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Storability of Summer Squash as Affected by Gene *B* and Genetic Background

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Abstract. **Three pairs of near-isogenic lines of summer squash (*Cucurbita pepo* L.) with and without gene *B* were compared for storability. The test included 'Bareqet' (B^+/B^+) and 'Goldy' (B/B^+) of the zucchini type, 'Caserta' (B^+/B^+) and 'Precocious Caserta' (B/B) of the vegetable marrow type, and 'Benning's Green Tint' (B^+/B^+) and the 'Benning's Yellow Tint' (B/B) of the scallop type. Fruit were hand-harvested between 3 and 5 days past anthesis and stored for up to 22 days at 5°C and 85% to 95% RH. Weight loss was higher in the cultivar with gene *B* for two of the three types (vegetable marrow and scallop). Shrivel, chilling injury, and overall appearance ratings were worse for the cultivar with gene *B* for all three types. Weight loss was highest in the vegetable marrow type, intermediate in the zucchini type, and lowest in the scallop type. Shrivel, chilling injury, and appearance, 7 days after harvest, were most severe in the vegetable marrow type.**

Summer squash are the immature fruit of *Cucurbita pepo* L. They come in a variety of shapes, including forms referred to as zucchini (long, uniformly cylindrical), vegetable marrow (short, tapered cylindrical, narrower at stem end, broader at blossom end), and scallop (flattened with wavy equatorial margins) (7). They also come in various shades of green and yellow. Of particular recent interest is the relatively new intense yellow color of some cultivars, including 'Golden Zucchini', 'Gold Rush', 'Goldy', and 'Sunburst'. This coloration is determined in part by gene *B* (17), the primary effect of which is the conditioning of precocious yellow fruit pigmentation. Gene *B* is pleiotropic, having numerous secondary effects, some of which are horticulturally beneficial and others detrimental (19). In addition to the control of intense yellow color, *B* also produces slimmer fruit shape (18), slower growth rate of fruits (15), reduced symptoms of watermelon mosaic virus-2 infection in yellow fruits (1), increased yield quality (10), and quicker harvesting (13) than squash lacking this gene.

Summer squash have a short-term storage life (4, 20) and they are susceptible to chilling injury at temperatures of ≈5°C or lower (3, 6, 16). Storability differences among cultivars have been noted (5, 16). A recent study (16) on straightneck-type cultivars implicated gene *B* in reduced storability and increased sensitivity to chilling injury. The objective of the present work was to determine if *B* does indeed reduce storability of summer squash, by comparing near-isogenic B^+/B^+ (green) and $B/-$ (yellow) lines and comparing different summer squash types for storability.

Three pairs of near-isogenic lines, one from each of three summer squash types, were examined: of the zucchini type, 'Bareqet' (B^+/B^+) (9) and 'Goldy' (B/B^+) (11); of the vegetable marrow type, 'Caserta' (B^+/B^+) (Northrup King Co.) and Precocious Caserta Breeding Line (B/B)(12); and of the scallop type, 'Benning's Green Tint' (B^+/B^+) (Northrup King Co.) and 'Benning's Yellow Tint' (B/B) (8). Seeds were sown on 12 Sept. 1985 at Gainseville, Fla. in single rows on raised beds with 1.8 m between bed centers. Standard cultural practices, including black plastic mulch, were employed.

Fruit selected for harvest were glossy, generally 3 to 5 days past anthesis, which, in the case of the zucchini and vegetable marrow fruit corresponded to an equatorial diameter of 3.5 to 5.5 cm. Fruit were hand-harvested by cutting the peduncle near the stem. The peduncles were trimmed to ≈2 cm length before storage. Initial weights of the trimmed squash averaged 129 g for the first harvest and 144 g for the second.

