

Parents and Mating Systems Affect the Transfer of Gynoecious Flowering to Chinese Monoecious Cucumbers

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Abstract. Monoecious cucumber (*Cucumis sativus* L.) parents with high, medium, and low percentage of nodes with distillate flowers had a stronger effect on the percentage of gynoecious plants in F₁ and F₂ progenies than did degree of gynoecious expression in incompletely gynoecious parents. Highest percentages of gynoecious plants were obtained by using both gynoecious and monoecious parents with the highest level of distillate flowering tendency. According to our data, monoecious parents with a low percentage of distillate flowering nodes should be avoided when gynoeciousness is transferred to monoecious cultivars. Self-pollination of gynoecious F₂ plants, requiring induction of staminate flowers by chemical treatment, was more effective in obtaining a high percentage of gynoecious plants in F₂ progenies than selfing predominately gynoecious plants, or sibmating predominately gynoecious plants.

Monoecious plants of cucumber vary quantitatively in sex expression from predominately staminate to predominately distillate. Some monoecious lines produce staminate and distillate flowers throughout the growing season. Others produce staminate flowers at the base, followed by a mixture of staminate and distillate flowers, and then only distillate flowers (Kubicki, 1965, 1969a, 1969b, 1972; Shifriss, 1961).

Gynoecious plants bear only distillate flowers that are mostly solitary in the leaf axils of the main axis and side branches. The gynoecious character is not always complete or stable in cucumbers. In this report, "PG" will refer to plants or lines that produce predominately distillate flowers, while the term "gynoecious" will refer to completely distillate plants. Gynoecious cucumbers can be induced to produce staminate flowers, when necessary, by treatment with silver ions, such as from Ag (SO₃O₃)₂ (Den Nijs et al., 1980; Lower et al., 1978).

A challenge to breeders is development of stable gynoecious lines for use as parents in F₁ hybrids. The development of lines with various levels of distillate flowering stability may be accomplished by repeated selection and self-pollination of monoecious plants that are predominately pistillate. Selected gynoecious plants may be intercrossed or crossed with monoecious or other sex types and reselected to develop new parental lines. In any of these approaches, obtaining stable gynoecy is difficult because gynoecious sex expression of cucumber is conditioned by a gene *F*, subject to considerable influence from modifying genes and environmental factors (Cantliffe, 1981; Ito and Saito, 1957; Lower et al., 1975). The *F* gene interacts with alleles at the *a* and *m* loci, and the interaction produces, unless modified by genetic background or environment, monoecious (*m⁺m⁺F+F--*), androecious (*--F⁺F⁺aa*), hermaphroditic (*mmFF--*), and gynoecious (*m⁺m⁺FF--*) genotypes (Galun, 1961; Kubicki, 1969a, 1969c; Rosa, 1928; Shifriss, 1961; Tkachenko, 1935; Wall, 1967). The gene *F* may also be modified by an intensifier gene *In-F*, which increases femaleness (Kubicki,

1969b). Choice of gynoecious parents is an important consideration when developing or improving gynoecious lines. Therefore, a study was designed to determine the influence of the level of distillate flowering tendency in PG and monoecious lines and of mating systems on the efficiency of converting Chinese monoecious cucumber cultivars to the gynoecious condition.

Materials and Methods

The PG parents used in this study were segregating inbred lines having 43%, 67%, and 91% gynoecious plants in preliminary tests and arbitrarily designated LF, MF, and HF, respectively. In the experiments, gynoecious plants bore only distillate flowers on the first 15 nodes. Three Chinese cultivars were used as the monoecious parents. Their percentage of distillate flowering nodes among the first 15 nodes was 36, 46, and 54, respectively. They were designated as LN, MN, and HN (Table 1). Fruit length and fruit ridging were used as markers to help determine success in combining gynoeciousness with the typical Chinese slicer fruit traits.

All crosses were made in greenhouses. Field studies were conducted in 1987 on the research farm of SunSeeds Co., Brooks, Ore., using commercial cucumber production practices typical of the region, which included sprinkler irrigation when needed to maintain normal growth.

Effect of parental distillate flowering level. In this experiment, PG lines G19 (HF), G16 (MF), and G15 (LF) were crossed with monoecious parents M18 (HN), M3 (MN), and M2 (LN) to make nine F₁ combinations. The F₁ populations were arranged in a randomized complete-block design with two replications. Each plot contained 100 plants of one cross spaced 20 cm apart in rows 150 cm apart. The respective F₂ progenies were planted in an adjacent area with the same arrangement; except that a completely randomized design was used. From the time the flower buds could be identified through development of the 15th node plants were examined weekly and the sex of each flower bud on the first 15 nodes was recorded. Each plant was discarded after the first 15 nodes were observed. The per-

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Abbreviations: HF, high female; HN, high distillate flowering percentage; LF, low female; LN, low distillate flowering percentage; MF, medium female; MN, medium distillate flowering percentage.

