Inheritance of Purple Spathes in *Anthurium*

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Abstract. A scheme for the genetic control of purple spathes in *Anthurium* is proposed. The recessive allele *p* modifies the color of anthocyanins controlled by the *M* and *O* loci. A spathe is purple when the genotype is *M-O-pp*. If the *P* locus is dominant, *M-O-* is red, while *mmO-* is orange. The *p* allele has no effect on the *-oo* (white) genotype.

The five major spathe colors of *Anthurium andraeanum* Hort. are red, pink, orange, coral, and white. These colors are determined by the concentration and ratio of two anthocyanins, cyanidin 3-rutinoside and pelargonidin 3-rutinoside (Iwata et al., 1979, 1985). Two major genes, *M* and *O*, determine the five spathe colors (Kamemoto et al., 1988). The gene *M* controls production of cyanidin 3-rutinoside and the gene *O* controls the production of pelargonidin 3-rutinoside. The recessive *oo* is epistatic to *M*. Genotypes for the red group (red and pink spathes) are *M-O-*, for the orange group (orange and coral spathes) are *mmO-*, and for white are *-oo*. The intensity of colors is affected by the dosage of *M* and *O* alleles.

The discovery of *A. amnicola*, a miniature species with lav-

ender spathes (Dressier, 1978), has stimulated interest in hybridization for the development of purple anthuriums. Several hybrids have been made between *A. amnicola* and species with other spathe colors. Generally, the first generation hybrids have pink or red spathes. The present study was undertaken to elucidate the genetic systems controlling purple spathes in anthuriums.

Materials and Methods

The anthurium plants used in this study were part of the breeding program at the Univ. of Hawaii. The parental species involved in producing interspecific hybrids for genetic analysis of purple spathe color were as follows: *Anthurium amnicola* Dressier with light lavender spathe; a few cultivars of *A. andraeanum* Hort.; *A. formosum* Schott., with very large creamy spathe; *A. kamemotoanum* Croat, with dark magenta spathe; and *A. lindenianum* Koch & Augustin, with white spathe.

A. amnicola was hybridized with four other species, producing 10 F₁ populations (Table 1). Due to male-sterility present in the single crosses, segregating populations were obtained by making multiway crosses.

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Table 1. Spathe colors of interspecific hybrids and multiway crosses in *Anthurium*.
Spathe colors are purple (P), pink-red (R), orange (O), and white (W).

Cross numbers	Parents	Spathe colors of offspring
F₁ hybrids:		
552, 559	<i>A. lindenianum</i> (W) × <i>A. amnicola</i> (P)	R
568, 572	<i>A. amnicola</i> (P) × <i>A. formosum</i> (P)	P
569, 575	<i>A. amnicola</i> (P) × <i>A. lindenianum</i> (W)	R
717, 718	<i>A. andraeanum</i> (O) × <i>A. amnicola</i> (P)	R
755	<i>A. andraeanum</i> 'Uniwai' (W) × <i>A. amnicola</i> (P)	R
756	<i>A. andraeanum</i> 'Marian Seefurth' (R) × <i>A. amnicola</i> (P)	R
Multiway crosses:		
573	<i>A. amnicola</i> × (<i>A. kamemotoanum</i> × <i>A. formosum</i>)	P,R
587	[(<i>A. andraeanum</i> 'Uniwai' × <i>A. kamemotoanum</i>) × <i>A. formosum</i>] × <i>A. amnicola</i>	P,R
634	Cross 552 (R) × <i>A. amnicola</i>	P,R
692, 696	[(<i>A. andraeanum</i> 'Uniwai' × <i>A. lindenianum</i>) × <i>A. amnicola</i>]	P,R,W
697 and 753	× <i>A. formosum</i>	
733	(<i>A. andraeanum</i> 'UH 712' (R) × <i>A. amnicola</i>) × <i>A. formosum</i>	P,R
739	Cross 587 (R) × <i>A. formosum</i>	P,R
747, 750	Cross 552 (R) × (<i>A. kamemotoanum</i> × <i>A. formosum</i>)	P,R,W
751	Cross 572 (P) × <i>A. formosum</i>	P,W
762	[(<i>A. andraeanum</i> × <i>A. kamemotoanum</i>) × <i>A. formosum</i>] × <i>A. formosum</i>	P,R,W

The color on the adaxial side of the spathe was subjectively classified into three discrete color groups: white, purple, and pink-red. Chi-square tests were performed to test goodness of fit of the observed phenotypic ratio to the expected ratios.

Results and Discussion

First-generation hybrids between the lavender *A. amnicola* and other species with pink-red, orange, and white spathes produced pink-red spathes (Table 1). The exception was *A. amnicola* × *A. formosum* (cross 568 and 572). The pink-red F₁ hybrid between *A. lindenianum* and *A. amnicola* backcrossed to *A. amnicola* produced a 1:1 ratio of pink-red and purple (cross 634, Table 2). These results suggest recessiveness for the purple phenotype.

The 13 multiway crosses listed in Table 1 were placed into five groups based on the spathe colors of parents and segregation of offspring (Table 2). Group 1 progenies of purple × red parents segregated into a 1:1 ratio of purple and red. This ratio suggests that the red parents are heterozygous at a locus controlling purple spathe, while the purple parents are homozygous recessive at that locus. This suggestion assumes that the two parents are both homozygous for the other color alleles.

One cross in Group 2 between purple and white parents (cross 751) yielded purple and white offspring in a 1:1 ratio, suggesting a difference between the two parents at the locus *O*.

