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 John H. Weinberger, California. Breeding peach, apricot, plum.
- 1970 Joseph R. Furr, Calif. Breeding & water relations of citrus.
 George D. Oberle, Va. Breeding peach, nectarine, apple, grape.
 George F. Waldo, Ore. Breeding strawberry, blackberry, red raspberry.
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- 1972 Paul C. Stark. Leading role in discovery and introduction of Golden Delicious apple; development of other new fruit varieties.
- 1973 Oliver A. Bradt. Breeding of Apricot, peach and grape.

Relationships Between Fruit Size and Seed Number and Size In Blackberries¹

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Introduction

Fruit enlargement in higher plants is controlled by complex physiological processes resulting from hormonal activity (2, 11, 12). In these processes, ovule fertilization and subsequent seed development play a leading role. In some "many seeded" fruits, it has been found that seed number is positively correlated with mature fruit size (1, 3, 5, 7, 8, 9). Seed size may also be important in determining fruit

size in some species (8) but not in others (9). In the blackberry, large fruit size is important in harvesting and marketability of the fruit and small seeds are preferred in fresh and processed blackberry products. Wide variations in seed size among genetic clones of blackberry (4, 14) and raspberry (13) have been reported. This investigation was conducted to determine the effects of seed number and size on fruit size of the cultivated blackberry.

¹Published with approval of the Director of the Arkansas Agricultural Experiment Station.

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Materials and Methods

In 1970, 50 primary fruits were collected at first harvest and 50 lower order fruits (tertiary, quaternary) were collected at last harvest from each of 41 genetic clones of blackberry (Table 1). The 50 fruits from each harvest of each clone were divided into 5 groups of 10 fruits each, weighed, and seed extracted by the blender-flotation method (10). Seeds were air-dried for 6 days, counted, and weighed. Correlations were run between fruit size and the various seed characteristics.

Results

Mean fruit weights, seed number per fruit, average seed weight, and fruit weight per seed are shown in Table 1. The interaction of clone \times fruit position was not significant, and only the means of the two harvests are shown. An association appears to exist between high seed number, large seed size, and large fruit size. For example, 'Wells Beauty' produced the largest fruit of the 41 clones and also had a large number of seeds per fruit and large seeds. The magnitude of this relationship is shown statistically by the correlation coefficients in Table 2. Fruit size is positively correlated ($P = .01$) with number of seeds per berry, total seed weight per berry, and mean seed size (weight) in both the large primary fruits of the first harvest and the small, lower order fruits of the last harvest. These correlations are for pooled data of the 41 clones, however, and individual exceptions occur. For example, 'Comanche' has relatively large fruit, although seed number is low (Table 1). Its seeds are large in size, however, which apparently contributes to its large fruit size. It is notable that most very large-fruited clones have both high seed numbers and large seeds.

If enlargement of a fruit is assumed to be due to the sum of the effects of

individual seeds, the average contribution of each seed to fruit size can be calculated as fruit weight per seed (8, 9) or, in the blackberry, as drupelet size. Marked differences were found among genetic clones in fruit weight per seed (Table 1). A significant positive correlation exists between seed size (weight) and fruit weight per seed, indicating that larger seed may be contributing more hormones for fruit enlargement. The highest correlation found in this study was between fruit weight and total seed weight per fruit (Table 2). Total seed weight reflects the individual effects of seed number and seed size and is a measure of the total effect of the seeds. This correlation is similar in magnitude to that reported for red raspberries (13). Darrow and Sherwood (4) concluded that the proportion of seed weight to total berry weight was more important in determining fruit size than seed size. These data support this conclusion.

The effect of fruit position on the inflorescence on fruit size and seed number and size is shown in Fig. 1. The primary (large) berries harvested early in the season contain more seeds and the individual seeds are slightly larger than the later harvested, lower order (small) fruits. In addition, seeds in primary berries produce more fruit weight per seed, (i.e., have larger drupelets). Thus, lower order fruits on the inflorescence are smaller because of fewer drupelets, smaller seeds, and less fruit enlargement per seed.

