLE 2. Segregation of flower color in selfs or crosses involving red and orange

PARENTAGE	RED	ORANGE	GENETIC RATIO	P
Acc. 38 (red) × Acc. 14 (red)	6		1:0	
Acc. 38 (red) × self	44	20	3:1	.25
Acc. 97 (orange) × self		6	0:1	
Acc. 15 (orange) × Acc. 41 (red)	55		1:0	
Acc. 97 (orange) × Acc. 98 (red)	12	9	1:1	.50

TABLE 3. Segregation of flower color in crosses involving red and white

PARENTAGE	RED	CORAL PINK	WHITE	GENETIC RATIO	P
Acc. 12 (white) × Acc. 13 (white)			56	0:0:1	
H13 (white) × H20 (white)			23	0:0:1	
H7 (white) × H25 (white)			47	0:0:1	
H21 (white) × Acc. 66 (red)	44	34		1:1:0	.25
H21 (white) × Acc. 26 (red)	49	45		1:1:0	.70
Acc. 38 (red) × Acc. 63 (white)	28	34		1:1:0	.45

TABLE 4. Segregation of flower color in crosses involving orange, coral pink, and white

PARENTAGE	ORANGE	CORAL PINK	WHITE	GENETIC RATIO	P
Acc. 15 (orange) × Acc. 87 (coral pink)	85	57		1:1:0	.02
H21 (white) × Acc. 97 (orange)		105		0:1:0	

Orange vs. Coral Pink vs. White—An orange, selfed, produced all orange (table 2). When crossed to white, the offspring were all coral pink (table 4). When an orange was crossed to a coral pink, the progeny segregated into orange and coral pink offspring. From these results orange can be assumed to be homozygous and coral pink to be heterozygous for the R^o gene.

The intensity of pigmentation among the offspring of H21 × Acc. 97 (white × orange) varied from light to dark, a few nearly approaching the intensity of the orange parent. Also, in the case of Acc. 15 × Acc. 87 (orange × coral pink), it was very difficult to classify the offspring into the two categories because of an intergrading series and, consequently, the .02 P value obtained for a 1:1 goodness of fit was probably influenced by misclassification (table 4). It appears that modifying genes are also involved in the expression of color intensity in the orange–coral pink series. The two classes, therefore, are often arbitrary, having the same anthocyanin pigment but in varying concentration.

Rose Opal vs. Coral Pink vs. White—Rose opal (o22, Hort. Color Chart) is distinct from coral pink (o619, Hort. Color Chart), but the genetic relationship has not been clearly differentiated. Three crosses involving rose opal and white have shed some light. As seen in table 5, the crosses segregated into white and nonwhite in equal proportions, indicating that the rose opal parent is heterozygous. The nonwhites can be classified into light coral pink and rose opal. A progeny of H21 (white) × H33 (pink) which was recently flowered and carefully observed revealed the following categories:

White spathe with yellow spadix	10
White spathe with red spadix	10
Light coral pink with yellow spadix	19
Rose opal with red spadix	12

It appears that the spadix color interacts with the coral pink spathe to produce the rose opal color. That spadix color exhibits some influence on spathe color is evident in flowers with white spathe and red spadix. The major veins of the spathe radiating from the juncture of the spadix are often strongly colored. This color sometimes extends to the entire spathe, rendering a light pink appearance.

Obake vs. Non-Obake—The nature of heritability of the Obake characteristic is difficult to establish, for the expression is affected by the size and vigor of the plant as well as by the season of the year. A young seedling with a fine-shaped, self-colored spathe may gradually develop Obake flowers as the plant matures, or if a young sucker of an Obake plant is propagated the first few flowers may be self-colored. Due to the demands on space in the lathhouse, it has not always been possible to retain a seedling population until full maturity in order to evaluate precisely the expression of this characteristic.

In table 5 are listed the few progenies which were observed for the character. The selfed progenies of Acc. 97 and Acc. 38, both non-Obake types, were non-Obake, while progenies from Obake parents produced predominantly Obake offspring. H8 × Acc. 13, an Obake × non-Obake cross, gave Obake and non-Obake offspring in nearly equal proportions. This might suggest a backcross ratio, since H8 itself has an Obake and non-Obake parentage.