Table 1. Designation, flowering type, and source of cucumber lines used as parents.

| Code | name | Percentage | | Class ^w | Source ^z |
|---------------|------|--|----|--------------------|---------------------|
| | | Type ^z (P F N ^y or G Y ^x) | | | |
| Chinese type | | | | | |
| M2-- | M | 36 | LN | NSCC, China | |
| M3-- | M | 46 | MN | NSCC, China | |
| M18 | M | 54 | HN | NSCC, China | |
| American type | | | | | |
| G15-- | PG | 43 | LF | SunSeeds | |
| G16-- | PG | 67 | MF | SunSeeds | |
| European type | | | | | |
| G19-- | PG | 91 | HF | SunSeeds | |

^aM = monoecious lines, PG = predominately gynoecious lines.

^bPFN = percentage of pistillate flowering nodes in monoecious parents.

^cGy = percentage of gynoecious plants in predominately gynoecious (PG) parents.

^dLN, MN, and HN = low, medium, and high percentage of female flowering nodes in monoecious parents. LF, MF, and HF = low, medium, and high percentage of gynoecious plants.

^eNSCC: Northern series of Chinese cucumbers.

centage of gynoecious plants was calculated from the weekly counts.

Effect of mating systems on transfer of gynoecy. The effect of mating systems on the occurrence of gynoeciousness in progeny generations was determined in F₃ families from F₂ progenies from the crosses G19 (HF) × M18 (HN), G16 (MF) × M18 (HN), and G15 (LF) × M18 (HN). Additionally, in the cross G19 (HF) × M18 (I-IN), the effect of mating system on recovery of gynoecious plants with Chinese slicer fruit type (long-ridged fruit) was determined. For each cross, we studied 15 F₃ families that were derived as follows: 1) five families from selfing PG F₂ plants, 2) five families from selfing (using chemical induction of staminate flowers) gynoecious F₂ plants, and 3) five families produced as half-sibs of gynoecious by sister PG F₂ plants. The F₃ families were grown in a split-plot experiment with crosses as unreplicated whole plots and mating systems as split-plot treatments with randomized replication of families within mating systems. The five families within each cross × mating system combination comprised five replications of mating systems.

The percentage of gynoecious plants in each family was determined weekly from the sex of the flowers at the first 15 nodes.

All data were transformed by arcsin square root because they were proportional.

Results and Discussion

Effect of parental distillate flowering level. The monoecious parent had a significant influence, at $P = 0.01$, on the percentage of gynoecious F₁ plants. However, the effect of degree of femaleness in the PG parent was not significant. There was no interaction between PG and monoecious parents. Means for HN, MN, and LN were different for each gynoecious parent (Table 2), and overall (column) means were significantly different. The dominant influence of the monoecious parent was evident, since the percentage of gynoecy was low (near 0%) in F₁ progeny when the LN parent was used, regardless of the PG parent used,

The level of distillate flowering of both the monoecious and

Table 2. Effects of levels of female flowering in predominately distillate and monoecious parents on the percentage of gynoecious plants in F₁ and F₂ progenies.

| Pistillate ^a flowering parent | Monoecious parent ^b | | | | | | | |
|--|-------------------------------------|--------|-------|------|-------------------------------------|---------|---------|--------|
| | F ₁ progeny ^c | | | | F ₂ progeny ^d | | | |
| | HN | MN | LN | Mean | HN | MN | LN | Mean |
| HF | 32.0 a | 11.0 b | 2.2 c | 15.1 | 36.9 ap | 32.0 ap | 21.0 ap | 30.0 P |
| MF | 32.2 a | 6.0 b | 0.6 c | 13.0 | 35.6 ap | 30.2 ap | 19.8 bp | 28.5 P |
| LF | 21.4 a | 6.9 b | 0.9 c | 9.7 | 29.5 aq | 17.7 bq | 12.8 bp | 20.0 Q |
| Mean | 28.5 a | 8.0 b | 1.3 c | | 34.0 a | 26.6 b | 17.9 c | |

^aHF, MF, and LF indicate high, medium, and low degrees of female expression in predominately distillate (PG) flowering parents.

^bHN, MN, and LN indicate high, medium, and low percentage of distillate flowering nodes in monoecious parents.