Discussion

Since seed are major contributing factors to fruit size in blackberries, seed content must be considered in breeding for large fruited cultivars. Fruit size can be increased by developing types with greater seed number or larger seeds, or both. Since large seed size is objectionable in many blackberry products, it appears that

Table 1. Fruit and seed characteristics of 41 blackberry clones at Clarksville, Arkansas, 1970.¹

Genetic clone ²	Fruit weight	Seeds per fruit	Mean seed weight	Fruit weight per seed
	(g)	(No)	(mg)	(mg)
Wells Beauty	6.8 a	72 bc	3.5 b	90 be
Ark. 548	6.0 b	73 bc	3.0 de	78 f-i
Brazos	5.7 bc	69 bcd	3.2 cd	79 e-h
Ark. 516	5.5 cd	66 de	2.9 ef	80 d-g
Ark. 514	5.4 cde	70 bcd	3.2 cd	74 g-k
Ark. 544	5.3 cde	50 mno	2.8 efg	106 a
Ark. 557	5.3 cde	83 a	3.0 de	62 mno
Ark. 546	5.1 def	58 g-j	2.6 gh	83 c-f
Comanche	5.0 efg	47 op	3.6 b	102 a
Ark. 537	4.7 fgh	50 mno	2.7 fgh	90 bc
Ark. 535	4.6 ghi	58 g-j	2.1 lmn	74 g-k
Ark. 545	4.6 ghi	68 cde	2.3 jkl	65 l-o
Ark. 512	4.5 hij	51 l-o	3.2 cd	86 b-e
Ark. 536	4.3 h-l	49 nop	2.6 gh	87 bcd
Cherokee	4.3 h-l	55 i-m	2.8 efg	75 g-j
Ark. 519	4.2 i-m	57 g-j	3.0 de	71 i-l
Ark. 538	4.1 j-m	59 ghi	2.4 ijk	68 j-m
Ark. 539	4.1 j-m	48 op	2.7 fgh	84 b-f
Ark. 533	4.1 j-m	54 i-m	2.1 lmn	71 i-l
Ark. 532	4.0 klm	65 def	2.6 gh	60 nop
Ark. 511	4.0 klm	55 i-m	3.0 de	72 h-k
Ark. 526	4.0 klm	73 bc	2.0 mno	54 pq
Ark. 541	3.9 lmn	44 pq	2.9 ef	86 b-e
Ark. 520	3.9 lmn	41 q	3.4 bc	91 b
Ark. 528	3.9 lmn	74 bc	2.5 hij	51 qr
Ark. 523	3.8 mno	54 i-m	2.2 lm	69 j-m
Ark. 529	3.8 mno	60 fgh	2.6 gh	62 mno
Ark. 543	3.8 mno	55 i-m	2.5 hij	68 j-m
Ark. 525	3.8 mno	51 l-o	2.8 efg	72 h-k

Ark. 534	3.8 mno	54 i-m	2.1 lmn	66 lmn
Ark. 513	3.5 nop	52 k-o	2.9 ef	67 k-n
Dallas	3.5 nop	65 def	2.5 hij	53 pq
Ark. 510	3.4 op	59 ghi	2.6 gh	58 opq
Humble	3.4 op	62 efg	2.3 jkl	53 pq
Ark. 530	3.4 op	56 h-k	2.3 jkl	58 opq
Ranger	3.1 pq	39 q	2.8 efg	75 g-j
Ark. 552	2.8 q	33 r	4.3 a	84 b-f
Ark. 542	2.8 q	40 q	2.5 hij	69 j-m
Hedrick	2.0 r	58 g-j	1.9 no	34 s
Darrow	2.0 r	55 i-m	1.8 o	35 s
Ark. 560	1.2 s	27 s	1.2 p	44 r

¹Mean separation within columns by Duncan's multiple range test at 5% level.

²Parentage of Selections:

Ark 510, 511, 512, 513, 514, 516, 520: Thornfree x Darrow.

Ark 523, 525, 526, 528, 529, 530, 532, 533, 534, 535, 536, 537, 538, 539, 543, 544, 545, 546, 548: Darrow x Brazos.

Ark. 541, 542: Ranger x Brazos.

Ark. 557: Thornfree x Brazos.

Ark. 552: (Thornfree x Darrow) x O.P.

Ark. 560: Early Harvest x Whitford Thornless.

Table 2. Correlation coefficients between fruit size, seed number, and seed size in blackberries.

Comparison	Inflorescence Position	
	Primary	Tertiary-Quaternary
Fruit weight x Seed number		0.56**
Fruit weight x Mean seed weight		0.51**
Fruit weight x Total seed weight		0.81**
Fruit weight x Fruit weight per seed		0.35*
Fruit weight per seed x mean seed weight		0.64**
Seed number x Mean seed weight		-0.07

**Significant at 1% level.

*Significant at 5% level.

