Effects of Gene B in Cucurbita moschata

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Additional index words. pumpkin, squash, Cucurbita pepo, pleiotropy, vegetable breeding

Abstract. The effects of gene B in Cucurbita moschata Poir. were studied by comparing 2 near-isogenic lines, PI 165561 (B+B+) and Precocious PI 165561 (BB) at 2 locations in Israel. B significantly increased femaleness and number of fruits, but decreased fruit size and yield and numerically decreased seed yield at one or both locations. Fruits of B+B heterozygotes were distinctly bicolor. There was a deficiency in the number of bicolor-fruited plants in BC5 progeny, the deviation from the expected 1:1 ratio of green-fruited to bicolor-fruited being significant. Overall, the effects of B in C. moschata were no different from its effects in C. pepo.

Gene B of Cucurbita pepo L. is pleiotropic. Its primary effect is yellow or bicolor yellow and green (instead of B+B+ normal green) color of the ovary, long before opening of the flower. Among the manifold secondary effects of B are yellow spotting of foliage, reduced growth rate of the fruit, reduced fruit size and productivity, increased fruit quality, increased cracking of maturing fruits, and decreased seed production. Which of these secondary effects are manifested is dependent on the genetic background. Gene B originated as an unstable gene in the bi-color ornamental gourds of C. pepo.

Besides the ornamental gourds, C. pepo includes a host of cultivars grown for their immature fruits (summer squash) as well as numerous cultivars grown for their mature fruits (pumpkins and winter squash). Among the summer squash cultivars, gene B has proven useful because it can impart intense golden-yellow fruit coloration (11), slower growth rate of the fruit (7), and slim fruit shape (12), these characteristics are important for increasing the yield quality (4) and speed and efficiency of the harvest (6). Among the pumpkin and winter squash cultivars, gene B has proven useful because it imparts attractive intense orange fruit coloration of the rind and flesh (3) and increases carotene content of the flesh (9).

Cucurbita moschata Poir. includes a wide range of cultivars grown for their mature fruits. Fruits of this species are considered in many cases to be superior in quality to those of C. pepo (16). Gene B was transferred recently, through 6 backcross generations, to C. moschata as a first step in determining if B could be useful in improving cultivars of this species (5). Our purpose was to study the effects of B in the genetic background of C. moschata into which it was first transferred, PI 165561.

Seeds of C. moschata PI 165561, B+B+, were kindly provided by the USDA North Central Plant Introduction Station, Ames, Iowa, and maintained by self-pollination. A BB line of PI 165561, designated "Precocious PI 165561," was developed by crossing a C. pepo accession carrying gene B with PI 165561, followed by 6 generations of backcrossing to PI 165561 and 2 generations of self-pollination and selection for BB (5).

A 2-generation inbred of PI 165561, designated PI 165561-1-6 (B+B+), and Precocious PI 165561 (BB) were compared in Spring-Summer 1985 at Hazera Seeds, Mivhoh Farm (near Qiryat Gat, southern Israel) and at Neve Ya'ar (near Qiryat Tiv'in, northern Israel) using standard cultural practices at each location. Seeds were sown at Mivhoh on 15 Apr. and at Neve Ya'ar on 9 Apr. in groups 1.0 m apart within single rows on raised beds, with 1.8 m between bed centers at the former location and 2.0 m at the latter. The plants were thinned to one per plant after expansion of the first true leaf, to give densities of 5556 plants ha⁻¹ and 5000 plants ha⁻¹ at each of the respective locations. A paired experimental design with 4 replicates was employed at each location, with 5 plants per plot at Mivhoh and 4 plants per plot at Neve Ya'ar.

The node at which the first female flower appeared on the main stem was recorded for each plant and averaged for each plot. Fruit yields and their components were determined for each plot. Seed yields and their components were determined for each plot only at Neve Ya'ar. Each of these variables was subjected to a paired t test.

Remnant seeds of the BC6 accession used in the development of Precocious PI 165561, which had been obtained by crossing PI 165561 (B+B+) with a BC6 bicolor (B+B) segregate, were sown singly, 0.5 m apart, at Neve Ya'ar on 9 Apr. All of the resulting plants were scored for fruit color, and the data subjected to χ² analysis.

The first female flower was produced earlier, on a developmental basis, by Precocious PI 165561, BB, than by the inbred of PI 165561, B+B+ (Tables 1 and 2). Node number is a reliable indicator of female tendency in cucurbits: the lower the node at which the first female flower appears, the stronger the female tendency (10). The increased female tendency of the precocious PI is in ac-

Table 1. Effects of gene B on pistillate flowering and yield of Cucurbita moschata at Mivhoh, Israel.

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Node of first female flower on main stem</th>
<th>No. fruits per plot</th>
<th>Fruit wt (kg)</th>
<th>Yield of fruits (t ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PI 165561, B+B+</td>
<td>33.3</td>
<td>8.0</td>
<td>4.96</td>
<td>42.7</td>
</tr>
<tr>
<td>Precocious PI 165561, BB</td>
<td>30.9</td>
<td>12.3</td>
<td>3.20</td>
<td>43.2</td>
</tr>
<tr>
<td>t</td>
<td>1.42</td>
<td>3.24</td>
<td>5.22</td>
<td>0.11</td>
</tr>
<tr>
<td>P</td>
<td>0.30-0.20</td>
<td>0.05-0.02</td>
<td>0.02-0.01</td>
<td>&gt;0.50</td>
</tr>
</tbody>
</table>
Table 2. Effects of gene $B$ on pistillate flowering and yield of Cucurbita moschata at Newe Ya’ar, Israel.

