Morphologic Variation for Fruit Characteristics in the USDA/ARS Capsicum baccatum L. Germplasm Collection

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Abstract. Mature fruit of 295 accessions of Capsicum baccatum from the USDA/ARS Capsicum germplasm collection were characterized for fruit length, width, weight, and color. Mean fruit weight was determined to be 5.91 g with a range of 0.15 to 22.8 g. Mean fruit length was 6.01 cm with a range of 0.8 to 16.0 cm. Mean fruit width was 1.86 cm and a range of 0.5 to 4.75 cm. Distributions of all characteristics were positively skewed and failed the Kolmogorov-Smirnov test for normality. The distribution of fruit weight values was the most highly skewed, possibly reflecting a more intense human selection pressure for this characteristic. Distributions of fruit width, length, weight, and length/width were leptokurtic (long-tailed). Ninety-three percent of accessions were elongate. Mature fruit color, length, and width were observed to be highly diverse, with a large area within Brazil. Capsicum baccatum var. pendulum has been introduced to Central America, Hawaii, the mainland United States, and elsewhere (Smith and Heiser, 1957). A third variety C. baccatum var. praetermissum (Heiser & P.G. Sm.) Hunz. (Hunziker, 1971) is believed to have arisen from isolated populations of C. baccatum var. baccatum. Its distribution appears to be restricted to southern Brazil (McLeod et al., 1983).

Morphologic differences within and between the cultivated ajis (var. pendulum) and the wild C. baccatum var. baccatum were discussed by D’Arcy and Eshbaugh (1974), who described both varieties as having off-white corollas with a pair of yellowish, greenish, or tan markings at the base of each lobe, a calyx with five distinct teeth, and yellow anthers. The fruit of C. baccatum var. pendulum can be brown, red, orange, or lemon yellow. Its fruit are pendant (very rarely erect), persistent, firm-fleshed, and mixed (3%). These data suggest that variability for mature fruit characteristics within this germplasm collection is considerable and that variability for fruit length, width, weight, and color is sufficient to provide the basis for the improvement of the aji crop.
I. General statistics on four fruit parameters among 295 accessions of Capsicum baccatum

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Fruit width (cm)</th>
<th>Fruit length (cm)</th>
<th>Fruit wt (g)</th>
<th>Fruit length: width</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>1.863</td>
<td>6.012</td>
<td>5.912</td>
<td>4.07</td>
</tr>
<tr>
<td>SD</td>
<td>0.816</td>
<td>3.227</td>
<td>4.705</td>
<td>2.188</td>
</tr>
<tr>
<td>SE</td>
<td>0.048</td>
<td>0.188</td>
<td>0.274</td>
<td>0.127</td>
</tr>
<tr>
<td>Confidence interval of mean</td>
<td>0.094</td>
<td>0.370</td>
<td>0.539</td>
<td>0.251</td>
</tr>
<tr>
<td>Range</td>
<td>4.250</td>
<td>15.20</td>
<td>22.65</td>
<td>11.50</td>
</tr>
<tr>
<td>Maximum</td>
<td>4.750</td>
<td>16.00</td>
<td>22.80</td>
<td>12.00</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.500</td>
<td>0.800</td>
<td>0.150</td>
<td>0.500</td>
</tr>
<tr>
<td>Median</td>
<td>1.750</td>
<td>5.500</td>
<td>4.800</td>
<td>4.000</td>
</tr>
<tr>
<td>Skewness</td>
<td>1.007</td>
<td>0.766</td>
<td>1.290</td>
<td>0.439</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>1.089</td>
<td>0.056</td>
<td>1.351</td>
<td>0.018</td>
</tr>
<tr>
<td>Kolmogorov-Smirnov distribution</td>
<td>0.160*</td>
<td>0.108*</td>
<td>0.131*</td>
<td>0.050*</td>
</tr>
</tbody>
</table>

*Nonsignificant.

(PI 439380 and 633751) to 16.0 cm (PI 260585). Average fruit weight was 5.9 g with a range of 0.15 g (PI 639129) to 22.8 g (Griff 9210). Fruit L:W averaged 4.08 with a range of 0.50 (PI 439368) to 12.00 (PI 260535). Fruit shapes were similar to those described by DeWitt and Bosland (1996). Ninety-three percent of accessions were elongate with a L:W greater than 1.0. These and other data presented in Table 1 provide a profile of the fruit characteristics of this species.

As indicated in Table 1 and Figure 1, the distributions of the values for mature fruit length, width, weight, and L:W were positively skewed. Assuming that selection for fruit size occurred over the course of the domestication of this species, as seems relatively certain (Eshbaugh, 1980; McLeod et al., 1982; Pickersgill, 1971), positively skewed distributions for these characteristics would be expected because major genes conditioning these traits were rapidly pyramided. All distributions failed the Kolmogorov-Smirnov test (Stuart and Ord, 1987), indicating nonnormality. The distributions of fruit weight and fruit width values were more positively skewed (1.29 and 1.00, respectively) than distributions for fruit length (0.76) or L:W (0.044). Distributions for fruit length, width, weight, and L:W were leptokurtic (Table 1, Fig. 1), having longer-than-expected tails. Observed ranges for fruit length and width were in relative agreement with those of Eshbaugh (1970), who noted ranges of 0.4 to 17.2 cm in fruit length and 0.3 to 2.6 cm in fruit width among 36 accessions of the species examined.

