Gene List 2001 for Cucumber

Jiahua Xie and Todd C. Wehner
Department of Horticultural Science, North Carolina State University, Raleigh, NC 27695-7609 U.S.A.

This is the latest version of the gene list for cucumber (Cucumis sativus L.). Complete lists and updates of genes for have been published previously (Pierce and Wehner, 1989; Robinson et al., 1976; Robinson et al., 1982; Wehner, 1993; Wehner and Staub, 1997). For the first time, this list includes genes that have been cloned from different plant tissues of cucumber. The genes on the 2001 list are of ten categories as follows: seedling markers, stem mutants, leaf mutants, flower mutants, fruit type mutants, fruit color mutants, resistance genes (mostly to diseases), protein (isozyme) variants, DNA (RFLPs and RAPDs) markers (Table 1), and cloned genes (Table 2).

Revisions to the 1997 cucumber gene list include the addition of nine genes that have been reported during past 5 years, including: bi-2, mj, msm, Prsv-2, rc-2, wmv-2, wmv-3, wmv-4, and zym-Dina. Six genes for virus resistance (mwm, zym, Prsv-2, wmv-2, wmv-3, and wmv-4) come from one inbred TMG-1.

Genes that have been published in previous lists but modified in this list are zymv (renamed zym, and then zym-TMG1 to distinguish it from zym-Dina). The gene mwm published in the literature may be the same as zym-TMG1. We also corrected the symbol for the flower mutant, male sterile-2 pollen sterile, ms-2(PS) (Zhang et al., 1994), with the superscript in parentheses to indicate an indistinguishable allele.

Isozyme variant nomenclature for this gene list follows the form according to Staub et al. (Staub et al., 1985), such that loci coding for enzymes (e.g. glutamine dehydrogenase, G2DH) are designated as abbreviations, where the first letter is capitalized (e.g. G2dh). If an enzyme system is conditioned by multiple loci, then those are designated by hyphenated numbers, which are numbered from most cathodal to most anodal and enclosed in parentheses. The most common allele of any particular isozyme is designated 100, and all other alleles for that enzyme are assigned a value based on their mobility relative to that allele. For example, an allele at locus 1 of FDP (fructose diphosphatase) which has a mobility 4 mm less that of the most common allele would be assigned the designation Fdp(1)-96.

RFLP marker loci were identified as a result of digestion of cucumber DNA with DraI, EcoRI, EcoRV, or HindIII (Kennard et al., 1994). Partial-genomic libraries were constructed using either PstI-digested DNA from the cultivar Sable and from EcoRV-digested DNA from the inbred WI 2757. Derived clones were hybridized to genomic DNA and banding patterns were described for mapped and unlinked loci (CsC482/H3, CsP314/E1, and CsP344/E1, CsC477/H3, CsP300/E1). Clones are designated herein as CsC = cDNA, CsP = PstI-genomic, and CsE = EcoRI-genomic. Lower-case a or b represent two independently-segregating loci detected with one probe. Lower-case s denotes the slowest fragment digested out of the vector. Restriction enzymes designated as DI, DraI; EI, EcoRI; E5, EcoRV; and H3, HindIII. Thus, a probe identified as CsC336b/E5 is derived from a cDNA library (from 'Sable') which was restricted using the enzyme EcoRV to produce a clone designated as 336 which displayed two independently segregating loci one of which is b. Clones are available in limited supply from Jack E. Staub.

RAPD marker loci were identified using primer sequences from Operon Technologies (OP; Alameda, California, U.S.A.) and the University of British Columbia (Vancouver, BC, Canada). Loci are identified by sequence origin (OP or BC), primer group letter (e.g., A), primer group array number (1-20), and locus (a, b, c, etc.) (Kennard et al., 1994). Information regarding unlinked loci can be obtained from Jack E. Staub.

Because of their abundance, common source (two mapping populations), and the accessibility of published information on their development (Kennard et al., 1994) DNA marker loci are not included in Table 1, but are listed below.
The 60 RFLP marker loci from mapping cross Gy 14 x PI 183967 (Kennard et al., 1994): CsP129/E1, CsC032a/E1, CsP064/E1, CsP357/H3, CsC386/E1, CsC365/E1, CsP046/E1, CsP347/H3, CsC694/E5, CsC588/H3, CsC230/E1, CsC593/D1, CsP193/H3, CsP078s/E3, CsC581/E5, CsE084/E1, CsC341/H3, CsP024/E1, CsP287/H3, CsC629/H3, CsP303/H3, CsE051/H3, CsC366a/E5, CsC032b/E1, CsP056/H3, CsC378/E1, CsP406/E1, CsP460/E1, CsE060/E1, CsE103/E1, CsP019/E1, CsP168/D1, CsC560/H3, CsP005/E1, CsP440s/E1, CsP221/H3, CsC625/E1, CsP475s/E1, CsP211/E1, CsP215/H3, CsC613/E1, CsC029/H3, CsP130/E1, CsC443/H3, CsE120/H3, CsE031/E1, CsC308/E5, CsP266/D1, CsC443/H3, CsE031/E1, CsE120/H3, CsE063/E1, CsP308/E1, CsP105/E1, and CsC166/E1.

The 31 RFLP marker loci from mapping cross Gy 14 x PI 432860 (Kennard et al., 1994): CsC560/D1, CsP024/E5, CsP287/H3, CsC384/E5, CsC366/E5, CsC611/D1, CsP055/D1, CsC482/H3, CsP019/E1, CsP059/D1, CsP471s/H13, CsC332/E5, CsP056/H3, CsC308/E5, CsP266/D1, CsC443/H3, CsE031/E1, CsE120/H3, CsC612/D1, CsC029/H3, CsP130/E1, CsC378/E1, CsP406/E1, CsP460/E1, CsE060/E1, CsE103/E1, CsP019/E1, CsP168/D1, CsC560/H3, CsP024/E5, CsP287/H3, CsC384/E5, CsC366/E5, CsC611/D1, CsP055/D1, CsC482/H3, CsP019/E1, CsP059/D1, CsP471s/H13, CsC332/E5, CsP056/H3, CsC308/E5, CsP266/D1, CsC443/H3, CsE031/E1, CsE120/H3, CsC612/D1, CsC029/H3, CsP130/E1, CsC378/E1, CsP406/E1, CsP460/E1, CsE060/E1, CsE103/E1, CsP019/E1, CsP168/D1, CsC560/H3, CsP005/E1, CsP440s/E1, CsP221/H3, CsC625/E1, CsP475s/E1, CsP211/E1, CsP215/H3, CsC613/E1, CsC029/H3, CsP130/E1, CsC443/H3, CsE120/H3, CsE031/H3, CsC366b/E5, CsC082/H13, CsP094/H3, CsC308/E1, CsC166/E1, and CsP303/H3.

The 20 RAPD marker loci from mapping cross Gy 14 x PI 432860 (Kennard et al., 1994): OPR04, OPW16, OPS17, OPE13a, OPN06, OPN12, OPP18b, BC211b, OPN04, OPA10, OPE09, OPT18, OPA14b, OPU20, BC460a, OPAB06, OPAB05, OPH12, OPA14a, and BC211a.

In addition to the isozymes, RFLPs and RAPDs, nearly 100 cloned genes are listed here (Table 2).

Researchers are encouraged to send reports of new genes, as well as seed samples to the cucumber gene curator (Todd C. Wehner), or to the assistant curators (Jack E. Staub and Richard W. Robinson). Please inform us of omissions or errors in the gene list. Scientists should consult the list as well as the rules of gene nomenclature for the Cucurbitaceae (Robinson et al., 1976; Robinson et al., 1982) before choosing a gene name and symbol. That will avoid duplication of gene names and symbols. The rules of gene nomenclature were adopted in order to provide guidelines for naming and symbolizing genes. Scientists are urged to contact members of the gene list committee regarding rules and gene symbols.

