AN ABSTRACT OF THE THESIS OF

Qi Zhang   for the degree of   Master of Science

in Horticulture   presented on April 11, 1989

Title: THE INFLUENCE OF PARENTS, MATING SYSTEMS AND

PLANTING DATE ON THE TRANSFER OF GYNOECIOUS FLOWERING TO

CHINESE CUCUMBERS (CUCUMIS SATIVUS L.).

Abstract approved:_____

Dr. A. C. Gabert   and

_____

Dr. J. R. Baggett

Gynoecious inbred lines of cucumbers (Cucumis sativus
L.) with high (HF), medium (MF) and low (LF) percentage of
gynoecious plants were used in crosses with monoecious
Chinese cultivars with high (HN), medium (MN) and low (LN)
percentage of nodes with female flowers. F_1 and F_2 progenies
from these parents crossed in all combinations were studied
to determine the effect of levels of female flowering
expression of gynoecious and monoecious parents on the
percent gynoecious plants. The effect of mating systems on
percent gynoecious plants and percent gynoecious plants with

Chinese cucumber characters, wart-spine and long fruit, was studied in F_3 families from crosses of HF, MF, and LF gynoecious lines with an HN monoecious parent. The effect of planting date on percent gynoecious plants recovered was studied in the F_2 progenies of an HF gynoecious line crossed with Taishan, an MN monoecious cultivar. Level of female flowering tendency, expressed by percentage of female flowering nodes, in the monoecious parents had a much greater effect on the percentage of gynoecious plants in the F_1 and F_2 generation than did the degree of female flowering in the gynoecious parents. The effect of the gynoecious parent and the interaction of gynoecious X monoecious parent on percent gynoecious plants in the F_1 were non significant.

In the mating system study, self pollination of selected completely gynoecious plants, requiring male flowering induction by chemical treatment, was significantly more effective in obtaining highly gynoecious progeny lines than selfing predominately gynoecious plants or sib-mating predominately gynoecious and completely gynoecious plants. There was no interaction between mating system and level of female flowering in the gynoecious parents.

Planting date did not affect the percent of plants producing male flowers during the entire growing period, but early planting produced fewer plants with male flowers during the first half of their respective growing period

than late plantings. By the end of the season, early and late planting were about equal in percentage of gynoecious plants, because a higher percentage of plants in the early plantings reverted from gynoecious to monoecious flowering during the last half of the growth period.

The Influence of Parents, Mating Systems, and Planting
Date on the Transfer of Gynoecious Flowering to Chinese
Cucumbers (Cucumis sativus L.)

by

Qi Zhang

A THESIS

Submitted to

Oregon State University

in partial fulfillment of

the requirements for the

degree of

Master of Science

Completed April 11, 1989

Commencement June, 1989

APPROVED:

_____

Professor of Horticulture in Charge of Major

_____

Professor of Horticulture in Charge of Major

_____

Head of Department of Horticulture

_____

Dean of Graduate School

Date thesis is presented___ April 11, 1989

ACKNOWLEDGEMENTS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES

LIST OF APPENDIX TABLES

THE INFLUENCE OF PARENTS, MATING SYSTEMS, AND PLANTING DATE ON THE TRANSFER OF GYNOECIOUS FLOWERING TO CHINESE CUCUMBERS (<u>CUCUMIS</u> <u>SATIVUS</u> L.)

Introduction

The development of gynoecious (all female) inbreds and hybrids in cucumber is of considerable commercial interest and has received increasing attention from cucumber breeders worldwide. The main reason is that the utilization of gynoecious lines in hybrid production can reduce the expenditure of manpower and time used in routine emasculation and pollination, and consequently reduces the cost of producing F_1 seeds. Gynoecious inbreds can be obtained by repeated selection and self pollination of predominantly gynoecious plants from a monoecious population with strong gynoecious tendency. New gynoecious inbreds also can be developed by crossing selected gynoecious plants with each other or with plants of other sex types. Unfortunately, it is difficult to get stable gynoecious lines due to the sensitivity of sex expression to environmental factors. Little is known about the specific effects of environments in the broad sense on sex expression of cucumber, although some reasonable hypotheses and interpretations have been advanced.

Chinese , American and European cucumbers have evolved separately in different environmental conditions. However,

there are no differences in their characteristics or
systematic botany. The Northern Series of Chinese cucumbers
(NSCC) used in this study are characterized by strong growth
potential, long fruit with large ridges and coarse-spines,
and low percentage of female nodes on the plants. In this
series, gynoecious plants or inbreds are hard to establish
by selection in an original cultivar population, but easy to
obtain by crossing with gynoecious inbreds such as those
existing in American and European type cucumbers.

