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INHERITANCE OF BERRY SIZE, COLOR AND FLOWER SEX IN MUSCADINE GRAPES

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Abstract. **Sixty-five F_1 hybrids from Muscadine (*Vitis rotundifolia*) cv 'Summit' × 'Noble' were analyzed for the inheritance of flower sex, berry size and color. The segregation of flower sex followed the 1: 1 Mendelian single gene ratio in perfect: female flowers. The color segregation followed 2:1:1 Mendelian ratio in black: red: bronze. These data indicate that the berry color is controlled by 2 pairs of independent genes. Berry size in 90% of the hybrids was confined within the size of their parents. Among those that were larger than parents, 85.7% were female flowers. This suggested that a large number of hybrids are necessary in order to select large fruited individuals with perfect flower in such a cross combination.**

The common objectives of most grape breeding programs are to produce locally adapted, high yielding cultivars with quality desirable for the intended use (Reisch and Pratt, 1996). No matter what the fruits are used for, flower sex must be taken into consideration in muscadine breeding. Since muscadines were formerly all dioecious (Detjen, 1917; Loomis, 1954) and many currently available cultivars are female flowers, pollinators are necessary in a commercial vineyard. Perfect flower vines are self-fertile and would obviate the need as pollinators for female vines. For this reason, perfect flower cultivars are preferred by grape growers. Fruit size is another important characteristics and large berry is always demanded by the fresh grape industry. Therefore, large berry with perfect flower would be one of the top priorities in muscadine grape breeding.

Early research on sex inheritance of muscadine grapes concluded that the perfect flowers was either heterozygous (Detjen, 1917; Dearing, 1917; 1918; Loomis, 1948; 1954), or homozygous (Loomis and Williams, 1957). Little is known of sex on muscadines. Similarly, the genetics of fruit size in muscadines has not been fully investigated. Barritt and Einset (1969) proposed 2 pairs of genes with epistatic action for fruit color in *V. vinifera*: B, a dominant gene for black fruit, and R, a dominant gene for red fruit, and white fruited grapes are considered to be recessive for both genes. Since muscadines are different in many aspects from *V. vinifera*, it is not clear that the genetic basis of fruit color in muscadine would be similar to *V. vinifera*. To fully understand the inheritance of these characteristics in muscadines, genetic analysis on a population of 'Summit' × 'Noble' was conducted. 'Summit' is known for its disease resistance, large fruit and high quality, while 'Noble' is considered to be good at every aspect except small fruit for fresh market.

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Materials and Methods

The cross of 'Summit' (bronze, female flower) × 'Noble' (black, perfect flower) was made in 1993 and hybrids were planted in 1994 at the Viticulture Center, Florida A&M University, Tallahassee. Flower sex, fruit size and color of the 65 hybrids was recorded in 1998 and 1999. Perfect flower type was discriminated from female flower by erect stamen during bloom. Berry color of mature fruits was visually divided into bronze, red, and black. Fruit size was determined by the average of berries in 5-10 clusters randomly collected from each vine.

Results and Discussion

Flower sex and fruit color. Among the 65 F_1 hybrids, 6 phenotypes were observed: red/perfect, red/female, black/perfect, black/female, green/perfect, and green/female. The ratio of female: male was 35:30 that was a close fit to the 1:1 Medelian ratio (Table 1). This flower sex segregation result was similar to the conclusions of Detjen (1917) and Loomis (1954). The flower sex is a clearly qualitative trait (Oberle, 1938; Loomis, 1960) and controlled by a single gene. According to Levadoux (1947), hermaphrodite flower (H) is dominant over female (h). The genotype of parent 'Noble' can therefore be interpreted as heterozygous Hh, and 'Summit' is homozygous hh. A fifty percent of perfect flower vines would be expected when 'Noble' is used to cross with a female vine.

The 65 F_1 hybrids segregated into 30 black, 14 red, and 21 bronze. It was a close fit to a of 2:1:1 separation (Table 2). The ratio of 2 black:1 red:1 bronze is similar to the observation made by Barritt and Einset (1969) in *V. vinifera* grapes. Both

Table 1. Segregation and chi-square analysis of perfect and female flowers in the hybrids of 'Summit' × 'Noble'.

Flower sex	Vine #	Expected	χ^2(3:1)
Perfect	30	32.5	0.19
Female	35	32.5	0.19
Total	65	65.0	0.34
p 0.50			0.46

Table 2. Segregation and chi-square analysis of fruit color in the hybrids of 'Summit' × 'Noble'.

Fruit color	Vine #	Expected	χ^2 (3:1)
Bronze	21	16.3	1.4
Red	14	16.3	0.3
Black	30	32.5	0.2
Total	65	65.0	1.9
p 0.3			2.4

Table 3. Distribution of different fruit size among the hybrids of 'Summit' × 'Noble'.

Size (g)	<2.8	2.8-8.5	>8.5
Number	1.0	57.0	7.0
Percentage	1.5	87.7	10.8

Table 4. Distribution of different size of fruits in different phenotypes among the hybrids of 'Summit' × 'Noble'.

Color	Flower	Vine numbers			Fruit size (g)		
		Total	Large fruit	%	Smallest	Average	Largest
Red	Perfect	5	0	0.0	3.9	4.5	4.9
Red	Female	9	1	1.5	1.8	6.5	11.6
Black	Perfect	13	0	0.0	2.9	4.2	6.9
Black	Female	17	2	3.0	3.6	5.9	10.6
Bronze	Perfect	12	1	1.5	3.6	6.1	9.4
Bronze	Female	9	3	4.6	4.8	7.5	11.3

black gene B- and red gene R- involved in the color development of muscadines. Because the dominance of black gene B- and red gene R- over white, no matter B- and R- are homozygous or heterozygous, the fruits would be colored. The bronze fruits are expected to be homozygous in gene b- and gene r-. A heterozygous BbRr and a homozygous bbrr are, therefore, suggested for 'Noble' and 'Summit', respectively.

Inheritance of berry size. Berry size of the 65 hybrids varied from 1.8 g to 11.3 g, and showed continuous distribution. Among them, berry size of fifty-seven vines were within the size of their parents, and only 7 (10.7%) were larger than 'Summit' (8.5 g) and 1 (1.5%) were smaller than 'Noble' (2.8 g) (Table 3). This indicated that the fruit size is a quantitative trait, and majority of hybrids would be expected between their parents, but small percentage of larger berry (bigger than parents) vines could also occur. While the chance of getting large fruit vine is relatively low, a large number of hybrid seedlings are necessary for producing certain number of such vines.

When the data were analyzed according to the phenotype groups: red/perfect, red/female, black/perfect, black/female, bronze/perfect, and bronze/female, it was found that the bronze fruits (6.8 g) were larger than red ones (5.5 g), and the black fruits (5.1 g) were smallest. An interesting phenomenon is that the largest fruit in each group are always females. No matter what color is, fruits with female flowers are larger than those fruits with perfect flowers (Table 4). These data suggest that fruit size might somehow link with flower sex.

Fruits larger than 'Summit' (8.5 g) are normally considered as large fruits for the market standard. Seven out of the 65 hybrids produced berries larger than 8.5 g. They were found in phenotypes of red/female (1), black/female (2), bronze/perfect (1), bronze/female (3), and none was found in red/perfect and black/perfect phenotypes. These large fruited vines only accounted for 1.5%, 3.0%, 1.5%, and 4.6% of the total hybrids (Table 4). All the large fruited vines but one were female. This indicated that the recombination frequency of perfect flower/large fruit is extremely low.

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