^cMean separation within rows (a, b, c) by LSD ($P = 0.05$) derived from arcsin-transformed data. The effects of pistillate flowering (PG) parent (within columns) were nonsignificant.

^dMean separation within rows (a, b, c) at $P = 0.05$. Mean separation within columns (P, Q) at $P = 0.05$.

gynoecious parents had a significant ($P = 0.01$) influence on the percentage of gynoecious plants in the F₂ generation. There was no interaction of PG parent with monoecious parent. The overall mean effects (column means) of the three monoecious parents were significantly different, with the highest percentage of gynoecious plants occurring when the HN parent was used (Table 2). Not all the differences from the influence of the three PG parents were significant. The overall means for gynoecious parent effects (row means) were the same for HF and MF. The percentage of gynoecious plants was significantly reduced when the LF parent was used in the crosses (Table 2).

The results shown in Table 2 indicate the importance of selecting the highest possible level of gynoecious sex expression in both PG and monoecious parents for production of gynoecious hybrids, or to provide F₂ populations for selection of gynoecious lines. Use of LF parents should be avoided. Each parent appeared to influence the percentage of gynoecious progeny plants independently; so that the highest level of gynoecious flowering tendency was achieved by use of HF and HN parents.

Effect of mating systems on transfer of gynoecy. In all three crosses and in the overall mating system means from the three crosses, families derived from selfed gynoecious F₂ selections (System C) were significantly higher in percentage of gynoecious plants than families obtained by selfing PG F₂ plants (System B), or families derived from half-sib-mating gynoecious plants with PG sister selections (System A) (Table 3). Values obtained from Systems A and B did not differ at $P = 0.05$. Due to the sensitivity of sex expression in cucumber, some F₂ plants may have been selected in error as PG or gynoecious plants because they were modified by environmental factors. This error could have led to higher variability in the percentage of gynoecious plants among tested families.

There was a trend among the crosses for the HF, MF, and LF parents to result in higher, intermediate, and lower percentages of gynoecious plants, respectively (Table 3), but the differences among crosses could not be properly tested statistically because crosses were not replicated. There was no interaction between crosses and mating systems.

Of the three crosses shown in Table 3, only HF (G19) × HN (M18) resulted in F₂ segregation for both levels of gynoecy and presence or absence of the Chinese monoecious cucumber character long-ridged fruit. The effect of mating systems on percentage of gynoecious plants with long-ridged fruit in F₃ families

Table 3. Effect of mating systems on the percentage of F₃ plants in F₄ families.

| Cross ^y | Percentage of gynoecious plants | | | |
|---------------------|--|--------------------|--------------------|----------------|
| | Mating systems ^z | | | Mean |
| | A | B | C | |
| HF (G19) × HN (M18) | 53.4 a ^x (40.5 a) ^w | 59.4 a (34.0 a) | 93.3 b (72.2 b) | 68.7 (48.9) |
| MF (G16) × HN (M18) | 52.9 a | 52.4 a | 77.9 b | 61.1 |
| LF (G15) × HN (M18) | 41.6 a | 45.5 a | 64.4 b | 49.2 |
| Mean | 49.3 a | 51.1 a | 78.6 b | |

^zA, Half-sib-mating: Gynoecious, plants pollinated by predominately distillate (PG) sisters. B, Self: Selected predominately distillate (PG) plants selfed with pollen from their own staminate flowers. C, Induced self: Gynoecious plants selfed with pollen from silver ion-induced staminate flowers.

^yHF, MF, and LF = high, medium, and low levels of distillate flowering in PG lines. HN = monoecious lines with high percentage of distillate flowering nodes.

^wMean separation within rows by LSD $P = 0.05$, derived from arcsin-transformed data. Means within columns were not tested because crosses were not replicated.

^{*}Percentage of gynoecious plants with long-ridged fruits typical of Chinese monoecious cucumbers. Only cross HF (Gy 19) × HN (M18) produced segregation for long-ridged fruit.

from this cross (Table 3, in parenthesis) was significant at $P = 0.01$. The percentage of gynoecious plants with long-ridged fruit produced by mating systems A (gynoecious plants pollinated by PG sisters) and B (selfed PG plants) was not different. A significantly higher percentage of gynoecious plants with long-ridged fruit were produced by mating system C (selfed gynoecious plants). The ratio of percentage of gynoecious plants with long-ridged fruit: total percentage of gynoecious plants for mating systems A, B, and C, respectively, was 0.76, 0.57, and 0.77. These values suggest that the mating system effect on percentage of gynoecious plants with long-ridged fruit is, mostly, just a reflection of differences in total percentage of gynoecious plants resulting from these "mating systems."

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