<table>
<thead>
<tr>
<th>Gene</th>
<th>Synonym</th>
<th>Character</th>
<th>References</th>
<th>Supplemental references</th>
<th>Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>-</td>
<td>androecious. Produces primarily staminate flowers if recessive for F. A from MSU 713-5 and Gy 14; a from An-11 and An-314, two selections from 'E-e-szan' of China.</td>
<td>Kubicki, 1969</td>
<td>P</td>
<td></td>
</tr>
<tr>
<td>Ak-2</td>
<td>-</td>
<td>Adenylate kinase (E.C.# 2.7.4.3). Isozyme variant found segregating in PI 339247, and 271754; 2 alleles observed.</td>
<td>Meglic and Staub, 1996</td>
<td>P</td>
<td></td>
</tr>
<tr>
<td>Ak-3</td>
<td>-</td>
<td>Adenylate kinase (E.C.# 2.7.4.3). Isozyme variant found segregating in PI 113334, 183967, and 285603; 2 alleles observed.</td>
<td>Meglic and Staub, 1996</td>
<td>P</td>
<td></td>
</tr>
<tr>
<td>al</td>
<td>-</td>
<td>albino cotyledons. White cotyledons and slightly light green hypocotyl; dying before first true leaf stage. Wild type Al from 'Nishiki-suyo'; al from M2 line from pollen irradiation.</td>
<td>Iida and Amano, 1990, 1991</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>Trait</td>
<td>Description</td>
<td>Ref.</td>
<td>Notes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------</td>
<td>-------------</td>
<td>------</td>
<td>-------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ar</td>
<td>Anthracnose resistance. One of several genes for resistance to <em>Colletotrichum lagenarium</em>. Ar from PI 175111, PI 175120, PI 179676, PI 183308, PI 183445; ar from 'Palmetto' and 'Santee'.</td>
<td>Barnes and Epps, 1952</td>
<td>P</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Black or brown spines. Dominant to white spines on fruit.</td>
<td>Strong, 1931; Tkachenko, 1935; Wellington, 1913</td>
<td>W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B-2</td>
<td>Black spine-2. Interacts with B to produce F₂ of 15 black: 1 white spine. B-2 from Wis. 9362; b-2 from PI 212233 and 'Pixie'.</td>
<td>Shanmugasundarum et al., 1971a</td>
<td>?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B-3</td>
<td>Black spine-3. Interacts with B-4 to produce an F₂ of nine black: 7 white spine. B-3 from LJ90430; b-3 from MSU 41.</td>
<td>Cowen and Helsel, 1983</td>
<td>W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B-4</td>
<td>Black spine-4. Interacts conversely with B-3. B-4 from LJ90430; b-4 from MSU 41.</td>
<td>Cowen and Helsel, 1983</td>
<td>W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>bi</td>
<td>bitterfree. All plant parts lacking cucurbitacins. Plants with bi less preferred by cucumber beetles. Plants with Bi resistant to spider mites in most American cultivars; bi in most Dutch cultivars.</td>
<td>Andeweg and DeBruyn, 1959</td>
<td>W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>bi-2</td>
<td>bitterfree-2. Leaves lacking cucurbitacins; bi-2 Wehner et al., 1998a from NCG-093 (short petiole mutant).</td>
<td></td>
<td>W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>bl</td>
<td>blind. Terminal bud lacking after temperature shock. bl from 'Hunderup' and inbred HP3.</td>
<td>Carlsson, 1961.</td>
<td>L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>bla</td>
<td>blunt leaf. Leaves have obtuse apices and reduced lobing and serration. bla from a mutant of 'Wis. SMR 18'.</td>
<td>Robinson, 1987a</td>
<td>W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bt</td>
<td>Bitter fruit. Fruit with extreme bitter flavor. Bt from PI 173889 (Wild Hanzil Medicinal Cucumber).</td>
<td>Barham, 1953</td>
<td>W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>bu</td>
<td>bush. Shortened internodes. bu from 'KapAhk 1'.</td>
<td>Pyzenkov and Kosareva, 1981</td>
<td>L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bw</td>
<td>Bacterial wilt resistance. Resistance to <em>Erwinia tracheiphila</em>. Bw from PI 200818; bw from 'Marketer'.</td>
<td>Nuttall and Jasmin, 1958</td>
<td>W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>by</td>
<td>bushy. Short internodes; normal seed viability. Wild type By from 'Borszczagowski'; by from induced mutation of 'Borszczagowski'. Linked with F and gy, not with B or bi.</td>
<td>Kubicki et al., 1986a</td>
<td>?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c</td>
<td>cream mature fruit color. Interaction with R is evident in the F₂ ratio of 9 red (RC) : 3 orange (Re) : 3 yellow (rC) : 1 cream (rc).</td>
<td>Hutchins, 1940</td>
<td>L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cca</td>
<td>Corynespora cassicola resistance. Resistance to target leaf spot; dominant to susceptibility. Cca from Royal Sluis Hybrid 72502; cca from Gy 3.</td>
<td>Abul-Hayja et al., 1975</td>
<td>W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ccu</td>
<td>Cladosporium cucumerinum resistance. Resistance to scab. Ccu from line 127.31, a selfed progeny of 'Longfellow'; ccu from 'Davis Perfect'.</td>
<td>Bailey and Burgess, 1934</td>
<td>W</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

cd - chlorophyll deficient. Seedling normal at first, later becoming a light green; lethal unless grafted. cd from a mutant selection of backcross of MSU 713-5 x 'Midget' F1 to 'Midget'.

Kubicki and Korzeniewska, 1984

cl - closed flower. Staminate and pistillate flowers do not open; male-sterile (nonfertile pollen).

Groff and Odland, 1963

cla - Colletotrichum lagenarium resistance. Resistance to race 1 of anthracnose; recessive to susceptibility. Cla from Wis. SMR 18; cla from SC 19B.

Currence, 1954

Cm - Corynespora melonis resistance. Resistance to C. melonis dominant to susceptibility. Cm from 'Spotvrie'; cm from 'Esvier'.

van Es, 1958

Cmv - Cucumber mosaic virus resistance. One of several genes for resistance to CMV. Cmv from 'Wis. SMR 12', 'Wis. SMR 15', and 'Wis. SMR 18'; cmv from 'National Pickling' and 'Wis. SR 6'.

Wasuwat and Walker, 1961

co - green corolla. Green petals that turn white with age and enlarged reproductive organs; female-sterile. co from a selection of 'Extra Early Prolific'.

Hutchins, 1935

Currence, 1954

cor-1 - cordate leaves-1. Leaves are cordate. cor-1 from 'Nezhinskii'.

Gornitskaya, 1967

L

cor-2 cor - cordate leaves-2. Leaves are nearly round with revolute margins and no serration. Insect pollination is hindered by short calyx segments that tightly clasp the corolla, preventing full opening. cor-2 from an induced mutant of 'Lemon'.

Robinson, 1987c

W

cp - compact. Reduced internode length, poorly developed tendrils, small flowers. cp from PI 308916.

Kaufman and Lower, 1976

W

cp-2 - compact-2. Short internodes; small seeds; similar to cp, but allelism not checked. Wild type Cp-2 from 'Borszczagowski'; cp-2 from induced mutation of 'Borszczagowski' called W97. Not linked with B or F; interacts with by to produce super dwarf.

Kubicki et al., 1986b

L

cr - crinkled leaf. Leaves and seed are crinkled.

Odland and Groff, 1963a

cs - carpel splitting. Fruits develop deep longitudinal splits. cs from TAMU 1043 and TAMU 72210, which are second and fifth generation selections of MSU 3249 x SC 25.

Caruth, 1975; Pike and Caruth, 1977

D g - Dull fruit skin. Dull skin of American cultivars, dominant to glossy skin of most European cultivars.

Poole, 1944; Strong, 1931; Tkachenko, 1935

W
**de**  I  
**determinate habit.** Short vine with stem terminating in flowers; modified by **In-de** and other genes; degree of dominance depends on gene background. **de** from Penn 76.60G*, Minn 158.60*, 'Hardin's PG57*', 'Hardin's Tree Cucumber', and S-1 (and inbred selection from Line 541)**.

**de-2**  I  
**determinate-2.** Main stem growth ceases after 3 to 10 nodes, producing flowers at the apex; smooth, fragile, dark-green leaves; similar to **de**, but not checked for allelism. Wild type **De-2** from 'Borszczagowski'; **de-2** from W-sk mutant induced by ethylene-imine from 'Borszczagowski'.

**df**  I  
**delayed flowering.** Flowering delayed by long photoperiod; associated with dormancy. **df** from 'Baroda' (PI 212896)* and PI 215589 (hardwickii)**.

**dl**  I  
**delayed growth.** Reduced growth rate; shortening of hypocotyl and first internodes. **dl** from 'Dwarf Marketmore' and 'Dwarf Tablegreen', both deriving dwarfness from 'Hardin's PG-57'.

**dm**  P  
**downy mildew resistance.** One of several genes for resistance to *Pseudoperonospora cubensis*. **Dm** from Sluis & Groot Line 4285; **dm** from 'Poinsett'.

**dm-1**  dm  
**downy mildew resistance-1.** One of three genes for resistance to downy mildew caused by *Pseudoperonospora cubensis* (Berk & Curt). Wild type **Dm-1** from Wisconsin SMR 18; **dm-1** from WI 4783. Not checked for allelism with **dm**.

**dm-2**  -  
**downy mildew resistance-2.** One of three genes for resistance to downy mildew caused by *Pseudoperonospora cubensis* (Berk & Curt). Wild type **Dm-2** from Wisconsin SMR 18; **dm-2** from WI 4783. Not checked for allelism with **dm**.

**dm-3**  -  
**downy mildew resistance-3.** One of three genes for resistance to downy mildew caused by *Pseudoperonospora cubensis* (Berk & Curt). Wild type **Dm-3** from Wisconsin SMR 18; **dm-3** from WI 4783. Not checked for allelism with **dm**.

**dvl**  dl  
**divided leaf.** True leaves are partly or fully divided, often resulting in compound leaves with two to five leaflets and having incised corollas.