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Node of first flower on main stem</th>
<th>No. fruits per plot</th>
<th>Fruit wt (kg)</th>
<th>Yield of fruits (t·ha$^{-1}$)</th>
<th>No. seeds per fruit</th>
<th>Seed wt (g)</th>
<th>Yield of seeds (kg·ha$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PI 165561, $B+B+$</td>
<td>25.0</td>
<td>9.0</td>
<td>4.25</td>
<td>46.7</td>
<td>342</td>
<td>0.14</td>
<td>509</td>
</tr>
<tr>
<td>Precocious PI 165561, $BB$</td>
<td>22.0</td>
<td>9.3</td>
<td>2.41</td>
<td>27.8</td>
<td>314</td>
<td>0.11</td>
<td>375</td>
</tr>
</tbody>
</table>

1. Concorde with a previous observation (14) that gene $B$ increases femaleness in some genetic backgrounds.

At Mivhor, the Precocious PI produced more fruits than the regular PI (Table 1). However, the regular PI produced larger fruits, and the yields of the 2 accessions were similar. At Newe Ya’ar, the 2 lines produced similar numbers of fruits, but fruits of the regular PI were once again larger and thus the yield of the regular PI was higher than that of the Precocious PI (Table 2). It has been noted elsewhere that yields of precocious yellow-fruited lines of some genetic backgrounds are inferior but in other cases equal or superior to the yield of their $B^+B^+$ counterparts, and that the relative performance of these lines may depend on the cultural practices used (4). The basis for smaller fruit size has been considered to be the lack of chlorophyll in ovaries and young fruits (7).

Substitution of $B$ for $B^+$ did not markedly affect number of seeds per fruit (Table 2). Seed weight and seed yield, although not significantly affected, were reduced by 27% and 36%, respectively.

In the backcross of PI 165561 with a BC$_3$ bicolar ($B^+B^+$) segregate, 74 green-fruited and 45 bicolar-fruited plants were obtained. This result deviates significantly from the expected 1:1 backcross ratio ($\chi^2 = 7.07$, $P = 0.01-0.005$). There are several possible explanations for this result. First, $B$ might be transmitted less successfully to the progeny than $B^+$. Second, $B$ might be unstable, mutating to $B^+$ (13). Third, and perhaps most likely, is the possibility that some $B^+B^+$ plants produced green instead of bicolar fruits. Precocious PI 165561 has been observed to be relatively sensitive to environmentally induced greening (2, 5). These explanations could be tested if some green-fruited plants were to be self-pollinated and the fruit color of their progeny observed.

As gene $B$ has been transferred into more genetic backgrounds, its effects have become successively more predictable. Schaffer and Boyer (7) have pointed out that several of the secondary effects on the fruits, including reduced growth rate, small size, and increased cracking, can be attributed directly to the lack of chlorophyll in the ovary and fruit and a consequent lack of self-sustaining photosynthesis by this organ (1). Other effects, such as an increase in carotenoid content of the flesh, have been attributed to formation of chromoplasts directly from plastids, at the expense of other plastids (8). Given the relatively large genetic distance of $C. moschata$ from $C. pepo$, the possibility of finding as yet unencountered secondary effects of $B$ in $C. moschata$ was expected to be relatively high, certainly higher than by merely backcrossing $B$ into a different $C. pepo$ cultivar or cultivar group. However, no new characteristics were observed in PI 165561, suggesting that transfer of $B$ into other backgrounds for the sole purpose of searching for as yet undescribed secondary effects would no longer be productive.

Essentially, gene $B$ was found to act in $C. moschata$ PI 165561 as it acts in $C. pepo$. It increased femaleness and number of fruits, reduced fruit size, and tended to reduce seed yields. It also was found to increase carotenoid and carotene contents of the fruit flesh in the closely related Precocious PI 165561 R ($BB$) breeding line (9). Most of the bicolar fruits produced by $B^+B^+C. moschata$ heterozygotes corresponded to the Grade 6 fruit color of Shifriss and Paris (15); that is, the surface area of the fruits was 50–89% yellow; the polar regions of the fruit were green and the equatorial region was yellow. Precocious yellow pigmentation occurs also in certain cultivars and strains of $C. maxima$ and $C. andreana$, most notably PI 165558 (11). However, true bicolar fruits, corresponding to fruit color grades 2, 4, and 6, have not been described in the latter 2 species, making it questionable whether the precocious yellow-fruited accessions carry $B$ or perhaps some other factor. $C. maxima$ has been considered to be more closely related to $C. moschata$ than $C. pepo$ (16). The transfer of $B$ to $C. moschata$ should, therefore, facilitate transfer of $B$ to $C. maxima$. Transfer of $B$ to $C. maxima$, if successful, would permit determining whether the precocious yellow fruit color gene of that species is or is not identical to $B$.

Literature Cited