Evaluation of combining ability, heterosis and genetic variance for plant growth and fruit quality characteristics in Thai-melon (Cucumis melo L., var. acidulus Naud.)

N. Kitroongruang*, W. Poo-Swangb and S. Tokumasua

*Laboratory of Plant Breeding, College of Agriculture, Ehime University, 3-5-7 Tarumi, Matsuyama, Ehime 790, Japan
bDepartment of Horticure, Chiang Mai University, Chiang Mai 50002, Thailand

(Received 30 September 1991)

ABSTRACT


Seven local muskmelon lines and five American cultivars were evaluated in a 7 × 5 design II cross during dry and rainy seasons in Chiang Mai, Thailand, for vine length at the age of 8 weeks, days to first harvest, number of fruits per plant, fruit weight, fruit weight per plant, percent flesh, percent soluble solids content, rind firmness, shape index, net appearance, and presence of vein tract. Variances among crosses and their parents were found to be highly significant for all traits. Correlations between the performance of parents and the average of their hybrids were positive in almost all cases except vine length. However, only the correlations on number of fruits per plant and shape index were significant. Favorable heterosis over the female parent was shown for all traits except days to first harvest. General combining ability of male parents (GCAm) and specific combining ability (SCA) accounted for a greater portion of the variability among crosses than general combining ability of female parents (GCAf) for all traits except shape index.

Keywords: cantaloupe; muskmelon; vegetable breeding.

Abbreviations: GCAf = general combining ability of female parents; GCAm = general combining ability of male parents; SCA = specific combining ability.

INTRODUCTION

Although Thai-melon (Cucumis melo L., var. acidulus Naud.) has long been cultivated in Thailand, its fruit qualities, especially flesh soluble solids con-
tent and rind firmness, are still commercially unacceptable (Chomechalaow, 1959). However, Thai-melon adapts well to hot-humid climates while introduced cultivars are easily killed by various diseases and insects throughout the growing period (Suthivanish, 1961). Since the introduction of new muskmelon genotypes in Thailand is rather difficult and risky, it would be beneficial to breed a melon which has a combination of both good adaptability to local environment and good fruit quality. To accomplish this goal, information on the types of gene action involved in the expression of various quantitative characteristics must be understood. This paper presents genetic information on plant growth and fruit quality characteristics of F₁ hybrids from a 7 × 5 design II cross between local Thai-melon lines and American cultivars.

MATERIALS AND METHODS

Five American muskmelon cultivars, 'Honeydew' (C. melo L., var. inodorus Naud.), 'PMR45', 'Topmark', 'Perlita', and 'Golden Delicious 51', (C. melo L., var. reticulatus Naud.), received from the Desert Seed Co., California, served as male parents which were each crossed to a series of seven local Thai-melon lines. These lines were MJ2801, MJ2802, TD1, TD6, TD7, TD8 and ST2801. Ten to fifteen plants of each cultivar and line were used to make the necessary crosses. Three-week-old seedlings of F₁ and the parents were transplanted into the fields in January, 1987, for the first trial and in September, 1987, for the second trial at Maejo Institute of Agricultural Technology and Chiang Mai Field Crops Research Center in Chiang Mai, Thailand, respectively. The 47 entries (35 hybrids and 12 parents) were planted in a randomized block with two replications. Each plot consisted of ten single plants individually spaced 60 cm apart and in rows spaced 120 cm apart. All mature, full-slip fruits were harvested daily from April to May for the first trial and in December for the second trial.

Observations for vine length at the age of 8 weeks, days from sowing to first harvest, number of fruits per plant, and total fruit weight per plant were recorded for each individual plant. Each individual fruit was evaluated for the following: fruit weight; percent soluble solids content determined in pericarp tissue at the center axis of fruit by hand refractometer; rind firmness, determined at the equator of the fruit by firmness tester and expressed as g cm⁻²; percent flesh, measured as the width of the flesh portion on the radial cross section divided by total fruit width, shape index, which is a ratio of fruit length and width; net appearance, rated on a scale 1 to 6 with 6 being the densest; and vein tract, rated on a scale 0 to 5 with 0 indicating very deep tract. Plot means were calculated and analyses of variance were computed separately for each trial. Combining ability as defined by Sprague and Tatum (1942) were determined. Estimates of additive and dominance variances were calculated according to the procedures described by Becker (1975).
RESULTS

The results reported herein are from the first trial. Those from the second trial, if significantly different from the first one, will be commented on in the text.