**dvl-2**  dl-2  
**divided leaf-2.** Divided leaves after the 2nd true leaf; flower petals free; similar to **dvl**, but allelism not checked. Wild type **Dvl-2** from 'Borszczagowski'; **dvl-2** from mutant induced by ethylene-imine from 'Borszczagowski'.

**dw**  -  
**dwarf.** Short internodes. **dw** from an induced mutant of 'Lemon'.

---

Denna, 1971*; George, 1970*; Hutchins, 1940 Nutall and Jasmin, 1958

W

Soltysiak et al., 1986

? W

Della Vecchia et al., 1982*; Shifriss and George, 1965**

W

Miller and George, 1979

W

van Vliet and Meysing, 1977 Jenkins, 1946; Shimizu, 1963

W

Doruchowski and Lakowska-Ryk, 1992

?

Doruchowski and Lakowska-Ryk, 1992

?

Doruchowski and Lakowska-Ryk, 1992

?

den Nijs and Mackiewicz, 1980

W

Rucinska et al., 1992b

?

Robinson and Mishanec, 1965

?
**dwc-1** - *dwarf cotyledons-1*. Small cotyledons; late germination; small first true leaf; died after 3rd true leaf. Wild type *Dwc-1* from 'Nishiki Suyo'; *dwc-1* from M<sub>2</sub> line from pollen irradiation.

Iida and Amano, 1990, 1991

**dwc-2** - *dwarf cotyledons-2*. Small cotyledons; late germination; small first true leaf. Wild type *Dwc-2* from 'Nishiki Suyo'; *dwc-2* from M<sub>2</sub> line from pollen irradiation.

Iida and Amano, 1990, 1991

**Es-1** - *Empty chambers-1*. Carpels of fruits separated from each other, leaving a small to large cavity in the seed cell. *Es-1* from PP-2-75; *es-1* from Gy-30-75.

Kubicki and Korzeniewska, 1983

**Es-2** - *Empty chambers-2*. Carpels of fruits separated from each other, leaving a small to large cavity in the seed cell. *Es-2* from PP-2-75; *es-2* from Gy-30-75.

Kubicki and Korzeniewska, 1983

**F** - *Acr, acr<sup>r</sup>, D, st* Female. High degree of pistillate sex expression; interacts with *a* and *M*; strongly modified by environment and gene background. *F* and *f* are from 'Japanese'.

Galun, 1961; Kubicki, 1965, 1969a; Poole, 1944; Shifriss, 1961

**fa** - *fasciated*. Plants have flat stems, short internodes, and rugose leaves. *fa* was from a selection of 'White Lemon'.

Robinson, 1987b; Shifriss, 1950

**Fba** - *Flower bud abortion*. Preanthesis abortion of floral buds, ranging from 10% to 100%. *fba* from MSU 0612.

Miller and Quisenberry, 1978

**Fdp-1** - *Fructose diphosphatase* (E.C.# 3.1.3.11). Isozyme variant found segregating in PI 192940, 169383 and 169398; 2 alleles observed.

Meglic and Staub, 1996

**Fdp-2** - *Fructose diphosphatase* (E.C.# 3.1.3.11). Isozyme variant found segregating in PI 137851, 164952, 113334 and 192940; 2 alleles observed.

Meglic and Staub, 1996

**Fl** - *Fruit length*. Expressed in an additive fashion, fruit length decreases incrementally with each copy of *fl* (H. Munger, personal communication).

Wilson, 1968

**Foc** - *Fcu-1* *Fusarium oxysporum f. sp. cucumerinum resistance*. Resistance to fusarium wilt races 1 and 2; dominant to susceptibility. *Foc* from WIS 248; *foc* from 'Shimshon'.


**G2dh** - *Glutamine dehydrogenase* (E.C.# 1.1.1.29). Isozyme variant found segregating in PI 285606; 5 alleles observed.

Knerr and Staub, 1992

**g** - *golden leaves*. Golden color of lower leaves. *G* and *g* are both from different selections of 'Nezhin'.

Tkachenko, 1935

**gb** - *gooseberry fruit*. Small, oval-shaped fruit. *gb* from the 'Klin mutant'.

Tkachenko, 1935

**gc** - *golden cotyledon*. Butter-colored cotyledons; seedlings die after 6 to 7 days. *gc* from a mutant of 'Burpless Hybrid'.

Whelan, 1971
gi - *ginkgo*. Leaves reduced and distorted, resembling leaves of Ginkgo; male- and female-sterile. Complicated background: It was in a segregating population whose immediate ancestors were offspring of crosses and backcrosses involving 'National Pickling', 'Chinese Long', 'Tokyo Long Green', 'Vickery', 'Early Russian', 'Ohio 31' and an unnamed white spine slicer. John and Wilson, 1952

*gi-2* - *ginkgo-2*. Spatulate leaf blade with reduced lobing and altered veins; recognizable at the 2nd true leaf stage; similar to gi, fertile instead of sterile. Wild type *Gi*-2 from 'Borszczagowski'; *gi*-2 from mutant in the Kubicki collection. Rucinska et al., 1992b

*gig* - *gigantism*. First leaf larger than normal. Wild type *Gig* from 'Borszczagowski'; *gig* from chemically induced mutation. Kubicki et al., 1984

*gl* - *glabrous*. Foliage lacking trichomes; fruit without spines. Iron-deficiency symptoms (chlorosis) induced by high temperature. *gl* from NCSU 75" and M834-6". Robinson and Mihanec, 1964’; Inngamer and de Ponti, 1980”; Robinson, 1987b

*glb* - *glabrate*. Stem and petioles glabrous, laminae slightly pubescent. *glb* from 'Burless Hybrid'. Whelan, 1973

*gn* - *green mature fruit*. Green mature fruits when *rr gn*; cream colored when *rr Gngn*; orange when *R_ __.* Wild type *Gn* from 'Chipper', SMR 58 and PI 165509; *gn* from TAMU 830397. Peterson and Pike, 1992

*Gpi-1* - *Glucose phosphate isomerase* (E.C.# 5.3.1.9). Isozyme variant found segregating (1 and 2) in PI 176524, 200815, 249561, 422192, 432854, 436608; 3 alleles observed. Knerr and Staub, 1992

*Gr-1* - *Glutathione reductase-1* (E.C.# 1.6.4.2). Isozyme variant found segregating in PI 109275; 5 alleles observed. Knerr and Staub, 1992


*H* - *Heavy netting of fruit*. Dominant to no netting and completely linked or pleiotropic with black spines (B) and red mature fruit color (R). Hutchins, 1940; Tkachenko, 1935

*h* - *heart leaf*. Heart shaped leaves. Wild type *H* from Wisconsin SMR 18; *hl* from WI 2757. Linked with *ns* and *ss* in the linkage group with Tu-u-D-pm. Vakalounakis, 1992

*hn* - *horn like cotyledons*. Cotyledons shaped like bull horns; true leaves with round shape rather than normal lobes; circular rather than ribbed stem cross section; divided petals; spineless fruits; pollen fertile, but seed sterile. Wild type *Hn* from 'Nishiki-suyo'; *hn* from M2 line from pollen irradiation. Iida and Amano, 1990, 1991

Intensifier of $P$. Modifies effect of $P$ on fruit warts in *Cucumis sativus* var. *tuberculatus*. Tkachenko, 1935

**Idh** - *Isocitrate dehydrogenase* (E.C.# 1.1.1.42). Isozyme variant found segregating in PI 183967, 215589; 2 alleles observed. Knerr and Staub, 1992

**In-de** - *Intensifier of de*. Reduces internode length and branching of de plants. *In-de* and *in-de* are from different selections (S$_5$-1 and S$_5$-6, respectively) from a determinant inbred S$_2$-1, which is a selection of line 541. George, 1970

**In-F** - *Intensifier of female sex expression*. Increases degree of pistillate sex expression of $F$ plants. *In-F* from monoeocious line 18-1; *in-F* from MSU 713-5. Kubicki, 1969b

**l** - *locule number*. Many fruit locules and pentamerous androecium; five locules recessive to the normal number of three. Youngner, 1952

**lg-1** - *light green cotyledons-1*. Light green cotyledons, turning dark green; light green true leaves, turning dark green; poorly developed stamens. Wild type $Lg$-1 from 'Nishiki-suyo'; $lg$-1 from $M_2$ line from pollen irradiation. Iida and Amano, 1990, 1991

**lg-2** - *light green cotyledons-2*. Light green cotyledons, turning dark green (faster than $lg$-1); light green true leaves, turning dark green; normal stamens. Wild type $Lg$-2 from 'Nishiki-suyo'; $lg$-2 from $M_2$ line from pollen irradiation. Iida and Amano, 1990, 1991

**lh** - *long hypocotyl*. As much as a 3-fold increase in hypocotyl length. *lh* from a 'Lemon' mutant. Robinson and Shail, 1981