The large Obakes often command premium prices, but the demand for these constitutes a small proportion of the anthuriums produced. Thus, in the breeding program, emphasis must be placed on the non-Obake types, and since the Obake character appears to be heritable, Obake should not be utilized in the breeding program unless improvement of Obake is specifically intended.

TABLE 5. Segregation of flower color in crosses between pink (rose opal) and white

PARENTAGE	WHITE	NONWHITE*	GENETIC RATIO	P
H21 (white) × (pink)	20	31	1:1	.10
Acc. 11 (pink) × Acc. 63 (white)	23	29	1:1	.45
Acc. 13 (white) × (pink)	43	35	1:1	.40
Total	86	95	1:1	.50

*Includes rose opal and coral pink.

TABLE 6. Segregation of Obake and non-Obake

PARENTAGE	OBAKE	NON-OBAKE
H7 (white Obake) × H25 (white Obake)	42	5
Suehiro White (Obake) × H25 (Obake)	21	
H8 (white Obake) × Acc. 13 (white)	10	7
Acc. 97 (orange) × self		6
Acc. 38 (red) × self		64

Spadix Color

The spadix color changes with the maturity of the botanical flowers. A common color is yellow changing to white when the botanical flowers mature, as indicated by the development of the stigmas. Other colors of immature spadices before this change are red, purple, brown, gold, cream, and green, along with intergrading shades. Reddish spadices may remain red, or may change to purple or white.

The spadix color has been classified into red or nonred (table 7). The expression of red color is not always complete, for many plants have been observed to produce flowers with a red spadix and a nonred spadix at one time or another. Thus, in all crosses involving a red spadix, the few non-reds recorded might possibly be those that lacked penetrance. Red × red has given all and nearly all reds. Acc. 97 (orange spathe with a yellow spadix) crossed to Acc. 98 (red spathe with a red spadix) gave all red spathes with red spadices, one red with yellow, and nine orange with yellow. In two crosses involving a red spathe with a red spadix and a white spathe with a yellow spadix, equal segregations of red spathes with red spadices and coral pink spathes with yellow spadices were obtained. It seems that the orange and coral pink spathes generally suppress anthocyanin development, while red spathes appear to favor the development of red spadices.

In the earlier section on inheritance of rose opal, it was noted that a rose opal crossed to a white gave the four groups—white with nonred spadix, white with red spadix, light coral pink with nonred spadix, and rose opal with red spadix in the approximate ratio of 1:1:1:1. It appears from this and other crosses that spadix and spathe colors are independently inherited.

TABLE 7. Segregation of spadix color

PARENTAGE	RED	NONRED	GENETIC RATIO	P
Acc. 95 (red) × Acc. 94 (red)	40		1:0	
Acc. 15 (nonred) × Acc. 41 (red)	50	5	1:0	
Acc. 97 (nonred) × Acc. 98 (red)	11	1	1:0	
H13 (red) × H20 (nonred)	14	9	1:1	.30
Acc. 13 (nonred) × pink (red)	22	21	1:1	.85
H21 (nonred) × H33 (nonred)	10	10	1:1	.99
Acc. 12 (nonred) × Acc. 13 (nonred)		56	0:1	
H7 (nonred) × H25 (nonred)		47	0:1	

The offspring of crosses involving white with either red or nonred spadices or the offspring with white spathe from crosses of rose opal and white are convenient for the study of spadix color since interactions need not be concerned. All three crosses, H13 × H20, Acc. 13 × pink, and H21 × H33, gave approximately a 1:1 ratio for this character. The latter crosses both involved nonred spadices, but it is believed that the red spadix color of the rose opal parent (H33) has been suppressed. Further studies are necessary to clarify the mode of inheritance of spadix color as well as the possible interaction between spathe color and spadix color.