Analyses of variance showed that differences among entries were highly significant for all traits (Table 1). However, the total number of entries in the first trial was reduced to 42 because all the male parents were killed by fusarium wilt at the time of flowering. All 47 entries survived in the second trial. Table 2 shows general and specific combining abilities estimated by the analysis of variance in the hybrids. General combining ability of male parents (GCA_m) was highly significant for vine length (insignificant in the second trial), rind firmness, percent flesh, and net appearance. The GCA_m for days to first harvest, and number of fruits per plant in the second trial was also significant. General combining ability of female parents (GCA_f) was highly significant for rind firmness (insignificant in the second trial), shape index, and days to first harvest. The GCA_f for number of fruits per plant, and soluble solids content in the second trial was also significant. Specific combining ability (SCA) was highly significant for most traits except number of fruits per plant, fruit weight per plant, and soluble solids content which were only significant. The SCA for percent flesh was not significant. In the second trial, the SCA for most traits except fruit weight, fruit weight per plant, shape index and vein tract were not significant.

Table 3 shows the mean performance of the parents and their hybrids for vine length and days to first harvest, correlations between the performance of

TABLE 1

Analyses of variance for plant growth and fruit quality characteristics of Thai-melon

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>df</th>
<th>Mean square for</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Vine length (cm)(^1)</td>
</tr>
<tr>
<td>Block</td>
<td>1</td>
<td>0.03</td>
</tr>
<tr>
<td>Variety</td>
<td>41</td>
<td>9.36**</td>
</tr>
<tr>
<td>Error</td>
<td>41</td>
<td>0.52</td>
</tr>
<tr>
<td>C.V. (%)</td>
<td></td>
<td>4.96</td>
</tr>
</tbody>
</table>

\(^1\)Variance values presented were multiplied by 10\(^{-2}\).
\(^2\)Variance values presented were multiplied by 10\(^{-4}\).
*P<0.05; **P<0.01.
### TABLE 2

Design II analyses of variance for plant growth and fruit quality characteristics of Thai-melon

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>df</th>
<th>Mean square for</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Vine length (cm)$^1$</td>
<td>Days to first harvest</td>
<td>Number of fruits per plant</td>
<td>Fruit weight (g)$^2$</td>
<td>Fruit weight per plant (g)$^2$</td>
<td>Soluble solids (%)</td>
<td>Rind firmness (g cm$^{-1}$)</td>
<td>Flesh (%)</td>
</tr>
<tr>
<td>Block</td>
<td>1</td>
<td>0.11</td>
<td>4.84</td>
<td>0.00</td>
<td>2.19</td>
<td>11.82</td>
<td>0.12</td>
<td>0.77</td>
<td>30.66</td>
<td>0.01</td>
</tr>
<tr>
<td>GCA$_{m}$</td>
<td>4</td>
<td>33.58**</td>
<td>52.65*</td>
<td>0.45</td>
<td>4.29</td>
<td>14.75</td>
<td>0.59</td>
<td>13.82**</td>
<td>57.20**</td>
<td>0.20</td>
</tr>
<tr>
<td>GCA$_{r}$</td>
<td>6</td>
<td>1.93</td>
<td>7.41</td>
<td>0.12</td>
<td>4.79</td>
<td>12.38</td>
<td>0.58</td>
<td>4.26**</td>
<td>21.46</td>
<td>0.90**</td>
</tr>
<tr>
<td>SCA</td>
<td>24</td>
<td>7.00**</td>
<td>15.29**</td>
<td>0.20*</td>
<td>4.72**</td>
<td>16.14*</td>
<td>0.48*</td>
<td>0.93**</td>
<td>9.14</td>
<td>0.09**</td>
</tr>
<tr>
<td>Error</td>
<td>34</td>
<td>0.60</td>
<td>1.15</td>
<td>0.11</td>
<td>1.92</td>
<td>7.88</td>
<td>0.22</td>
<td>0.18</td>
<td>7.60</td>
<td>0.03</td>
</tr>
<tr>
<td>C.V. (%)</td>
<td>-</td>
<td>5.30</td>
<td>1.37</td>
<td>25.98</td>
<td>17.04</td>
<td>27.62</td>
<td>6.65</td>
<td>6.68</td>
<td>5.60</td>
<td>10.46</td>
</tr>
</tbody>
</table>

$^1$Variance values presented were multiplied by 10$^{-1}$.

$^2$Variance values presented were multiplied by 10$^{-4}$.

GCA$_{m}$, general combining ability of male parents; GCA$_{r}$, general combining ability of female parents; SCA, specific combining ability.