**ll** - *little leaf*. Normal-sized fruits on plants with miniature leaves and smaller stems. *ll* from Ark. 79-75. Goode et al., 1980; Wehner et al., 1987

**ls** - *light sensitive*. Pale and smaller cotyledons, lethal at high light intensity. *ls* from a mutant of 'Burpless Hybrid'. Whelan, 1972b

**ls** - *g* *light sensitive*. Yellow cotyledons, lethal in high light. Abstract gave $g$ as symbol; article that followed gave *ls* as symbol. Mutant *ls* from a selection of 'Burpless Hybrid'. Whelan, 1971, 1972

**m** - *andromonoecious*. Plants are andromonoecious if (*mf*); monoecious if (*Mf*); gynoecious if (*MF*) and hermaphroditic if (*mF*). *m* from 'Lemon'. Rosa, 1928'; Shifriss, 1961; Tkachenko, 1935; Wall, 1967; Youngner, 1952

**m-2** - *andromonoecious-2*. Bisexual flowers with normal ovaries. Iezzoni, 1982; Kubicki, 1974

**Mdh-1** - *Malate dehydrogenase-1* (E.C.# 1.1.1.37). Isozyme variant found segregating in PI 171613, 209064, 326594; 3 alleles observed. Knerr and Staub, 1992

**Mdh-2** - *Malate dehydrogenase-2* (E.C.# 1.1.1.37). Isozyme variant found segregating in PI 174164, 185690, 357835, 419214; 2 alleles observed. Knerr and Staub, 1992

**Mdh-3** - *Malate dehydrogenase-3* (E.C.# 1.1.1.37). Knerr et al., 1995
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mdh-4</strong>&lt;sup&gt;3&lt;/sup&gt;</td>
<td>Malate dehydrogenase-4 (E.C.# 1.1.1.37). Isozyme variant found segregating in PI 255236, 267942, 432854, 432887; 2 alleles observed.</td>
<td>Knerr and Staub, 1992</td>
</tr>
<tr>
<td><strong>mj</strong></td>
<td>A single recessive gene for resistance to the root-knot nematode (<em>Meloidogyne javanica</em>) from <em>Cucumis sativus</em> var. <em>hardwickii</em>; <em>mj</em> from NC-42 (LJ 90430).</td>
<td>Walters et al., 1996; Walters and Wehner, 1998</td>
</tr>
<tr>
<td><strong>mp</strong>&lt;sub&gt;pf&lt;/sub&gt;, <strong>pf</strong>&lt;sub&gt;d&lt;/sub&gt;, <strong>pf</strong>&lt;sub&gt;p&lt;/sub&gt;</td>
<td><em>Multi-pistillate</em>. Several pistillate flowers per node, recessive to single pistillate flower per node. <em>mp</em> from MSU 604G and MSU 598G.</td>
<td>Nandgaonkar and Baker, 1981; Fujieda et al., 1982</td>
</tr>
<tr>
<td><strong>Mpi-1</strong></td>
<td>Mannose phosphate isomerase (E.C.# 5.3.1.8). Isozyme variant found segregating in PI 176954, and 249562; 2 alleles observed.</td>
<td>Meglic and Staub, 1996</td>
</tr>
<tr>
<td><strong>Mpi-2</strong></td>
<td>Mannose phosphate isomerase (E.C.# 5.3.1.8). Isozyme variant found segregating in PI 109275, 175692, 200815, 209064, 263049, 354952; 2 alleles observed.</td>
<td>Knerr and Staub, 1992</td>
</tr>
<tr>
<td><strong>mpy mpi</strong></td>
<td><em>Male pygmy</em>. Dwarf plant with only staminate flowers. Wild type <em>Mpy</em> from Wisconsin SMR 12; <em>mpy</em> from Gnome 1, a selection of 'Rochford's Improved'.</td>
<td>Pyzhenkov and Kosareva, 1981</td>
</tr>
<tr>
<td><strong>ms-1</strong>&lt;sup&gt;1&lt;/sup&gt;</td>
<td><em>Male sterile-1</em>. Staminate flowers abort before anthesis; partially female-sterile. <em>ms-1</em> from selections of 'Black Diamond' and 'A &amp; C'.</td>
<td>Shiffriss, 1950; Robinson and Mishanec, 1967</td>
</tr>
<tr>
<td><strong>ms-2</strong>&lt;sup&gt;2&lt;/sup&gt;</td>
<td><em>Male sterile-2</em>. Male-sterile; pollen abortion occurs after first mitotic division of the pollen grain nucleus. <em>ms-2</em> from a mutant of 'Burpless Hybrid'.</td>
<td>Whelan, 1973</td>
</tr>
<tr>
<td><strong>ms-2&lt;sup&gt;(PS)&lt;/sup&gt;</strong>&lt;sub&gt;2&lt;/sub&gt;</td>
<td><em>Male sterile-2 pollen sterile</em>. Male-sterile; allelic to <em>ms-2</em>, but not to <em>ap</em>. <em>ms-2&lt;sup&gt;(PS)&lt;/sup&gt;</em> from a mutant of Sunseeds 23B-X26.</td>
<td>Zhang et al., 1994</td>
</tr>
<tr>
<td><strong>mwm</strong></td>
<td>Moroccan watermelon mosaic virus resistance single recessive gene from Chinese cucumber cultivar 'TMG-1'</td>
<td>Kabelka and Grumet, 1997</td>
</tr>
<tr>
<td><strong>n</strong></td>
<td><em>Negative geotropic peduncle response</em>. Pistillate flowers grow upright; <em>n</em> from 'Lemon'; <em>N</em> produces the pendant flower position of most cultivars.</td>
<td>Odland, 1963b</td>
</tr>
<tr>
<td><strong>ns</strong></td>
<td><em>Numerous spines</em>. Few spines on the fruit is dominant to many. <em>ns</em> from Wis. 2757.</td>
<td>Fanourakis, 1984; Fanourakis and Simon, 1987</td>
</tr>
<tr>
<td><strong>O y</strong>&lt;sup&gt;1&lt;/sup&gt;</td>
<td><em>Orange-yellow corolla</em>. Orange-yellow dominant to light yellow. <em>O</em> and <em>o</em> are both from 'Nezhin'.</td>
<td>Tkachenko, 1935</td>
</tr>
<tr>
<td><strong>opp</strong>&lt;sup&gt;1&lt;/sup&gt;</td>
<td><em>Opposite leaf arrangement</em>. Opposite leaf arrangement is recessive to alternate and has incomplete penetrance. <em>opp</em> from 'Lemon'.</td>
<td>Robinson, 1987e</td>
</tr>
<tr>
<td><strong>P</strong>&lt;sup&gt;1&lt;/sup&gt;</td>
<td><em>Prominent tubercles</em>. Prominent on yellow rind of <em>Cucumis sativus</em> var. <em>tuberculatus</em>, incompletely dominant to brown rind without tubercles. <em>P</em> from 'Klin'; <em>p</em> from 'Nezhin'.</td>
<td>Tkachenko, 1935</td>
</tr>
</tbody>
</table>
**Pc**  
Parthenocarpy. Sets fruit without pollination.  
*Pc* from 'Spotvrie’; *pc* from MSU 713-205.

**Pe**  
Palisade epidermis. Epidermal cells arranged perpendicular to the fruit surface. Wild type *Pe* from 'Wisconsin SMR 18', 'Spartan Salad' and *Gy 2 compact; pe* from WI 2757.  
Pike and Peterson, 1969; Wellington and Hawthorn, 1928; Whelan, 1973  
Fanourakis and Simon, 1987

**Pep-gl-1**  
Peptidase with glycyll-leucine (E.C.# 3.4.13.11). Isozyme variant found segregating in PI 113334, 212886; 2 alleles observed.  
Meglic and Staub, 1996

**Pep-gl-2**  
Peptidase with glycyll-leucine (E.C.# 3.4.13.11). Isozyme variant found segregating in PI 137851, 212886; 2 alleles observed.  
Meglic and Staub, 1996

**Pep-la**  
Peptidase with leucyl-leucine (E.C.# 3.4.13.11). Isozyme variant found segregating in PI 169380, 175692, 263049, 289698, 354952; 5 alleles observed.  
Knerr and Staub, 1992

**Pep-pap**  
Peptidase with phenylalanyl-L-proline (E.C.# 3.4.13.11). Isozyme variant found segregating in PI 163213, 188749, 432851; 2 alleles observed.  
Knerr and Staub, 1992

**Per-4**  
Peroxidase (E.C.# 1.11.1.7). Isozyme variant found segregating in PI 215589; 2 alleles observed.  
Knerr and Staub, 1992

**Pgd-1**  
Phosphogluconate dehydrogenase-1 (E.C.# 1.1.1.43). Isozyme variant found segregating in PI 169380, 175692, 222782; 2 alleles observed.  
Knerr and Staub, 1992

**Pgd-2**  
Phosphogluconate dehydrogenase-2 (E.C.# 1.1.1.43). Isozyme variant found segregating in PI 171613, 177364, 188749, 263049, 285606, 289698, 354952, 419214, 432858; 2 alleles observed.  
Knerr and Staub, 1992