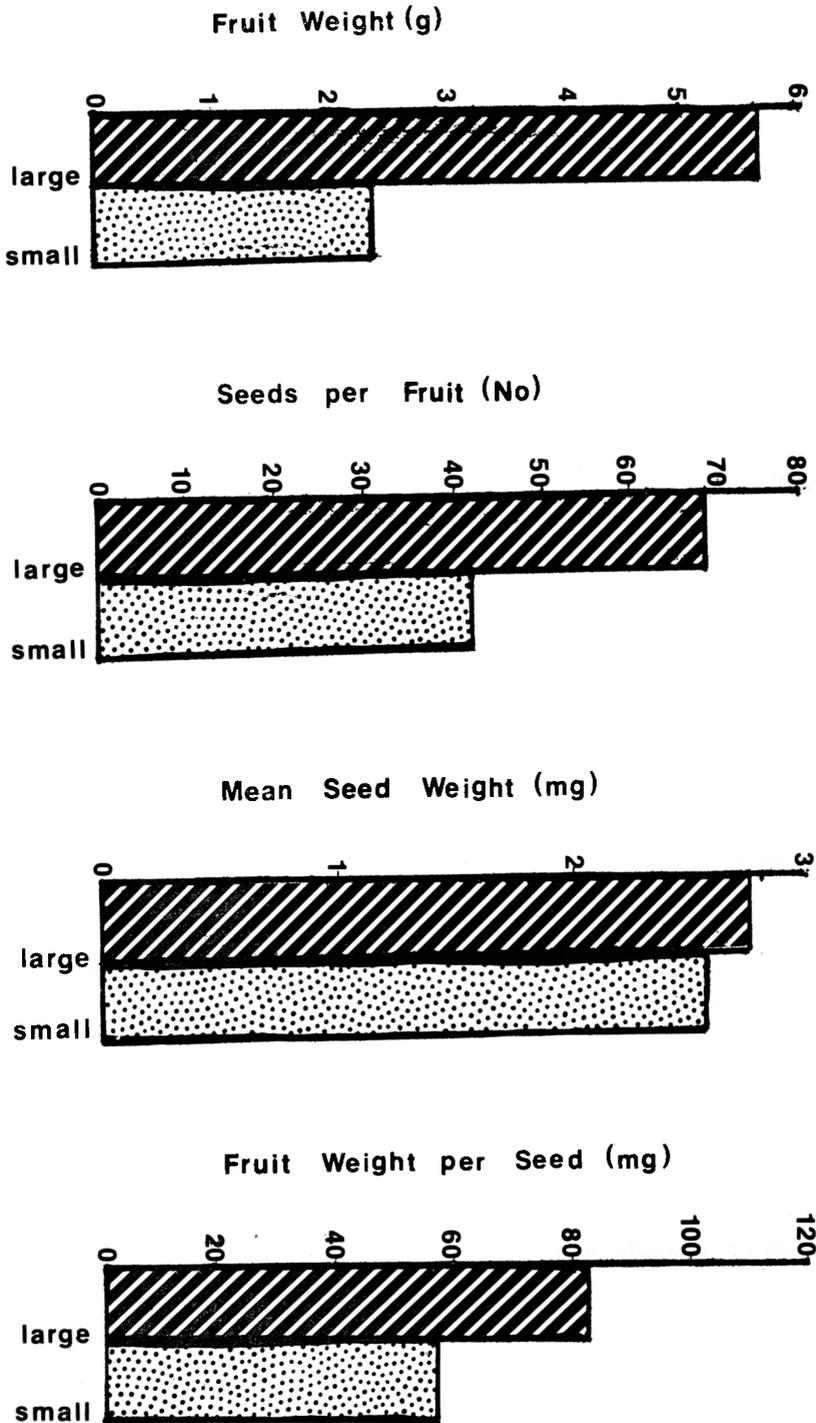


Fig. 1. Relationship between fruit size, seed number, seed weight, and fruit weight per seed in blackberry. (Means of 14 genetic clones).

breeders should select for genetic material with high seed number per berry. Seed number per fruit is largely a response of the number of pistils developed in the flower and of ovule fertility. Kerr (6) found a high degree of pistil sterility, within individual flowers, ranging from 40 to 100% among clones of blackberry. Selection for high fertility would result in higher seed content and larger fruit.

It is interesting to speculate on the possible inheritance of fruit and seed characters in blackberry. In these tests, 21 of the varieties and selections are sister seedlings from the cross of 'Darrow' x 'Brazos' (Table 1). While this number is too small to make definite conclusions, it is noteworthy that all but one of the seedlings were between the parental limits for fruit weight and seed size. Three seedlings had more seeds than 'Brazos' and 7 had fewer seeds than 'Darrow.' Mean fruit weight of the 21 sister selections was 4.31 g compared to the parental mean of 3.85 g. Mean seed number of the seedlings, 57.7, was slightly less than the parental mean, 62.0. Mean seed weight of the seedlings was exactly the same as the parental mean, 2.5 mg. Thus, it appears that fruit weight, seed number, and seed size of seedlings tends to be intermediate between the parents. Selection and hybridization of parents with high seed number should result in populations of seedlings with high seed number and large fruit size. Maximum fruit size, however, will probably be achieved by combining high seed content and large seed size.

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