two cultivars resemble mature plants and thus could be marketed earlier.

The potential of micropropagation technology for commercial production of Episcia is high. Data from Table 3 and Table 4 indicate that as many as 87 transplantable sized green Episcia 'Ember Lace' plantlets were produced per jar in 2 months. Our 30ml tissue culture jars occupy 6.5 square cm of growing space. As many as 800,000 Episcias can be produced annually per m² of micorculture space.

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**Inheritance of Dwarf and Determinate Growth Habits in Cucumber**

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**Additional index words.** Cucumis sativus

**Abstract.** The inheritance of reduced vine size was studied in 2 dwarf lines of cucumber (Cucumis sativus L.) derived from Hardin’s PG-57. The dwarfs were crossed with 3 standard cultivars and 3 determinate breeding lines and found to carry a recessive determinate gene, allelic with gene *de*. There was evidence for the existence of another recessive gene, *dl* (delayed growth) which reduced the length of the hypocotyl and the first few internodes, and reduced growth rate; *dl* appeared weakly linked with *de*. The presence of genetic modifiers of determinate habit make it feasible to breed determinate cucumbers over a wide range of final vine sizes.

Standard cucumbers have an indeterminate growth habit which allow the vine to grow indefinitely under the proper conditions. Several lines exist, however, that have a determinate growth habit in which terminal growth ceases after a period of time and lateral branches are suppressed.

George (2,3) reported that the determinate character was controlled by a single recessive gene, *de*. The number of leaves to termination was influenced by an intensifier gene, *In(de)*; proposed new symbol, *In-de* (5). Gene *In-de* was reported to shorten internode length and cause determinate plants to have fewer leaves than plants carrying the *in-de* allele. Winter-growing conditions further decreased the number of leaves in all determinate plants.

Denna (1) found that the determinate character from 3 separate sources was controlled by a single gene; the genes in all 3 lines being allelic. The determinate gene from Hardin’s PG-57 was reported dominant to the indeterminate alleles in 12 standard cultivars. In contrast, Kaufman and Lower (4) reported that the determinate gene from PG-57 was recessive. In both studies, authors expressed difficulty in classifying determinate and indeterminate segregates.

Confusion about the inheritance of dwarf and determinate growth habits prompted our investigation of growth habit genetics.

**Materials and Methods**

Two dwarf lines of cucumber used in this study (Table 1) exhibited decreased hypocotyl and internode length for the first few internodes and a reduced growth rate. Both lines were also determinate in accordance with their derivation from PG-57, a determinate breeding line. The dwarf lines, MmD and TgD, were both crossed with each of the non-dwarf lines, Mk, Mm, Tg, Mkde, Inde, and inde (abbreviations used as those of Table 1). The resulting *F₁* hybrids were selfed to form *F₂*’s, and backcrossed to the respective parents.

Parental, *F₁*, *F₂*, and BC generations were grown from June 15 to August 12 in a greenhouse equipped with evaporative coolers. Summer conditions were long days (15-16 hours)
and temp of 24-32°C day, 18-21°C night. Seeds were sown into 15 cm plastic pots containing 2:1:1 (soil:peat:vermiculite) soil mix supplemented with 5.9 kg/m³ “Mag-Amp” fertilizer (7-4.4-5). The pots were spaced 19 cm x 23 cm center to center on benches equipped with sub-irrigation mats and drip irrigation tubes. The vines were supported by tying to bamboo stakes. Parthenocarpic fruit set was minimal.

The experimental design was a randomized complete block with 5 blocks. Two plants of each parent and F₁, 10 of each F₂, and 5 of each BC were placed in each block.

A portion of the genetic analysis was repeated during the summer in the same greenhouse. Winter conditions were short days (9-10 hr) and temp of 21-24°C (day), 15-18°C (night). Growing practices and experimental design were similar except that the pots were spaced 46 x 36 cm and sub-irrigation was not used.

Results and Discussion

Determinate growth habit. Plants at 8 weeks of age were classified as determinate or indeterminate based on several gross morphological and developmental indices as previously described (3). Determine shoot tips of both main stems and lateral branches exhibit flowers and few visible leaves with a characteristic narrow shape.

Data obtained during the summer (Table 2) verified that the determinate habit of the dwarf parents, MmD and TgD, is recessive and allelic with gene de. All segregating populations yielded acceptable fits to expected genetic ratios using chi-square tests.

Two F₂ populations segregating for determinate habit were grown during the winter; wherein, the assessment of determinate habit was very difficult. Some plants were unquestionably determinate or indeterminate, but many seemed intermediate, and were classified as semi-determinate (Table 2). The data provided acceptable fits to 1:2:1 ratios, indicating incomplete dominance at the de locus. Apparently, the dominance of de is affected by the environment with winter growing conditions favoring the expression of determinate habit. The contention of incomplete dominance may help resolve the conflict as to whether de (from Hardin’s PG-57) is dominant (1) or recessive (4).