**Pgm-1**  
Phosphoglucomutase (E.C.# 5.4.2.2). Isozyme variant found segregating in PI 171613, 177364, 188749, 263049, 264229, 285606, 289698, 354952; 2 alleles observed.  
Knerr and Staub, 1992

**pl**  
pale lethal. Slightly smaller pale-green cotyledons; lethal after 6 to 7 days. *Pl* from 'Burpless Hybrid'; *pl* from a mutant of 'Burpless Hybrid'.  
Whelan, 1973

**pm-1**  
powdery mildew resistance-1. Resistance to *Sphaerotheca fuliginia*. *pm-1* from 'Natsufushinari'.  
Fujieda and Akiya, 1962; Kooistra, 1971  
Shanmugasundarum et al., 1971

**pm-2**  
powdery mildew resistance-2. Resistance to *Sphaerotheca fuliginia*. *pm-2* from 'Natsufushinari'.  
Fujieda and Akiya, 1962; Kooistra, 1971  
Shanmugasundarum et al., 1971

**pm-3**  
powdery mildew resistance-3. Resistance to *Sphaerotheca fuliginia*. *pm-3* found in PI 200815 and PI 200818.  
Kooistra, 1971  
Shanmugasundarum et al., 1971

**pm-h**  
powdery mildew resistance expressed by the hypocotyl. Resistance to powdery mildew as noted by no fungal symptoms appearing on seedling cotyledons is recessive to susceptibility. *Pm-h* from 'Wis. SMR 18'; *pm-
$pr$ - protruding ovary. Exerted carpels. $pr$ from 'Lemon'.

$prsv$ wmv-1-1 watermelon mosaic virus 1 resistance. Resistance to papaya ringspot virus (formerly watermelon mosaic virus 1). Wild type $Prsv$ from WI 2757; $prsv$ from 'Surinam'.

$Prsv$-2 Resistance to papaya ringspot virus; $Prsv$-2 from TMG-1.

$psl$ pl Pseudomonas lachrymans resistance. Resistance to $Pseudomonas lachrymans$ is recessive. $Psl$ from 'National Pickling' and 'Wis. SMR 18'; $psl$ from MSU 9402 and Gy 14.

$R$ - Red mature fruit. Interacts with $c$; linked or pleiotropic with $B$ and $H$.

$rc$ - revolute cotyledon. Cotyledons are short, narrow, and cupped downwards; enlarged perianth. $rc$ from 'Burpless Hybrid' mutant.

$rc$-2 recessive gene for revolute cotyledons; $rc$-2 from Wehner et al., 1998b NCG-0093 (short petiole mutant)

$ro$ - rosette. Short internodes, muskmelon-like leaves. $ro$ from 'Megurk', the result of a cross involving a mix of cucumber and muskmelon pollen.

$s$ f, a spine size and frequency. Many small fruit spines, characteristic of European cultivars is recessive to the few large spines of most American cultivars.

$s$-2 - spine-2. Acts in duplicate recessive epistatic fashion with $s$-3 to produce many small spines on the fruit. $s$-2 from Gy 14; $s$-2 from TAMU 72210.

$s$-3 - spine-3. Acts in duplicate recessive epistatic fashion with $s$-2 to produce many small spines on the fruit. $S$-3 from Gy 14; $s$-3 from TAMU 72210.

$sa$ - salt tolerance. Tolerance to high salt levels is attributable to a major gene in the homozygous recessive state and may be modified by several minor genes. $Sa$ from PI 177362; $sa$ from PI 192940.

$sc$ cm stunted cotyledons. Small, concavely curved cotyledons; stunted plants with cupped leaves; abnormal flowers. $Sc$ $sc$ from Wis. 9594 and 9597.

$Sd$ - Sulfur dioxide resistance. Less than 20% leaf damage in growth chamber. $Sd$ from 'National Pickling'; $sd$ from 'Chipper'.

$sh$ - short hypocotyl. Hypocotyl of seedlings 2/3 the length of normal. Wild type $Sh$ from 'Borszczagowski'; $sh$ from khp, an induced mutant from 'Borszczagowski'.

Youngner, 1952. W

Wang et al., 1984 W

Wai and Grumet, 1995 Wai et al., 1997 W

Dessert et al., 1982 W

Hutchins, 1940 W

Whelan et al., 1975 L

de Ruiter et al., 1980 W

Strong, 1931; Tkachenko, 1935 Caruth, 1975; Poole, 1944 W

Caruth, 1975 ?

Caruth, 1975 ?

Jones, 1984 P

Shanmugasundarum and Williams, 1971; Shanmugasundarum et al., 1972. W

Bressan et al., 1981 W

Soltysiak and Kubicki 1988?
**shl** - _shrunken leaves_. First and 2nd true leaves smaller than normal; later leaves becoming normal; slow growth; often dying before fruit set. Wild type _Shl_ from 'Nishiki-suyo'; _shl_ from M2 line from pollen irradiation. Iida and Amano, 1990, 1991

**Skdh** - _Shikimate dehydrogenase_ (E.C.# 1.1.1.25). Isozyme variant found segregating in PI 302443, 390952, 487424; 2 alleles observed. Meglic and Staub, 1996

**sp** - _short petiole_. Leaf petioles of first nodes 20% the length of normal. _sp_ from Russian mutant line 1753. den Nijs and de Ponti, 1983

**sp-2** - _short petiole-2_. Leaf petioles shorter, darker green than normal at 2-leaf stage; crinkled leaves with slow development; short hypocotyl and stem; little branching. Not tested for allelism with _sp_. Wild type _Sp-2_ from 'Borszczagowski'; _sp-2_ from chemically induced mutation. Rucinska et al., 1992a

**ss** - _small spines_. Large, coarse fruit spines is dominant to small, fine fruit spines. _Ss_ from 'Spartan Salad', 'Wis. SMR 18' and 'GY 2 cp cp'; _ss_ from Wis. 2757. Fanourakis, 1984; Fanourakis and Simon, 1987

**T** - _Tall plant_. Tall incompletely dominant to short. Hutchins, 1940

**td** - _tendrilless_. Tendrils lacking; associated with misshapen ovaries and brittle leaves. _Td_ from 'Southern Pickler'; _td_ from a mutant of 'Southern Pickler'. Rowe and Bowers, 1965

**te** - _tender skin of fruit_. Thin, tender skin of some European cultivars; recessive to thick tough skin of most American cultivars. Poole, 1944; Strong, 1931

**Tr** - _Trimonoecious_. Producing staminate, perfect, and pistillate flowers in this sequence during plant development. _Tr_ from Tr-12, a selection of a Japanese cultivar belonging to the Fushinari group; _tr_ from H-7-25. MOA-309, MOA-303, and AH-311-3. Kubicki, 1969d

**Tu** - _Tuberculate fruit_. Warty fruit characteristic of American cultivars is dominant to smooth, non-warty fruits characteristic of European cultivars. Strong, 1931; Wellington, 1913 Andeweg, 1956; Poole, 1944

**u** _ uniform immature fruit color_. Uniform color of European cultivars recessive to mottled or stippled color of most American cultivars. Strong, 1931 Andeweg, 1956

**ul** - _umbrella leaf_. Leaf margins turn down at low relative humidity making leaves look cupped. _ul_ source unknown. den Nijs and de Ponti, 1983