Double Spathe

Accession 94 has produced double spathes regularly, while Acc. 95 has thrown doubles sporadically (table 8). The cross between the two produced 6 doubles, 8 occasional doubles, and 26 singles. Acc. 94 (double) × Acc. 97 (single), on the other hand, gave only 14 occasional doubles and 146 singles. Thus, doubleness is transmitted in varying degrees depending upon the parentage, with the percentage of doubles increasing if both parents are double. Figure 3*D* shows a good double-spathe variety.

TABLE 8. Transmission of double spathe

PARENTAGE	DOUBLES REGULARLY	DOUBLES IRREGULARLY	SINGLE	TOTAL
Acc. 95 × Acc. 94	6	8	26	40
Acc. 94 × Acc. 97		14	146	160

Sucker Production

Observations on accessions have revealed clonal variation in the production of suckers. It was observed also that this character is generally transmitted to the offspring. A high-suckering clone tended to produce offspring with higher suckering capacity, while a low-yielding clone tended to produce few suckers. For example, seedlings of Kaumana or Nitta gave higher sucker yields than those of other crosses. Figure 5 shows Nitta, a high-suckering variety on the left and a low-suckering selection on the right.

SELECTIONS INTRODUCED

The first group of seedling selections made in 1953 totaled 34 plants, the second group made in 1955–56 numbered 22, and since then 126 additional selections were made. Several selections were discarded after preliminary evaluation because of inferior qualities. Continuous observation revealed two seedlings of exceptional merit among the early selections and these have been named for release to the trade.

FIGURE 5. Plant on left shows numerous sucker growths from a single plant. Plant on right shows only the parent plant with no suckers. Both plants were repotted on the same date.

Uniwai

This selection with white flowers originated from a cross between Acc. 12 and Acc. 13, both whites with very high yielding capacity. This seedling has shown an exceptionally high yield of 7.7 flowers per plant per year over a consecutive period of 101 weeks. The week intervals between flowering averaged only 6.7.

The smooth and pliable white spathe is broad and heart-shaped with overlapping lobes (fig. 6*A*). During the spring months, the young spathes often develop a slight tinge of pink. The spadix is yellow, short, and drooping when young but turning upright with age. Sucker production is relatively poor. Thus, the flower characteristics are not outstanding for exhibition purposes but this variety may have its place in cut-flower production. Since good commercial white varieties are uncommon, this exceptionally high yielder should be of interest and value to the grower.

Marian Seefurth (H33)

Emphasis in the breeding program has been placed on improving whites and pastels. The appearance of this seedling with attractive pink spathe

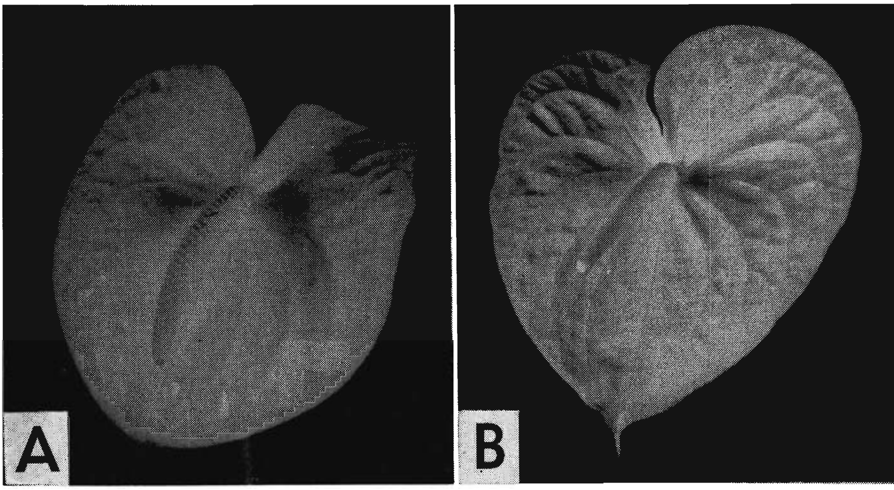

FIGURE 6. *A*, Uniwai; *B*, Marian Seefurth.