*P<0.05, **P<0.01.
TABLE 3

Mean performance of parents (P) and the average of their hybrids (H), correlations between P and H, and heterosis values for vine length and days to first harvest

<table>
<thead>
<tr>
<th>Parent</th>
<th>Vine length</th>
<th>Days to first harvest</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>First trial</td>
<td>Second trial</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>H</td>
</tr>
<tr>
<td>MJ 2801</td>
<td>142.83</td>
<td>144.30</td>
</tr>
<tr>
<td>MJ 2802</td>
<td>140.67</td>
<td>153.13</td>
</tr>
<tr>
<td>TD 1</td>
<td>124.83</td>
<td>151.73</td>
</tr>
<tr>
<td>TD 6</td>
<td>104.67</td>
<td>144.24</td>
</tr>
<tr>
<td>TD 7</td>
<td>173.34</td>
<td>142.50</td>
</tr>
<tr>
<td>TD 8</td>
<td>129.34</td>
<td>142.40</td>
</tr>
<tr>
<td>ST 2801</td>
<td>162.84</td>
<td>145.73</td>
</tr>
<tr>
<td>Honeydew</td>
<td>-</td>
<td>170.38</td>
</tr>
<tr>
<td>PMR 45</td>
<td>-</td>
<td>143.86</td>
</tr>
<tr>
<td>Topmark</td>
<td>-</td>
<td>136.24</td>
</tr>
<tr>
<td>Perita</td>
<td>-</td>
<td>130.45</td>
</tr>
<tr>
<td>Golden Delicious 51</td>
<td>-</td>
<td>150.53</td>
</tr>
<tr>
<td>Mean</td>
<td>139.79</td>
<td>146.29</td>
</tr>
</tbody>
</table>

P-H Correlation (r) = 0.18 0.07 0.34 0.10

Heterosis > SP = 7.58 - 16.45 -
Heterosis > MP = 18.57 - 3.35
(midparent)

the parents and their hybrids, and heterosis values. The same procedures were used for every trait examined (Table 4). Correlations between the performance of female parents and the average of their hybrids were positive for all traits except vine length. However, only the correlations for the number of fruits per plant and the shape index were significant. Favorable heterosis over the female parents was shown for all traits. Favorable heterosis over the mid-parents was shown for all traits except rind firmness and net appearance.

Estimated levels for male parent additive variances (σ²m) and dominance variances (σ²d) either exceeded or equalled those of female parent additive variances (σ²f) for most traits except shape index (Table 5). The σ²f for soluble solids content was larger than σ²m and σ²d in the second trial.

DISCUSSION

There are many lines of muskmelon cultivated locally in Thailand, but their combining ability has not been reported. In this study, the 7 × 5 factorial cross was used to evaluate seven local Thai-melon lines and five American cultivars
<table>
<thead>
<tr>
<th>Characteristic</th>
<th>First trial</th>
<th></th>
<th></th>
<th>Second trial</th>
<th>P-H correlation</th>
<th>Heterosis &gt; female</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>P</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vine length (cm)</td>
<td>139.79</td>
<td>146.29</td>
<td>−0.18</td>
<td>7.58</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Days to first harvest</td>
<td>93.68</td>
<td>78.21</td>
<td>0.34</td>
<td>−16.45</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of fruits per plant</td>
<td>1.25</td>
<td>1.27</td>
<td>0.63**</td>
<td>8.42</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fruit weight (g)</td>
<td>673.11</td>
<td>812.37</td>
<td>0.42</td>
<td>26.51</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fruit weight per plant (g)</td>
<td>851.60</td>
<td>1001.07</td>
<td>0.40</td>
<td>37.29</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soluble solids (%)</td>
<td>4.83</td>
<td>7.00</td>
<td>0.22</td>
<td>46.65</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rind firmness (g cm⁻²)</td>
<td>4.52</td>
<td>6.31</td>
<td>0.21</td>
<td>40.70</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percent flesh (%)</td>
<td>47.88</td>
<td>49.23</td>
<td>0.48</td>
<td>2.99</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shape index</td>
<td>1.66</td>
<td>1.70</td>
<td>0.82**</td>
<td>5.74</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net</td>
<td>1.00</td>
<td>1.86</td>
<td>0.48</td>
<td>8.586</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vein tract</td>
<td>4.90</td>
<td>4.84</td>
<td>0.04</td>
<td>1.10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>185.40</td>
<td>211.61</td>
<td>0.07</td>
<td>18.57</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>80.52</td>
<td>77.78</td>
<td>0.10</td>
<td>−3.35</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.24</td>
<td>1.27</td>
<td>0.08</td>
<td>6.38</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>700.32</td>
<td>992.61</td>
<td>0.17</td>
<td>44.22</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>946.98</td>
<td>1362.79</td>
<td>0.04</td>
<td>55.11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

¹Correlation coefficient.
**P < 0.01.
TABLE 5

Estimated additive and dominance variance of plant growth and fruit quality characteristics of muskmelon