**v** - _viresent_. Yellow leaves becoming green. Strong, 1931; Tkachenko, 1935

**vvi** - _variegated viresent_. Yellow cotyledons, becoming green; variegated leaves. Abul-Hayja and Williams, 1976

**w** - _white immature fruit color_. White is recessive to green. _W_ from 'Vaughan', 'Clark's Special', 'Florida Pickle' and 'National Pickling'; _w_ from 'Bangalore'. Cochran, 1938
<table>
<thead>
<tr>
<th>Trait</th>
<th>Description</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>wf</strong></td>
<td>White flesh. Intense white flesh color is recessive to dingy white; acts with <em>yf</em> to produce F₂ of 12 white (<em>Wf Yf</em> and <em>wf Yf</em>) : 3 yellow (<em>Wf yf</em>): 1 orange (<em>wf yf</em>). <em>Wf</em> from EG and G6, each being dingy white (<em>Wf Yf</em>); <em>wf</em> from 'NPL' which is orange (<em>wf yf</em>).</td>
<td>Kooistra, 1971</td>
</tr>
<tr>
<td><strong>wi</strong></td>
<td>Wilty leaves. Leaves wilting in the field, but not in shaded greenhouse; weak growth; no fruiting. Wild type <em>Wi</em> from 'Nishiki-suyo'; <em>wi</em> from M₂ line from pollen irradiation.</td>
<td>Iida and Amano, 1990, 1991</td>
</tr>
<tr>
<td><strong>Wmv</strong></td>
<td>Watermelon mosaic virus resistance. Resistance to strain 2 of watermelon mosaic virus. <em>Wmv</em> from 'Kyoto 3 Feet'; <em>wmv</em> from 'Beit Alpha'.</td>
<td>Cohen et al., 1971</td>
</tr>
<tr>
<td><strong>wmv-1</strong></td>
<td>Watermelon mosaic virus-1 resistance. Resistance to strain 1 of watermelon mosaic virus by limited systemic translocation; lower leaves may show severe symptoms. <em>Wmv-1</em> from Wis. 2757; <em>wmv-1</em> from 'Surinam'.</td>
<td>Wang et al., 1984, Provvidenti, 1985</td>
</tr>
<tr>
<td><strong>wmv-2</strong></td>
<td>Watermelon mosaic virus resistance. Expressed in the cotyledon and throughout the plant; <em>wmv-2</em> from TMG-1.</td>
<td>Wai et al., 1997</td>
</tr>
<tr>
<td><strong>wmv-3</strong></td>
<td>Watermelon mosaic virus resistance. Expressed only in true leaves; <em>wmv-3</em> from TMG-1.</td>
<td>Wai et al., 1997</td>
</tr>
<tr>
<td><strong>wmv-4</strong></td>
<td>Watermelon mosaic virus resistance. Expressed only in true leaves; <em>wmv-4</em> from TMG-1.</td>
<td>Wai et al., 1997</td>
</tr>
<tr>
<td><strong>wy</strong></td>
<td>Wavy rimed cotyledons. Wavy rimed cotyledons, with white centers; true leaves normal. Wild type <em>Wy</em> from 'Nishiki-suyo'; <em>wy</em> from M₂ line from pollen irradiation.</td>
<td>Iida and Amano, 1990, 1991</td>
</tr>
<tr>
<td><strong>yf</strong></td>
<td>Yellow flesh. Interacts with <em>wf</em> to produce F₂ of 12 white (<em>Wf Yf</em> and <em>wf Yf</em>): 3 yellow (<em>Wf yf</em>): 1 orange (<em>wf yf</em>). <em>Yf</em> from 'Natsufushinari', which has an intense white flesh (<em>Yf wf</em>); <em>yf</em> from PI 200815 which has a yellow flesh (<em>yf Wf</em>).</td>
<td>Kooistra, 1971</td>
</tr>
<tr>
<td><strong>yg</strong></td>
<td>Yellow-green immature fruit color. Recessive to dark green and epistatic to light green. <em>yg</em> from 'Lemon'.</td>
<td>Youngner, 1952</td>
</tr>
<tr>
<td><strong>yp</strong></td>
<td>Yellow plant. Light yellow-green foliage; slow growth.</td>
<td>Abul-Hayja and Williams, 1976</td>
</tr>
<tr>
<td><strong>ys</strong></td>
<td>Yellow stem. Yellow cotyledons, becoming cream-colored; cream-colored stem, petiole and leaf veins; short petiole; short internode. Wild type <em>Ys</em> from 'Borsczagowski'; <em>ys</em> from chemically induced mutation.</td>
<td>Rucinska et al., 1991</td>
</tr>
<tr>
<td><strong>zym-Dina</strong></td>
<td>Zucchini yellow mosaic virus resistance; <em>zym-Dina</em> from Dina-1.</td>
<td>Kabelka et al., 1997, Wai et al., 1997</td>
</tr>
</tbody>
</table>
zym- zymv *zucchini yellow mosaic virus resistance.* Inheritance is incomplete, but usually inherited in a recessive fashion; source of resistance is 'TMG-1'.

Provvidenti, 1987; Wai et al., 1997

W

Kabelka et al., 1997

W

z Asterisks on cultigens and associated references indicate the source of information for each.

y W = Mutant available through T.C. Wehner, cucumber gene curator for the Cucurbit Genetics Cooperative; P = mutants are available as standard cultivars or accessions from the Plant Introduction Collection; ? = availability not known; L = mutant has been lost.

* Isozyme nomenclature follows a modified form of Staub et al. (1985) previously described by Richmond (1972) and Gottlieb (1977).

Table 2. The cloned genes of cucumber and their function.\(^z\)

<table>
<thead>
<tr>
<th>Gene accession</th>
<th>Tissue source</th>
<th>Function</th>
<th>Clone type</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>X85013</td>
<td>Cotyledon cDNA library</td>
<td>Encoding a T-complex protein</td>
<td>cDNA</td>
<td>Ahnert et al., 1996</td>
</tr>
<tr>
<td>AJ13371</td>
<td>Cotyledon cDNA library</td>
<td>Encoding a matrix metalloproteinases</td>
<td>cDNA</td>
<td>Delorme et al., 2000</td>
</tr>
<tr>
<td>X15425</td>
<td>Cotyledon cDNA library</td>
<td>Glyoxysomal enzyme malate synthase</td>
<td>Genomic DNA fragment</td>
<td>Graham et al., 1989; 1990</td>
</tr>
<tr>
<td>X92890</td>
<td>Cotyledon cDNA library</td>
<td>Encoding a lipid body lipoxigenase</td>
<td>cDNA</td>
<td>Höhne et al., 1996</td>
</tr>
<tr>
<td>L31899</td>
<td>Senescing cucumber cotyledon cDNA library</td>
<td>Encoding an ATP-dependent phosphoenolpyruvate carboxykinase (an enzyme of the gluconeogenic pathway)</td>
<td>cDNA</td>
<td>Kim and Smith, 1994a</td>
</tr>
<tr>
<td>L31900</td>
<td>Cotyledon cDNA library</td>
<td>Encoding microbody NAD(+) dependent malate dehydrogenase (MDH)</td>
<td>cDNA</td>
<td>Kim and Smith, 1994b</td>
</tr>
<tr>
<td>L44134</td>
<td>Senescing cucumber cDNA library</td>
<td>Encoding a putative SPF1-type DNA binding protein</td>
<td>cDNA</td>
<td>Kim et al., 1997</td>
</tr>
<tr>
<td>U25058</td>
<td>Cotyledons</td>
<td>Encoding a lipoxygenase-1 enzyme</td>
<td>cDNA</td>
<td>Matsui et al., 1995; 1999</td>
</tr>
<tr>
<td>Y12793</td>
<td>Cotyledon cDNA library</td>
<td>Encoding a patatin like protein</td>
<td>cDNA</td>
<td>May et al., 1998</td>
</tr>
<tr>
<td>X67696</td>
<td>Cotyledon cDNA library</td>
<td>Encoding the 48539 Da precursor of thiolase</td>
<td>cDNA</td>
<td>Preisig-Muller and Kindl, 1993a</td>
</tr>
<tr>
<td>X67695</td>
<td>Cotyledon cDNA library</td>
<td>Encoding homologous to the bacterial dnaJ protein</td>
<td>cDNA</td>
<td>Preisig-Muller and Kindl, 1993b</td>
</tr>
<tr>
<td>X79365</td>
<td>Seedling cDNA library</td>
<td>Encoding glyoxysomal tetrafunctional protein</td>
<td>cDNA</td>
<td>Preisig-Muller et al., 1994</td>
</tr>
<tr>
<td>X79366</td>
<td>Seedling cDNA library</td>
<td>Encoding glyoxysomal tetrafunctional protein</td>
<td>cDNA</td>
<td>Preisig-Muller et al., 1994</td>
</tr>
<tr>
<td>Z35499</td>
<td>Genomic library</td>
<td>Encoding the glyoxylate cycle enzyme isocitrate lyase</td>
<td>Genomic gene</td>
<td>Reynolds and Smith, 1995</td>
</tr>
<tr>
<td>M59858</td>
<td>Cotyledon cDNA library</td>
<td>Encoding a stearoyl-acyl-carrier-protein (ACP) desaturase</td>
<td>cDNA</td>
<td>Shanklin and Somerville, 1991</td>
</tr>
<tr>
<td>M16219</td>
<td>Cotyledon cDNA library</td>
<td>Encoding glyoxysomal malate synthase</td>
<td>cDNA</td>
<td>Smith and Leaver, 1986</td>
</tr>
</tbody>
</table>