Observations suggest that growth termination in determinate cucumbers involves an irreversible suppression of vegetative growth rather than conversion of the sympodial bud to floral tissue (1). Evidence for a growth-suppressing mechanism lies with the observation that terminal leaves of determinate plants are characteristically small and narrow with short internodes between these leaves. The report that fruit set reduces the size of determinate plants (1) is consistent with a physiological model, as is George’s (2) suggestion that a gibberellin antagonist may be the cause of determinate growth. Since suppression of growth can occur to varying degrees, influenced by the environmental and genetic modifiers, genotypic classification of determinate plants based upon phenotypic observation is difficult and inaccurate under certain growing conditions.

Dwarf growth habit. During early growth stages the dwarf parents, MmD and TgD, were substantially shorter than the standard cultivars or other determinate lines. This reduced height represented the combined reduction of internode length and number of nodes. The F₁ hybrids from all dwarf x non-dwarf crosses were intermediate in height or approached the height of the non-dwarf parent. The distribution of plant

Table 1. Parental lines used in genetic study including growth habits and sources.

<table>
<thead>
<tr>
<th>Growth habit</th>
<th>Cultivar or genotype</th>
<th>Abbreviations used in text</th>
<th>Source and history</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>Marketer</td>
<td>MK</td>
<td>O. Shiffris — selfed at least 20 times</td>
</tr>
<tr>
<td></td>
<td>Marketmore</td>
<td>Mm</td>
<td>W. L. George, Jr. — from Harris Seed Co. then selfed at least 9 times</td>
</tr>
<tr>
<td></td>
<td>Tablegreen 65</td>
<td>Tg</td>
<td>W. L. George, Jr. — from Harris Seed Co. then selfed at least 9 times</td>
</tr>
<tr>
<td>Determinate</td>
<td>Marketer (de/de, In-de/In-de)</td>
<td>Mkde</td>
<td>W. L. George, Jr. — derived from back-crossing de of line 541 into 'Marketer'</td>
</tr>
<tr>
<td></td>
<td>de/de, In-de/In-de</td>
<td>inde</td>
<td>W. L. George, Jr. — derived from line 541 (2,3)</td>
</tr>
<tr>
<td>Dwarf</td>
<td>dwarf Marketmore</td>
<td>MmD</td>
<td>H. M. Munger, Cornell University — derived from Hardin’s PG-57 (1)</td>
</tr>
<tr>
<td></td>
<td>dwarf Tablegreen</td>
<td>TgD</td>
<td>H. M. Munger, Cornell University — derived from Hardin’s PG-57 (1)</td>
</tr>
</tbody>
</table>

Table 2. Expression of growth habit² in crosses between dwarf and non-dwarf cucumbers grown under greenhouse conditions.

<table>
<thead>
<tr>
<th>Parents</th>
<th>F₁</th>
<th>F₂</th>
<th>BC(F₁ x dwarf)</th>
<th>Winter-grown</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of plants</td>
<td>No. of plants</td>
<td>X² (3:1)</td>
<td>No. of plants</td>
</tr>
<tr>
<td>Dwarf</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-dwarf</td>
<td>I T</td>
<td>I T</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MmD (T) x Mkde (T)</td>
<td>20</td>
<td>98</td>
<td>46</td>
<td>TgD</td>
</tr>
<tr>
<td>x Inde (T)</td>
<td>20</td>
<td>99</td>
<td>46</td>
<td></td>
</tr>
<tr>
<td>x inde (T)</td>
<td>19</td>
<td>97</td>
<td>46</td>
<td></td>
</tr>
<tr>
<td>TgD (T) x Mk (I)</td>
<td>20</td>
<td>70 29 0.76</td>
<td>20 26 0.54</td>
<td>TgD</td>
</tr>
<tr>
<td>x Mm (I)</td>
<td>20</td>
<td>66 30 1.68</td>
<td>17 22 0.41</td>
<td>TgD</td>
</tr>
<tr>
<td>x Tg (I)</td>
<td>20</td>
<td>64 25 0.30</td>
<td>26 19 0.80</td>
<td>TgD</td>
</tr>
</tbody>
</table>

²T = determinate; S = semi-determinate; I = indeterminate.

Data obtained from all possible dwarf x non-dwarf hybrids, selfed F₁'s, and BC grown during the summer; progeny from both dwarf parents were combined.

X² values not significant, 5% level.
heights at an early stage of growth in the F2 of a Tg x TgD cross (Fig. 1) was clearly bimodal or perhaps trimodal as would be expected if the population were segregating in a 3:1 (tall:dwarf) or 1:2:1 (tall:intermediate:dwarf) fashion. This suggested a single, recessive gene for dwarfness. Height distributions of all 12 F2 populations were generally consistent with this pattern of segregation, but environmental variability and “background” genes precluded definitive classification of dwarf and tall segregates. Nevertheless, it was found that dwarf plants were not necessarily determinate. Thus, it is proposed that dwarfness is controlled by a single, recessive gene designated dl, for delayed growth. Gene dl can be described as causing a shortening of the hypocotyl and first few internodes and a reduction in the growth rate. It is strongly expressed in early growth stages, and after 3 or 4 nodes, growth of the vine approaches that of standard lines. Thus, the suggested genotype of the dwarf parents, MmD and TgD, is de/de, dl/dl, and that of the standard cultivars is De/De, D/D.