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Estimated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\sigma_{am}^2 \pm SE$</td>
</tr>
<tr>
<td>Vine length (cm)</td>
<td>7.59 ± 5.57</td>
</tr>
<tr>
<td>Days to first harvest* (days)</td>
<td>10.67 ± 8.77</td>
</tr>
<tr>
<td>Number of fruits per plant</td>
<td>0.07 ± 0.08</td>
</tr>
<tr>
<td>Fruit weight (g)</td>
<td>0.00 ± 0.80</td>
</tr>
<tr>
<td>Fruit weight per plant (g)</td>
<td>0.00 ± 2.75</td>
</tr>
<tr>
<td>Soluble solids (%)</td>
<td>0.00 ± 0.10</td>
</tr>
<tr>
<td>Rind firmness (g cm$^{-2}$)</td>
<td>3.68 ± 2.28</td>
</tr>
<tr>
<td>Flesh (%)</td>
<td>13.73 ± 9.46</td>
</tr>
<tr>
<td>Shape index</td>
<td>0.03 ± 0.03</td>
</tr>
<tr>
<td>Net</td>
<td>0.00 ± 0.93</td>
</tr>
<tr>
<td>Vein tract</td>
<td>0.00 ± 0.14</td>
</tr>
</tbody>
</table>

$^1$Variance values presented were multiplied by $10^{-2}$.
$^2$Variance values presented were multiplied by $10^{-4}$.
All negative estimates were set equal to zero.

$\sigma_{am}$, $\sigma_{af}$, and $\sigma_b$, estimated male parent additive variance, additive female parent variance, and dominance variance, respectively.

to provide information on combining ability and types of gene action involved in the expression of various plant growth and fruit quality characteristics. The information obtained will be useful in planning breeding schemes for further improvement of local Thai-melon crops.

The results clearly showed that differences among crosses and their parents were highly significant for all traits (Table 1), suggesting genetic diversity in this population. Therefore, the improvement of local Thai-melon is feasible through the incorporation of desirable genes from cultivars introduced from abroad, as has been done for both the Indian (Chadha and Nandpuri, 1980) and the American muskmelon (Lippert and Legg, 1972).

Most commercial muskmelon varieties currently grown in various parts of the world are F$_1$ hybrids. This study showed that the hybrids outperformed their female parents in all characteristics (Table 4), which indicates that there is high potential for improvement of local Thai-melon. Furthermore, the hybrids showed heterosis over their female parents and midparents in almost all characteristics except rind firmness and net appearance. Rind firmness and net appearance, however, are the most prominently improved characteristics when compared with the female parents (Table 1). Specific combining ability variances were highly significant for many characteristics (Table 2). Therefore, the utilization of F$_1$ hybrids seems very promising in Thai-melon breeding. Performance of male and female parents did not always coincide
with combining ability, as shown by the rather small and inconsistent correlation coefficients for most traits (Table 4). Selecting parents for use in an F₁ breeding scheme, therefore, must rely solely on the combining ability of promising lines. In conducting such combining ability studies, more replications and additional seasons should be used in order to minimize the standard error in the variance components of most of the quantitative characteristics.

The hybrids remained healthy in the first trial, even when all the male parents died. This resistance characteristic will be easily maintained in the hybrids and their progenies through selection, because resistance to fusarium wilt is reportedly controlled by only one dominant gene (Zink and Gubler, 1985).

Fruit shape and the presence of vein tracts were previously reported to be controlled monogenically (Kubici, 1962; Bains and Kang, 1963). Kalb II and Davis (1984) mentioned that the large degree of dominance variance for these traits in American bush melon was probably due to their monogenic inheritance. In this study, however, only the dominance variance for vein tracts was larger than the additive variance. For shape index, the female parent additive variance was much larger than the dominance variance. Therefore, it is likely that the local Thai-melons have additional genes or modifiers other than the ones determined by the above authors. Moreover, since the female parent additive variance for shape index was greater than that of male parents, it will be rather difficult to change the fruit shape of local Thai-melons through cross-breeding.

Soluble solids content and net appearance of the fruit surface are commercially important traits, notably in Thailand, Japan, and other Asian countries. The inheritance of soluble solids, mostly sugars, is complicated. Arasimovitch (1934) reported that high glucose and fructose content behaved dominantly, and high sucrose content recessively, all of which appeared to be controlled by polymorphic genes. According to Hagiiwara and Kamimura (1936), at least five genes are involved in the inheritance of netting, through Ramaswamy et al. (1977) reported that only two genes were involved. Recurrent and mass selections should be effective in increasing the means of such polymorphic traits, since mass selection has been successful in increasing the frequency of many favorable genes governing the expression of quantitative traits (Andrus and Bohn, 1976). Recurrent selection should be very successful, since recombination among selections in each generation will generally occur as a result of the local Thai-melon lines and their hybrids in this study being monoecious.

REFERENCES