Genes involved in photosynthesis and photorespiration activities
<table>
<thead>
<tr>
<th>Accession</th>
<th>Library Type</th>
<th>Description</th>
<th>Gene Product</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>M16056</td>
<td>Cotyledon cDNA library</td>
<td>Encoding ribulose bisphosphate carboxylase/oxygenase</td>
<td>cDNA</td>
<td>Greenland et al., 1987</td>
</tr>
<tr>
<td>M16057</td>
<td>Cotyledon cDNA library</td>
<td>Encoding chlorophyll a/b-binding protein</td>
<td>cDNA</td>
<td>Greenland et al., 1987</td>
</tr>
<tr>
<td>M16058</td>
<td>Cotyledon cDNA library</td>
<td>Encoding chlorophyll a/b-binding protein</td>
<td>cDNA</td>
<td>Greenland et al., 1987</td>
</tr>
<tr>
<td>X14609</td>
<td>cotyledon cDNA library</td>
<td>Encoding a NADH-dependent hydroxypropyruvate reductase (HPR)</td>
<td>cDNA</td>
<td>Greenler et al., 1989</td>
</tr>
<tr>
<td>Y09444</td>
<td>Chloroplast genomic library</td>
<td>Chloroplast tRNA gene</td>
<td>Chloroplast DNA fragment</td>
<td>Hande and Jayabaskaran, 1997</td>
</tr>
<tr>
<td>X75799</td>
<td>Chloroplast genomic library</td>
<td>Chloroplast tRNA (Leu) (cAA) gene</td>
<td>Genomic DNA fragment</td>
<td>Hande et al., 1996</td>
</tr>
<tr>
<td>D50456</td>
<td>Cotyledon cDNA library</td>
<td>Encoding 17.5-kDa polypeptide of cucumber photosystem I</td>
<td>cDNA</td>
<td>Iwasaki et al., 1995</td>
</tr>
<tr>
<td>S69988</td>
<td>Hypocotyls</td>
<td>Cytoplasmic tRNA (Phe)</td>
<td>Cytoplasmic DNA fragment</td>
<td>Jayabaskaran and Puttaraju, 1993</td>
</tr>
<tr>
<td>S78381</td>
<td>Cotyledon cDNA library</td>
<td>Encoding NADPH-protochlorophyllide oxidoreductase</td>
<td>cDNA</td>
<td>Kuroda et al., 1995</td>
</tr>
<tr>
<td>D26106</td>
<td>Cotyledon cDNA library</td>
<td>Encoding ferrochelatase</td>
<td>cDNA</td>
<td>Miyamoto et al., 1994</td>
</tr>
<tr>
<td>U65511</td>
<td>Green peelings cDNA library</td>
<td>Encoding the 182 amino acid long precursor stellacyanin</td>
<td>cDNA</td>
<td>Nersissian et al., 1996</td>
</tr>
<tr>
<td>AF099501</td>
<td>Petal cDNA library</td>
<td>Encoding the carotenoid-associated protein</td>
<td>cDNA</td>
<td>Ovadis et al., 1998</td>
</tr>
<tr>
<td>X67674</td>
<td>Cotyledon cDNA library</td>
<td>Encoding ribulosebisphosphate carboxylase/oxygenase activase</td>
<td>cDNA</td>
<td>Preising-Muller and Kindl, 1992</td>
</tr>
<tr>
<td>X58542</td>
<td>Cucumber genomic library</td>
<td>Encoding NADH-dependent hydroxypropyruvate reductase</td>
<td>Genomic DNA fragment</td>
<td>Schwartz et al., 1991</td>
</tr>
<tr>
<td>U62622</td>
<td>Seedling cDNA library</td>
<td>Encoding monogalactosyl-diaclylglycerol synthase</td>
<td>cDNA</td>
<td>Shimojima et al., 1997</td>
</tr>
<tr>
<td>D50407</td>
<td>Cotyledon cDNA library</td>
<td>Encoding glutamyl-tRNA reductase proteins</td>
<td>cDNA</td>
<td>Tanaka et al., 1996</td>
</tr>
<tr>
<td>D67088</td>
<td>Cotyledon cDNA library</td>
<td>Encoding glutamyl-tRNA reductase proteins</td>
<td>cDNA</td>
<td>Tanaka et al., 1996</td>
</tr>
<tr>
<td>D83007</td>
<td>Cotyledon cDNA library</td>
<td>Encoding a subunit XI (psi-L) of photosystem I</td>
<td>cDNA</td>
<td>Toyama et al., 1996</td>
</tr>
</tbody>
</table>

**Genes expressed mainly in roots.**

<table>
<thead>
<tr>
<th>Accession</th>
<th>Library Type</th>
<th>Description</th>
<th>Gene Product</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB025717</td>
<td>Root RNA</td>
<td>Lectin-like xylem sap protein</td>
<td>cDNA</td>
<td>Masuda et al., 1999</td>
</tr>
<tr>
<td>U36339</td>
<td>Root cDNA library</td>
<td>Encoding root lipoxygenase</td>
<td>cDNA</td>
<td>Matsui et al., 1998</td>
</tr>
<tr>
<td>AB015173</td>
<td>Root cDNA library</td>
<td>Encoding glycine-rich protein-1</td>
<td>cDNA</td>
<td>Sakuta et al., 1998</td>
</tr>
<tr>
<td>AB015174</td>
<td>Root cDNA library</td>
<td>Encoding glycine-rich protein-1</td>
<td>cDNA</td>
<td>Sakuta et al., 1998</td>
</tr>
</tbody>
</table>

**Flower genes**

<table>
<thead>
<tr>
<th>Accession</th>
<th>Library Type</th>
<th>Description</th>
<th>Gene Product</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>AF035438</td>
<td>Female flower cDNA library</td>
<td>MADS box protein CUM1</td>
<td>cDNA</td>
<td>Kater et al., 1998</td>
</tr>
<tr>
<td>AF035439</td>
<td>Female flower cDNA library</td>
<td>MADS box protein CUM10</td>
<td>cDNA</td>
<td>Kater et al., 1998</td>
</tr>
<tr>
<td>D89732</td>
<td>Seedlings</td>
<td>Encoding 1-aminocyclo-propane-</td>
<td>cDNA</td>
<td>Kamachi et al.,</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Accession</th>
<th>Sample Type</th>
<th>Description</th>
<th>Type</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB003683</td>
<td>Seedlings</td>
<td>Encoding 1-aminocyclo-propane-1-carboxylate synthase</td>
<td>cDNA</td>
<td>1997</td>
</tr>
<tr>
<td>AB003684</td>
<td>Seedlings</td>
<td>Encoding 1-aminocyclo-propane-1-carboxylate synthase</td>
<td>cDNA</td>
<td>1997</td>
</tr>
<tr>
<td>AB035890</td>
<td>Fruit RNA</td>
<td>Encoding polygalacturonase</td>
<td>cDNA</td>
<td>1999</td>
</tr>
<tr>
<td>AF022377</td>
<td>Floral buds</td>
<td>Encoding agamous-like putative transcription factor (CAG1) mRNA</td>
<td>cDNA</td>
<td>1998</td>
</tr>
<tr>
<td>AF022378</td>
<td>Floral buds</td>
<td>Encoding agamous-like putative transcription factor (CAG2) mRNA</td>
<td>cDNA</td>
<td>1998</td>
</tr>
<tr>
<td>AF022379</td>
<td>Floral buds</td>
<td>Encoding agamous-like putative transcription factor (CAG3) mRNA</td>
<td>cDNA</td>
<td>1998</td>
</tr>
<tr>
<td>U59813</td>
<td>Genomic DNA</td>
<td>Encoding 1-aminocyclo-propane-1-carboxylate synthase Genomic DNA fragment</td>
<td></td>
<td>1997</td>
</tr>
<tr>
<td>X95593</td>
<td>Corolla cDNA library</td>
<td>Encoding carotenoid-associated protein</td>
<td>cDNA</td>
<td>1996</td>
</tr>
<tr>
<td>AB026498</td>
<td>Shoot apex RNA</td>
<td>Ethylene-receptor-related gene</td>
<td>cDNA</td>
<td>2000</td>
</tr>
</tbody>
</table>

**Genes involved in fruit development and maturation**

<table>
<thead>
<tr>
<th>Accession</th>
<th>Sample Type</th>
<th>Description</th>
<th>Type</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB010922</td>
<td>Fruit cDNA library</td>
<td>Encoding the ACC synthase</td>
<td>cDNA</td>
<td>1999</td>
</tr>
<tr>
<td>J04494</td>
<td>Fruit cDNA library</td>
<td>Encoding an ascorbate oxidase</td>
<td>cDNA</td>
<td>1989; 1990</td>
</tr>
<tr>
<td>AB006803</td>
<td>Fruit cDNA library</td>
<td>Encoding ACC synthase</td>
<td>cDNA</td>
<td>1998</td>
</tr>
<tr>
<td>AB006804</td>
<td>Fruit cDNA library</td>
<td>Encoding ACC synthase</td>
<td>cDNA</td>
<td>1998</td>
</tr>
<tr>
<td>AB006805</td>
<td>Fruit cDNA library</td>
<td>Encoding ACC synthase</td>
<td>cDNA</td>
<td>1998</td>
</tr>
<tr>
<td>AB006806</td>
<td>Fruit cDNA library</td>
<td>Encoding ACC oxidase</td>
<td>cDNA</td>
<td>1998</td>
</tr>
<tr>
<td>AB006807</td>
<td>Fruit cDNA library</td>
<td>Encoding ACC oxidase</td>
<td>cDNA</td>
<td>1998</td>
</tr>
<tr>
<td>AB008846</td>
<td>Pollinated fruit cDNA library</td>
<td>Corresponding genes preferentially expressed in the pollinated fruit</td>
<td>cDNA</td>
<td>1999</td>
</tr>
<tr>
<td>AB008847</td>
<td>Pollinated fruit cDNA library</td>
<td>Corresponding genes preferentially expressed in the pollinated fruit</td>
<td>cDNA</td>
<td>1999</td>
</tr>
<tr>
<td>AB008848</td>
<td>Pollinated fruit cDNA library</td>
<td>Corresponding genes preferentially expressed in the pollinated fruit</td>
<td>cDNA</td>
<td>1999</td>
</tr>
</tbody>
</table>