The linkage relationships of de and dl are unclear due to the difficulty in definitive classification of genotypes. However, observations suggest that dl may be weakly linked to de.

Modification of determinate habit. Both the environment and the genetic background affect the expression of determinate habit in cucumbers. George (3) described the effect of a gene (In-de) and the environment on plant height and total leaf number. Observations during the present study provide additional information regarding modification by gene In-de and the environment on growth habit.

George (3) reported a possible pleiotropic effect of In-de on shortening of internodes. Internode lengths measured during the present study suggested that there was no difference in internode length between In-de and in-de plants. The reported reduction in average internode length (3) was due to the very short internodes between terminal leaves which reduced the average internode length for In-de plants (fewer total leaves) more than those for in-de plants.

An interesting observation was that regardless of when the plants were grown, the length of time to termination of growth was nearly constant. Specifically, Inde and Mkde terminated growth in about 6 weeks, while inde terminated growth in about 8 weeks. The dwarf plants of determinate habit had terminated by 8 weeks but the specific time of termination was more difficult to ascertain. These time scales are consistent with reports in the literature (2,4).

We suggest the following model for genetic and environmental modification of determinate habit: The relative length of time to termination is determined genetically; the rate of growth until this time determines the final number of leaves and final length of the vine. This explains why plants of the same genotype have more leaves when grown in the summer than when grown in the winter (3). Based on this model, genetic modifiers of determinate habit can be of 2 kinds, those which...
The Mung Bean Rooting Bioassay: A Re-examination\(^1\)

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*Additional index words.* auxin, light intensity, *Phaseolus aureus*

**Abstract.** Inconsistent results obtained with the mung bean (*Phaseolus aureus* Roxb.) rooting bioassay led to a re-examination of procedures. Autoclaving the double distilled water used completely eliminated the inconsistent results, but boiling and filter sterilization were not completely satisfactory. A decrease in rooting of both control and auxin-treated cuttings was noted in seedlings older than 10 and 9 days respectively. Adventitious roots were initiated within 5 days; incubation for 2 additional days did not increase rooting response. Increasing irradiance from 380 to 4080 \(\mu W/cm^2\) decreased rooting of both control and auxin treated cuttings.

The mung bean rooting bioassay (5) is used to detect and quantify naturally occurring substances which stimulate adventitious root initiation in the presence or absence of auxin. Initially the assay was carried out in the dark using etiolated mung bean cuttings (4). Subsequently, light-grown plants were used and the assay procedures were carried out in the light (5). The assay is ideally suited for studying the root initiation process. Plants are available from seed in 9 days and the assay time is 5 days. The assay is also sensitive to added auxins and the number of root primordia formed varies directly with auxin concentration (1,7). The system has been used to detect inhibitors and/or promoters of adventitious root initiation in a wide range of plants (6).

Variation in adventitious root formation in rooting assays has been attributed to the kind of water used. Jackson and Harvey (7) reported that root growth of light-grown mung beans was poor in distilled water. Distilled water also inhibited rooting of light-grown dwarf bean (1), although roots developed readily in tap water. Dwarf bean cuttings failed to root in distilled water despite the addition of minerals to simulate the composition of tap water (3).

The promotive influence of boron on root initiation was first reported by Hemberg (3). Of the micronutrients investigated, boron was the only element capable of counteracting the inhibitory properties of distilled water. Boron reportedly stimulates both root initiation and elongation. Torsell (12), Gorter (2), and Murray et al. (10) noted that boron enhanced root growth but not root initiation. Weiser and Blaney (13), on the other hand, found that boron in the presence of auxin increased the percentage of cuttings rooting, the number and length of roots, and speed of rooting. In our laboratory, however, boron failed to eliminate inconsistencies in the rooting of mung bean cuttings.

Our purpose in this study was to investigate the cause of inconsistent rooting in distilled water in the mung bean assay through an analysis of water type, cutting age, and irradiance.

**Materials and Methods**

*Plant material and bioassay.* 'Oriental Giant' mung bean from one seed lot were surface sterilized in 10% Clorox for 10 min, rinsed in tap water and aerated for 24 hr in tap water before sowing 1 cm deep in plastic trays containing vermiculite. Germination, growth, and rooting occurred at 26 ± 1°C with a 16-hr photoperiod and an irradiance of approximately 2640 \(\mu W/cm^2\) at plant height.

Following the basic method outlined by Hess (5), uniform cuttings were made from 9-day-old seedlings and the bases were placed in distilled water prior to use. Unless otherwise stated, the water was double distilled and sterilized by autoclaving (20 min at 122°C and 931 Torr). Each cutting consisted of 3

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