Fruit were stored at 5°C and 85% to 95% RH for up to 22 days. Treatments were arranged in a completely randomized design with a minimum of 14 replications in the first harvest and six in the second. Weight loss was determined, and fruit were rated repeatedly for shrivel, chilling injury, and overall appearance at 2- or 3-day intervals during storage for each individual fruit. Shrivel was rated on a scale of 1 to 5, with 1 = none; 2 = slight, not objectionable; 3 = moderate, detracts from salability; 4 = severe, normally not marketable; and 5 = ex-

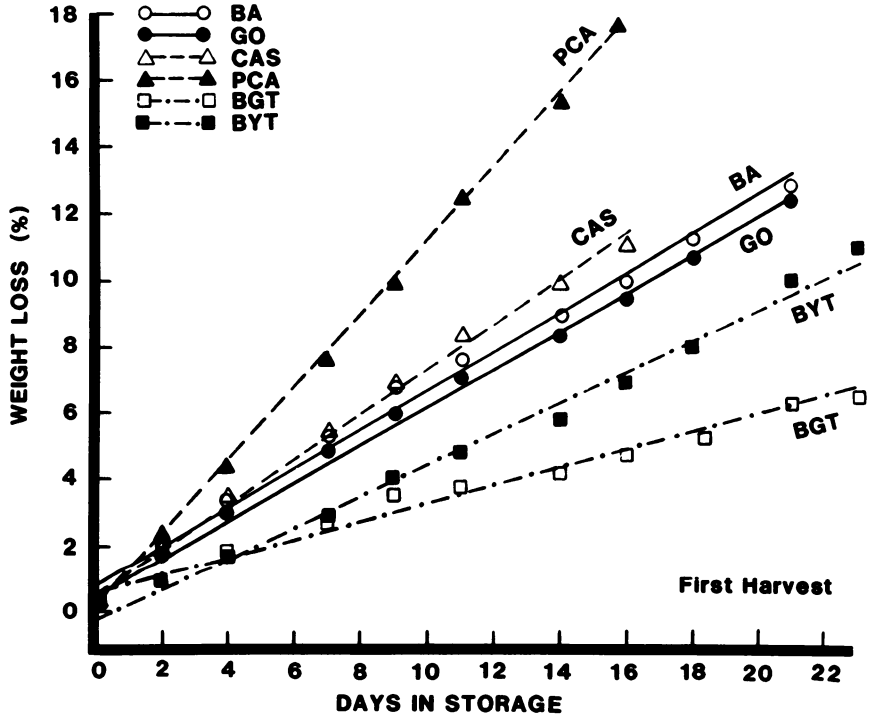

Fig. 1. Weight loss of summer squash during storage at 5°C and 85% to 95% RH. PCA = 'Precocious Caserta', CAS = 'Caserta', BA = 'Bareqet', GO = 'Goldy', BYT = 'Benning's Yellow Tint', and BGT = 'Benning's Green Tint'. Lines represent highly significant linear regressions that had R^2 values ranging from 0.7248 to 0.9323. Each point is the mean of 14 values for BGT and BYT and 16 values for PCA, CAS, BA, and GO.

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Table 1. Ratings for shrivelling of summer squash during storage at 5°C, 85% to 95% RH, from 1 = no shrivelling to 5 = extreme shrivelling.[z]

Cultivar	Cultivar type	Genotype	Harvest 1 (days in storage) 2	7	14	Harvest 2 (days in storage) 2	7	14
Caserta	Vegetable marrow	B^+/B^+	1.0	1.2	2.1	1.0	1.3	2.2
Precocious Caserta	Vegetable marrow	B/B	1.0	2.8	4.9	1.3	2.8	5.0
Bareqet	Zucchini	B^+/B^+	1.0	1.0	1.4	1.0	1.1	1.7
Goldy	Zucchini	B/B^+	1.0	1.6	3.8	1.1	2.2	2.7
Benning's Green Tint	Scallop	B^+/B^+	1.0	1.0	1.0	1.0	1.0	1.4
Benning's Yellow Tint	Scallop	B/B	1.0	1.2	2.9	1.0	2.5	4.8
Significance								
Cultivar type			NS	***	***	NS	**	***
Genotype			NS	***	***	NS	***	***
Interaction			NS	***	*	NS	NS	***

[z]Data for harvest 1 are means of 14 values for scallops and 16 values for vegetable marrows and zucchinis. Data for harvest 2 are means of six values for vegetable marrows, eight for scallops, and 11 for zucchinis.
NS,*,**,***Not significant or significant at 5%, 1%, or 0.1% levels, respectively, by F test.