**Genes involved in cell wall loosening and cell enlargement**

<table>
<thead>
<tr>
<th>Accession</th>
<th>Sample Type</th>
<th>Description</th>
<th>Type</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB001586</td>
<td>Hypocotyl RNA</td>
<td>Encoding homologous to serine/threonine protein kinases (for CsPK1.1)</td>
<td>cDNA</td>
<td>1999</td>
</tr>
<tr>
<td>AB001587</td>
<td>Hypocotyl RNA</td>
<td>Encoding homologous to serine/threonine protein kinases (for CsPK1.2)</td>
<td>cDNA</td>
<td>1999</td>
</tr>
<tr>
<td>AB001588</td>
<td>Hypocotyl RNA</td>
<td>Encoding homologous to serine/threonine protein kinases (for CsPK2.1)</td>
<td>cDNA</td>
<td>1999</td>
</tr>
<tr>
<td>AB001589</td>
<td>Hypocotyl RNA</td>
<td>Encoding homologous to serine/threonine protein kinases</td>
<td>cDNA</td>
<td>1999</td>
</tr>
<tr>
<td>Accession</td>
<td>Type</td>
<td>Description</td>
<td>Journal References</td>
<td></td>
</tr>
<tr>
<td>-----------</td>
<td>-------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>-------------------------------------</td>
<td></td>
</tr>
<tr>
<td>AB001590</td>
<td>Hypocotyl RNA</td>
<td>Encoding homologous to serine/threonine protein kinases (for CsPK2.2)</td>
<td>Chono et al., 1999</td>
<td></td>
</tr>
<tr>
<td>AB001591</td>
<td>Hypocotyl RNA</td>
<td>Encoding homologous to serine/threonine protein kinases (for CsPK3)</td>
<td>Chono et al., 1999</td>
<td></td>
</tr>
<tr>
<td>AB001592</td>
<td>Hypocotyl RNA</td>
<td>Encoding homologous to serine/threonine protein kinases (for CsPK4.1)</td>
<td>Chono et al., 1999</td>
<td></td>
</tr>
<tr>
<td>AB001593</td>
<td>Hypocotyl RNA</td>
<td>Encoding homologous to serine/threonine protein kinases (for CsPK4.2)</td>
<td>Chono et al., 1999</td>
<td></td>
</tr>
<tr>
<td>U30382</td>
<td>Hypocotyl cDNA library</td>
<td>Encoding expansins</td>
<td>Shcherban et al., 1995</td>
<td></td>
</tr>
<tr>
<td>U30460</td>
<td>Hypocotyl cDNA library</td>
<td>Encoding expansins</td>
<td>Shcherban et al., 1995</td>
<td></td>
</tr>
</tbody>
</table>

**Genes induced or repressed by plant hormones**

<table>
<thead>
<tr>
<th>Accession</th>
<th>Type</th>
<th>Description</th>
<th>Journal References</th>
</tr>
</thead>
<tbody>
<tr>
<td>D49413</td>
<td>Hypocotyl cDNA library</td>
<td>Corresponding to a gibberellin-responsive gene encoding an extremely hydrophobic protein</td>
<td>Chono et al., 1996</td>
</tr>
<tr>
<td>AB026821</td>
<td>Seedling RNA</td>
<td>Encoding IAA induced nuclear proteins</td>
<td>Fujii et al., 2000</td>
</tr>
<tr>
<td>AB026822</td>
<td>Seedling RNA</td>
<td>Encoding IAA induced nuclear proteins</td>
<td>Fujii et al., 2000</td>
</tr>
<tr>
<td>AB026823</td>
<td>Seedling RNA</td>
<td>Encoding IAA induced nuclear proteins</td>
<td>Fujii et al., 2000</td>
</tr>
<tr>
<td>M32742</td>
<td>Cotyledon cDNA library</td>
<td>Encoding ethylene-induced putative peroxidases</td>
<td>Morgens et al., 1990</td>
</tr>
<tr>
<td>D29684</td>
<td>Cotyledon cDNA library</td>
<td>Cytokinin-repressed gene</td>
<td>Teramoto et al., 1994</td>
</tr>
<tr>
<td>D79217</td>
<td>Genomic library</td>
<td>Cytokinin-repressed gene</td>
<td>Genomic DNA fragment</td>
</tr>
<tr>
<td>D63451</td>
<td>Cotyledon cDNA library</td>
<td>Homologous to Arabidopsis cDNA clone 3003</td>
<td>Toyama et al., 1995</td>
</tr>
<tr>
<td>D63384</td>
<td>Cotyledon cDNA library</td>
<td>Encoding catalase</td>
<td>Toyama et al., 1995</td>
</tr>
<tr>
<td>D63385</td>
<td>Cotyledon cDNA library</td>
<td>Encoding catalase</td>
<td>Toyama et al., 1995</td>
</tr>
<tr>
<td>D63386</td>
<td>Cotyledon cDNA library</td>
<td>Encoding catalase</td>
<td>Toyama et al., 1995</td>
</tr>
<tr>
<td>D63387</td>
<td>Cotyledon cDNA library</td>
<td>Encoding lectin</td>
<td>Toyama et al., 1995</td>
</tr>
<tr>
<td>D63388</td>
<td>Cotyledon cDNA library</td>
<td>Encoding 3-hydroxy-3-methylglutaryl CoA reductase</td>
<td>Toyama et al., 1995</td>
</tr>
<tr>
<td>D63389</td>
<td>Cotyledon cDNA library</td>
<td>Encoding 3-hydroxy-3-methylglutaryl CoA reductase</td>
<td>Toyama et al., 1995</td>
</tr>
<tr>
<td>D63388</td>
<td>Cotyledon cDNA library</td>
<td>Encoding a basic region/helix-loop-helix protein</td>
<td>Toyama et al., 1999</td>
</tr>
</tbody>
</table>

**Resistance genes**

<table>
<thead>
<tr>
<th>Accession</th>
<th>Type</th>
<th>Description</th>
<th>Journal References</th>
</tr>
</thead>
<tbody>
<tr>
<td>M84214</td>
<td>Genomic library</td>
<td>Encoding the acidic class III chitinase</td>
<td>Lawton et al., 1994</td>
</tr>
<tr>
<td>M24365</td>
<td>Leave cDNA library</td>
<td>Encoding a chitinase</td>
<td>Metraux et al., 1989</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Accession</th>
<th>Description</th>
<th>Type</th>
<th>Notes</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>D26392</td>
<td>Seedling cDNA library</td>
<td>Encoding FAD-Enzyme</td>
<td>cDNA</td>
<td>Sano and Asada, 1994</td>
</tr>
<tr>
<td></td>
<td></td>
<td>monodehydroascorbate (MDA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>reductase</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X97801</td>
<td>Embryogenic callus cDNA library</td>
<td>MADS-box gene</td>
<td>cDNA</td>
<td>Filipecki et al., 1997</td>
</tr>
<tr>
<td>X03768</td>
<td>Genomic DNA</td>
<td>Satellite type I</td>
<td>Genomic DNA fragment</td>
<td>Ganal et al., 1986</td>
</tr>
<tr>
<td>X03769</td>
<td>Genomic DNA</td>
<td>Satellite type II</td>
<td>Genomic DNA fragment</td>
<td>Ganal et al., 1986</td>
</tr>
<tr>
<td>X03770</td>
<td>Genomic DNA</td>
<td>Satellite type III</td>
<td>Genomic DNA fragment</td>
<td>Ganal et al., 1986</td>
</tr>
<tr>
<td>X69163</td>
<td>Genomic DNA</td>
<td>Satellite type IV</td>
<td>Genomic DNA fragment</td>
<td>Ganal et al., 1988a</td>
</tr>
<tr>
<td>X07991</td>
<td>rDNA</td>
<td>Ribosomal DNA intergenic spacer</td>
<td>Genomic DNA fragment</td>
<td>Ganal et al., 1988b</td>
</tr>
<tr>
<td>X51542</td>
<td>Cotyledons</td>
<td>Ribosomal DNA intergenic spacer</td>
<td>Genomic DNA fragment</td>
<td>Zentgraf et al., 1990</td>
</tr>
</tbody>
</table>

2 Only the sequences published in both journals and the genebank database are listed.

**Literature Cited**


Fanourakis, N. E. 1984. Inheritance and linkage studies of the fruit epidermis structure and investigation of linkage relations of several traits and of meiosis in cucumber. Ph.D. Diss., Univ. of Wisconsin, Madison.


Poole, C. F. 1944. Genetics of cultivated cucurbits. J. Hered. 35:122-128.