A variety of mature fruit colors were recorded among the 295 accessions of C. baccatum. These included red [217 (73.6%)], orange [58 (19.7%)], yellow [9 (3%)], and green [1 (0.3%)]. Ten accessions (3.4%) yielded mixtures of red and yellow or red and orange mature fruit. Although the occurrence of brown- (or chocolate) colored mature fruit was reported in this species by Eshbaugh (1970), brown fruits were not observed in this study, suggesting the absence of the full range of variability for this characteristic. Some accessions yielded fruit of more than a single color. This can be attributed to the occurrence of accessions that were segregating for fruit color and also accessions that were likely originally obtained as mixtures of two or more distinct forms.

Previous investigators (Eshbaugh, 1970; Pickersgill et al., 1979) examined the morphologic variation present in this species to assess the validity of its division into the two currently recognized varieties, var. baccatum and var. pendulum. Before 1961, C. baccatum var. baccatum and C. baccatum var. pendulum were recognized as C. microcarpum Cav. and C. pendulum Willd., respectively. Hunziker (1961) suggested uniting these into a single species, C. baccatum. Eshbaugh (1970) subsequently provided justification for their classification as varieties. Although defining the validity of the two varieties is tangential to the purposes of the present study, it is of interest to note that the bimodal distributions for mature fruit length and width that were reported and used by Eshbaugh (1970) to separate the species into two varieties were not observed (Figs. 1). It seems likely that the bimodal distributions previously reported may have been the result of the relatively small sample size used. However, the absence of bimodal distributions for these or other fruit characteristics neither supports nor disproves the validity of the current two-variety classification system. Such a division should be based on a broader range of characteristics than those reported here (Pickersgill et al., 1979). More or less continuous distributions for the characters analyzed would appear to support the evolution of the large-fruited domesticated types from the smaller-fruited form.

As noted by Pickersgill et al. (1979), the distinction between wild peppers with small red deciduous erect fruits and domesticated peppers with large pendant nondeciduous fruit of various colors is not clear cut. Many of the characters initially used to define the two varieties do not appear to be unique to either. For example, although data on fruit persistence were not recorded, deciduous large-fruited accessions were observed as upright, persistent small-fruited forms. The occurrence of nondeciduous upright fruit in an accession of the nondomesticated Capsicum cardenasi Heiser & P.G. Sm. (PI 590507) has also been observed. Although fruit of C. baccatum var. baccatum are typically red (Eshbaugh, 1970), accessions of C. baccatum with orange or yellow fruit that were both small and small that otherwise shared many of the characteristics of var. baccatum have been reported (DeWitt and Bosland, 1996). Among the materials examined in the present study, pedicels of most accessions were erect, or nearly so, at anthesis. Pendent small-fruited accessions of C. baccatum were not observed. Large-fruited accessions with upright fruit were not observed and were not expected. As fruit size increased as the result of human selection, the relatively long pedicel characteristic of C. baccatum could no longer support the fruit in an upright position, and the fruit became pendant. Thus, pendant fruit are a manifestation of human selection for fruit.
size in the absence of selection for enhanced pedicel strength (or perhaps in the absence of genetic variability within *C. baccatum* for this characteristic) and not necessarily a reflection of any inherent difference in the initial orientation of the fruit. Numerous transitional forms with smallish to moderately sized semipendulous fruit were observed (for example, PI 188481, 215739, 260564, 281313, and 439409).

To use biochemical/molecular methods to differentiate var. *pendulum* from var. *baccatum* have met with limited success. For example, Ballard et al. (1970) noted that the flavonoid profiles of both varieties were identical. Jensen et al. (1979) reported that *C. baccatum* var. *pendulum* and *C. baccatum* var. *baccatum* could not be differentiated from each other based on isozymes (23 loci, 63 alleles), although *C. baccatum* var. *pae­termiuss* was distinct from both of these. Walsh and Hoot (2001) separated the two varieties from one another using sequence data obtained from *waxy* introns and *atpB-rbcL* noncoding spacer regions. However, because only a single accession of each variety was included in the study, the possibility that those differences reflected only intraspecific variability cannot be discounted. Additional or more recent studies either did not include both varieties or did not identify them as such (Buso et al., 2003; Prince et al., 1995; Rodríguez et al., 1999; Toquica et al., 2003) From a practical standpoint, the absence of a single defining characteristic that might be used to differentiate semidomesticated forms from either the wild (var. *baccatum*) or domesticated (var. *pendulum*) forms precludes the unequivocal identification of these forms.

Crop germplasm collecting/acquisition frequently occurs as opportunity permits and not always in a systematic or comprehensive manner. A collector’s perception of what constitutes unique or potentially valuable material may be influenced (biased) by the extent of the collector’s previous exposure to the diversity already characterized within the taxa being collected. Hence, a thorough and random sampling of the gene pool of many crop plants and their wild relatives has not always been accomplished. The ascensions evaluated in the present study, although substantially greater in number than in previous studies (DeWitt and Bosland 1996; Eshbaugh, 1970) represent only a portion of the phenotypic diversity present in the *C. baccatum* gene pool. For example, the orange- or yellow-fruit armed *C. baccatum* var. *baccatum* described by DeWitt and Bosland (1996) and the chocolate-colored forms of var. *pendulum* noted by Eshbaugh (1970) were not observed. Several fruit shapes reported by DeWitt and Bosland (1996) were also not observed.

The data presented suggest that variability for mature fruit characteristics within the USDA/ARS *C. baccatum* germplasm collection is somewhat representative of the diversity within this species, and that variability for fruit morphologic characteristics is likely sufficient to provide the basis for the improvement of the aji crop. Congruencies in the distributions for the fruit characteristics that were observed can almost certainly be attributed in part to inadequate sampling of the gene pool.

**Literature Cited**