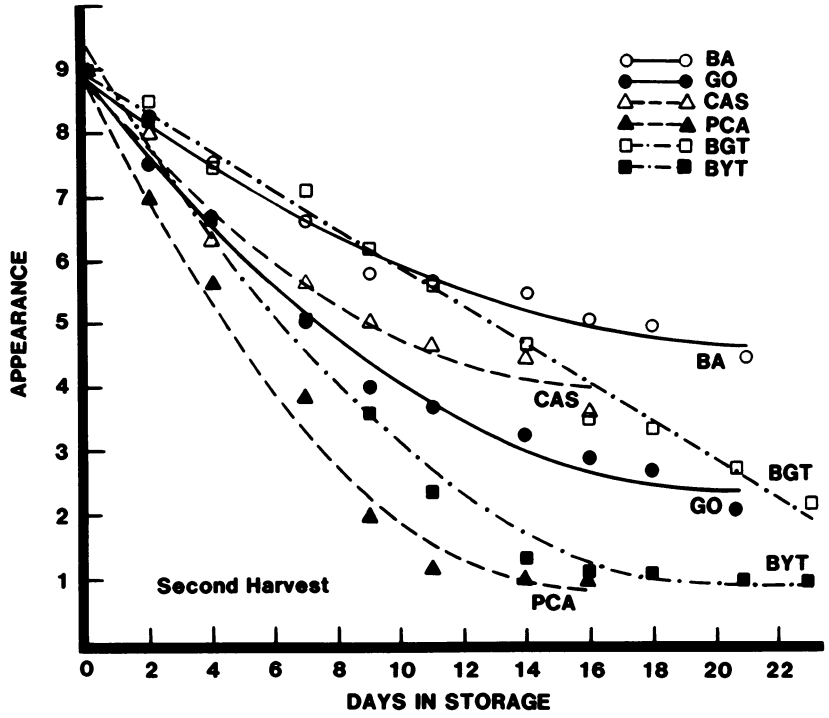

Fig. 2. Appearance ratings of summer squash during storage at 5°C and 85% to 95% RH, from 9 = excellent to 1 = not usable. BA = 'Bareqet', BGT = 'Benning's Green Tint', CAS = 'Caserta', GO = 'Goldy', BYT = 'Benning's Yellow Tint', and PCA = 'Precocious Caserta'. Quadratic equations plotted were highly significant with the exception of BGT, where the linear regression is shown. R^2 values ranged from 0.5360 to 0.9607. Each point is the mean of six values for CAS and PCA, eight values for BGT and BYT, and 11 values for BA and GO.

treme, not usable. Chilling injury (CI) was rated on a 1 to 5 scale, with 1 = none; 2 = slight pitting or browning; 3 = moderate pitting or browning; 4 = severe pitting or browning, normally not marketable; 5 = extreme pitting or browning, not usable. Appearance was rated on a pretransformed scale from 9 to 1, with 9 = excellent, no defects; 8 = very good, slight defects; 7 = good, defects readily visible; 6 = fairly good, defects becoming objectionable; 5 = fair, defects objectionable and detract from salability; 4 = fairly poor, lower limit of salability; 3 = poor, not marketable; 2 = very poor, much of the product would have to be trimmed before use; and 1 = not usable. Analyses of variance and linear and nonlinear analyses were performed with the Statistical Analysis System (14). Results for weight loss and appearance were essentially identical for the two harvests; representative results for these two variables are presented.

The vegetable marrow type ('Precocious Caserta' and 'Caserta') had the greatest amount of weight loss (Fig. 1). The zucchini type ('Bareqet' and 'Goldy') was intermediate in weight loss, and the scallop type ('Benning's Yellow Tint' and 'Benning's Green Tint') lowest. Weight loss was increased in the cultivar with gene B for two of the three types, vegetable marrow and scallop (Fig. 1). In the zucchini type, 'Goldy' (B/B^+) lost slightly less weight than 'Bareqet' (B^+/B^+).

Ratings for shrivel generally agreed with data for weight loss, with the vegetable marrows being most affected (Table 1). The zucchini type was intermediate and the scallop type was least shrivelled. Within types, ratings for shrivel were always worse for the cultivar with gene B than for the B^+/B^+ cultivars. Thus, 'Goldy' appeared more shrivelled than 'Bareqet' although it lost less weight (Fig. 1.) Shrivelling appeared earlier in squash from the second harvest, compared to the first, and 'Benning's Yellow Tint' shrivelled more severely than 'Goldy' in the second harvest (Table 1).