There were two types of red × white crosses. One cross (739) in Group 3 produced purple and red offspring in a 1:1 ratio. In this case, the red parent must have been homozygous at the locus *O* and heterozygous at the locus controlling purple spathe, while the white parent was homozygous recessive at the *O* locus

and homozygous recessive at the locus controlling purple color.

The other type of red × white crosses placed in Group 4 consisted of five crosses (692, 696, 697, 753, and 762) that gave purple, red, and white in a 1:1:2 ratio, indicating segregation at two loci. In this case, the genotype of the red parent was double-heterozygous at both the locus *O* and the locus controlling purple color, while the white parent had the same genotype as the white parent in the preceding group.

Two red × red crosses (747 and 750) in Group 5 gave red, purple, and white in a 9:3:4 recessive epistatic ratio, suggesting that both parents were double-heterozygous at the locus *O* and the locus controlling purple spathe.

From these results, we postulate that the purple spathes are produced by an allele in the homozygous recessive state, which we designate *asp*. The *pp* purple phenotype, however, is only expressed when the *O* locus has at least one dominant allele, otherwise the spathe will be white. No plant with *mmO-pp* was encountered. The genotypes represented in the groups in Table 2 are as follows:

Group 1) Purple × red gives 1 purple: 1 red

$MMOOpp \times MMOOpp = 1 MMOOpp: 1 MMOOpp$

Group 2) Purple × white gives 1 purple: 1 white

$MMOopp \times MMoopp = 1 MMOopp: 1 MMoopp$

Group 3) Red × white gives 1 purple: 1 red

$MMOOPp \times MMoopp = 1 MMOopp: 1 MMOOpP$

Group 4) Red × white gives 1 red: 1 purple: 2 white

$MMOOpP \times MMoopp = 1 MMOOpP: 1 MMOopp: 2 MMoOpP \text{ and } MMoopp$

Group 5) Red × red gives 9 red: 3 purple: 4 white

$MMOOpP \times MMOOpP = 9 MMO-P-: 3 MMO-pp: 4 MMoOpP \text{ and } MMoopp$

Table 2. Segregating populations from 13 crosses involving purple, red, and white spathe colors in *Anthurium*.

Color of parents (cross numbers, hypothesized genotypes)	Phenotypes of offspring			χ^2	P
	Purple	Red	White		
	(expected ratio)				
Purple x red (573, 587, 634 and 733) (<i>MMOoPp</i> x <i>MMOoPp</i>)	59 (1:	60 1:	0 0)	0.016 ^z	0.9–0.95
Purple x white (751) (<i>MMOoPp</i> x <i>MMOoPp</i>)	9 (1:	0 0:	6 1)	0.667 ^z	0.3–0.5
Red x white (739) (<i>MMOOPp</i> x <i>MMOoPp</i>)	3 (1:	8 1:	0 0)	2.363 ^z	0.1–0.2
Red x White (692, 696, 697, 753 and 762) <i>M – OoPp</i> x <i>MMOoPp</i>)	36 (1:	19 1:	49 2)	5.904	0.05–0.1
Red x red (747 and 750) (<i>MMOoPp</i> x <i>MMOoPp</i>)	10 (3:	15 9:	7 4)	3.003 ^z	0.2–0.3

^zYates' corrected χ^2 .

All species involved in this study, except for the cultivars of *A. andraeanum*, were assumed to be homozygous for the spathe color genes, because of the uniformity of spathe color of species in natural populations (Croat, 1983, 1986). Based on the preceding assumption, the genotypes of the species were deduced from the progeny results as follows: of the 10 crosses of the type *Pp* × *pp*, seven (692, 696, 697, 733, 739, 753, and 762) were crossed to *A. formosum* and three (573, 587, and 634) were crossed to *A. amnicola*. Therefore, it seems that these two species must both be homozygous for the *p* allele. Since *A. formosum* is white, its genotype is *oopp*. The lavender *A. amnicola* thus should be *OOpp*. Crosses between *A. amnicola* and an orange *A. andraeanum* (717 and 718) gave all-red offspring; therefore, *A. amnicola* must have been *MMOoPp*.

A red hybrid obtained by crossing white *A. lindenianum* and purple *A. amnicola* backcrossed to *A. amnicola* (634) gave a 1:1 red and white progeny. The genotype of *A. lindenianum* must be *MMooPP*.

The fourth group that gave ratios of 1:1:2 all involved four different species, but in all cases the last cross was with *A. formosum* (*oopp*). Four of these crosses (692, 696, 697, and 753) involved the hybrid (*A. andraeanum* × *A. lindenianum*) × *A. amnicola*, which has the *OoPp* genotype. Since the genotype of *A. amnicola* is *MMOoPp* and *A. lindenianum* is *MMooPP*, the white *A. andraeanum* cultivar, previously designated as *mmoo* (Kamemoto et al., 1988), is *mmooPP*.

The last group, which segregated 9:3:4 at both the *O* and *P* loci, included *A. kamemotoanum* in its pedigree. Since *Anthurium formosum* is *oopp* and *A. kamemotoanum* crossed to a white *A. andraeanum* cultivar with *mmoo* genotype gave all pink-red progeny, *A. kamemotoanum* must be *MMOOPP*.

Thus, the following genotypes are proposed for the parental species: *MMOoPp* for *A. amnicola*, *mmooPP* for *A. andraeanum* 'Uniwai', *MMooPP* for *A. lindenianum*, *MMOOPP* for *A. kamemotoanum*, and *MMoopp* for *A. formosum*.

In summary, the *O* locus is recessively epistatic to the *M* and *P* loci. If the *O* locus is homozygous recessive, the color is white. When the *M* and *O* loci are dominant and the *P* locus is homozygous recessive, the spathe is purple. The interaction between *M* and *P* loci has not been determined.

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