(rose opal—o22/1 of Hort. Color Chart) has been most gratifying, particularly since pinks are not commonly obtained in random hybridizations. The spathe, measuring 6½ inches long and 5½ inches wide, is broad and heart-shaped with overlapping lobes (fig. 6*B*). The spadix is greenish yellow when young, white when mature, drooping when young, upright when mature. Like other pinks, the color intensity is influenced by environment and age. Flower yield over a consecutive period of 151 weeks averaged 6.9 flowers per plant per year, which can be considered excellent.

This selection arose from a cross between Acc. 13 and a pink clone. It has been named Marian Seefurth in honor of the wife of Mr. Nathaniel Seefurth, who made an unsolicited grant-in-aid for anthurium research at the University of Hawaii.

PROMISING SELECTIONS

H17

An offspring of Acc. 13 (white) × Acc. 18 (red Obake), the spathe is rose opal Obake and the spadix is reddish. The yield of 7.3 flowers per plant per year reflects the high yields of both parents. The Obake characteristic is transmitted by Acc. 18. The attractive Obake spathe measures 15½ inches long and 8½ inches wide (see fig. 3*C*).

H19

This plant has a large, white, smooth spathe measuring 7¼ inches long and 5¼ inches wide, with overlapping lobes. The spadix is reclining and yellow. The average flower yield during 145 weeks was 6.5 (see fig. 3*A*).

H84

This is a high-yielding white Obake with a broad, heart-shaped spathe measuring 8¼ inches long and 7¾ inches wide. The spadix is yellow and reclining. An offspring of H7 and H25, it is a vigorous grower with an average yield of 6.7 flowers per plant per year (see fig. 3*E*).

SUMMARY

Progress in anthurium breeding at the University of Hawaii since its inception in 1950 has been summarized.

The accessions assembled from commercial establishments and private collections were observed and evaluated, and outstanding clones for commercial production were singled out. Haga White, Nitta, Kaumana, Ozaki, Kansako No. 1, and Hirose were among those evaluated favorably.

Major emphasis in breeding has been placed on increased yields and on the improvement of white- and pastel-colored forms. Two seedling selections were deemed worthy of naming and introducing into the trade. Selection H21, a white with exceptional yield, was named Uniwai. A second selection with excellent yielding capacity and an attractive rose opal spathe was named Marian Seefurth.

The genetics of flower color was investigated. Red, R^r, appears to be dominant to orange, R^o; white, rr, breeds true for white. A red in heterozygous condition, R^rR^o, crossed to a white, rr, will give red, R^rr, and coral pink, R^or, in equal proportions. Orange, R^oR^o, crossed to white, rr, results in coral pink, R^or. Although the mode of inheritance of rose opal is not established, it is suggested that this color is a result of an interaction between coral pink, R^or, and a red spadix color.

Red or nonred spadix color appears to be simply inherited and to interact to some extent with spathe color. Also, development of chlorophyll in the spathe seems to be simply inherited, but the transmission of sucker productivity and doubleness of spathe is not clearly defined.

LITERATURE CITED

British Colour Council in Collaboration with the Royal Horticultural Society. 1938. Horticultural colour chart, vols. I and II.

Kamemoto, H., and H. Y. Nakasone. 1953. Effect of media on production of anthuriums. Hawaii Agric. Exp. Sta. Prog. Notes No. 94. 8 pp.

——— and ———. 1955. Improving anthuriums through breeding. Hawaii Farm Sci. 3 (3) : 4–5.

Nakasone, H. Y., and H. Kamemoto. 1957. Wood shavings as a medium for anthuriums. Hawaii Agric. Exp. Sta. Circ. 53. 11 pp.

——— and ———. 1962. Anthurium culture with emphasis on the effects of some induced environments on growth and flowering. Hawaii Agric. Exp. Sta. Tech. Bull. 50. 19 pp.

UNIVERSITY OF HAWAII
COLLEGE OF TROPICAL AGRICULTURE
HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU, HAWAII

THOMAS H. HAMILTON
President of the University

MORTON M. ROSENBERG
Dean of the College and
Director of the Experiment Station

G. DONALD SHERMAN
Associate Director of the Experiment Station