Ratings for appearance declined during storage (Fig. 2). Appearance during storage deteriorated most rapidly in 'Precocious Caserta'. 'Bareqet' and 'Benning's Green Tint' maintained the best appearance during storage. Within the pairs of near-isogenic lines, the cultivars with gene B declined more rapidly in appearance during storage than those of B^+/B^+ genotype (Fig. 2). Among the cultivar types, the vegetable marrow declined most rapidly during the first 2 weeks of storage.

The scallop-type cultivars developed less severe symptoms of CI than the others during storage (Table 2). The zucchini-type cultivars were intermediate and the vegetable marrow-type cultivars developed the worst CI symptoms. The $B/-$ genotypes developed more severe CI symptoms than the B^+/B^+ genotype. The scallop-type cultivars developed CI symptoms earlier and more severely during storage following the second than following the first harvest.

To the best of our knowledge, this is the first report comparing several types of summer squash and near-isogenic lines within those types for fresh-market storage characteristics. The inferiority of the $B/-$ cultivars and of the vegetable marrow-type cultivars was fairly consistent, although not absolute, for the storability characteristics considered. The highly significant genotype–cultivar type interactions for shrivel (Table 1) and CI (Table 2) can be attributed to the relatively good performance of 'Ben-

Table 2. Ratings for chilling injury of summer squash during storage at 5°C, 85% to 95% RH, from 1 = none to 5 = extreme.[z]

Cultivar	Cultivar type	Genotype	Harvest 1 (days in storage) 2	7	14	Harvest 2 (days in storage) 2	7	14
Caserta	Vegetable marrow	B^+/B^+	1.0	1.8	3.3	1.2	2.5	3.3
Precocious Caserta	Vegetable marrow	B/B	1.0	3.1	4.9	1.5	3.5	5.0
Bareqet	Zucchini	B^+/B^+	1.0	1.6	2.1	1.2	2.1	2.5
Goldy	Zucchini	B/B^+	1.0	2.9	4.2	1.6	2.9	3.5
Benning's Green Tint	Scallop	B^+/B^+	1.0	1.0	2.0	1.0	1.3	3.5
Benning's Yellow Tint	Scallop	B/B	1.0	1.0	2.6	1.0	1.6	4.8
Significance								
Cultivar type			NS	***	***	*	***	***
Genotype			NS	***	***	**	***	***
Interaction			NS	***	***	NS	NS	NS

[z]Data for harvest 1 are means of 14 values for scallops and 16 values for vegetable marrows and zucchinis. Data for harvest 2 are means of six values for vegetable marrows, eight for scallops, and 11 for zucchinis.
NS,*,**,***Not significant or significant at 5%, 1%, or 0.1% levels, respectively, by F test.

ning's Yellow Tint' (B/B) in the first harvest and the relatively good performance of 'Goldy' (B/B^+) in the second harvest.

The mode by which gene B imparts an increased sensitivity to CI development is unknown. B perhaps induces a fruit characteristic that leads to enhanced water loss, but the greater sensitivity of 'Goldy' to CI in spite of losing less water than its B^+/B^+ counterpart argues against this explanation. Use of near-isogenic lines that clearly differ in their susceptibility to water loss ('Precocious Caserta' and 'Caserta', 'Benning's Green Tint' and 'Benning's Yellow Tint') may prove to be an ideal system for testing hypotheses related to water loss (2).

Although $B/-$ cultivars stored less well than their B^+/B^+ counterparts, the degree of inferiority varied. Goldy (B/B^+) stored better in relation to its B^+/B^+ counterpart than did 'Benning's Yellow Tint' (B/B) and 'Precocious Caserta' (B/B) in relation to their respective B^+/B^+ counterparts. These results suggest that the genetic background and/or the dosage of B would be important considerations in the future breeding of intensely yellow cultivars having satisfactory storability.

Breeders face a challenge greater than yield barriers when attempting to develop commercially acceptable cultivars containing novel characteristics. Genotype selection that includes postharvest testing would have practical benefits for a crop as perishable as summer squash. The release into marketing channels of fruit from poor gene combinations (e.g., 'Precocious Caserta') might result in an irreparably bad reputation to a novel and otherwise desirable characteristic. The chances for successful marketing of improved gene combinations, including the novel characteristic (e.g., 'Goldy'), can be enhanced by postharvest research into improved methods of handling the new genetic material.

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