The objective of this study was to estimate the effects
of the female flowering tendencies of parents, planting
dates, and mating systems on the transfer of the gynoecious
character from American and European gynoecious inbreds to
Chinese monoecious cultivars.

Literature Review

<u>Sex Expression in Cucumber</u>

In cucumber (<u>Cucumis</u> <u>sativus</u> L.), there is a greater
diversity of true breeding sex type than in any other
species of flowering plants which have been studied (2). The
many types of sex expression reported include monoecious,
female or gynoecious (F), gynomonoecious, androecious (A),
andromonoecious, hermaphroditic (H) and trimonoecious (1, 2,
10). The predominant type is monoecious, which bears
staminate and pistillate flowers on the same plants (1,2).
Monoecious cultivars differ in sex expressivity with
quantitative variations ranging from almost male to
predominantly gynoecious individuals (9,11). Kubicki(1965)
reported that the male to female flower ratio may range
between 3 and 20. Some monoecious lines produce male and
female flowers throughout the entire growing season. Others
produce male flowers at the base followed by a mixture of
male and female flowers and then only female flowers(79, 3,
4). This gradient is particularly striking along the main
stem. The branches always reach the terminal phase sooner
than the main stem and some branches are entirely female
(9). Most of the NSCC cultivars, such as, Chang chun Mici
and Yeersan , only have the " mixed flower stage ". These
cultivars are considered normal monoecious types (2, 88).

Gynoecious plants bear only pistillate flowers (1, 2) that appear, mostly solitary, in the leaf axils of the main axis and the side branches. They are sometimes inhibited in the first few nodes of the main axis (2). Gynoecious plants first were found in a group of Japanese and Korean cultivars, e.g., Shoigon, Kurume, Seoul Mady, Black Pearl, and Chung Yup in the 1950's (9). Due to the advantages of femaleness in F_1 hybrids, gynoecious line breeding is greatly emphasized in many countries. There are many ways of obtaining desirable gynoecious inbreds: 1.) by repeated selection and self pollination; 2.) by international exchange; 3.) by transference from other gynoecious lines or stocks (50). However, there is a general feeling in breeding and commercial production that the gynoecious characteristic is unstable and that hybrids made with gynoecious inbreds do not perform uniformly with regard to sex expression and yield (53).

Androecious plants are those which only have male flowers (1). It rarely occurs in natural populations. Mieszczerow (1961) reported finding a male specimen in glasshouse varieties grown in a high temperature and high humidity environment. Reproduction of the androecious lines is a problem and its use is therefore limited. In 1966, two male plants of an F_2 generation produced single pistillate flowers after treatment with indoleacetic acid (IAA) by Kubicki (6). Androecious lines may be maintained by

treatment with ethephon to induce pistillate flowers (42).
It was discovered that hybrids with androecious pollen
parents were consistently more female than 3-way hybrids
derived from the same F_1 seed parents crossed with either
androecious or monoecious pollen parents. Hybrids derived
from androecious pollen parents were as highly female, or
more so, than hybrids derived from monoecious pollen parents
(42). Therefore, they speculated that the use of androecious
instead of monoecious pollen parents would increase the
yields of hybrid seed.

Hermaphroditic plants are those which bear only perfect
flowers (1). This type of cucumber has clustered or solitary
bisexual flowers in each leaf axil (12, 13). The true
hermaphrodite and its mixed types, such as gynomonoecious
(bearing pistillate and perfect flowers on the same plants),
andromonoecious (staminate and perfect flowers), and
trimonoecious (staminate, pistillate, and perfect flowers),
are rarely present in natural populations. Only two
andromonoecious varieties, " Hitheto" and "Lemon " were
known prior to 1965(12, 13). In the past several years, "
Crystal Apple ", Polish breeding lines from Kubicki, and
other hermaphrodites have been developed by selection
followed by crossing, backcrossing and selfing. In spite of
recent progress, there still are not many hermaphroditic
inbreds. However, the possibility of using hermaphrodites as
pollinators for producing gynoecious parents has been

advanced . Staub found that progeny of F X H hybrids was more stable than those from F X A hybrids. He suggested that increased quality and yield of cucumber hybrids can be obtained by using gynoecious and bisexual parents (52).

Inheritance of Sex Expression

Since genetic studies of sex expression in cucumber have been conducted by researchers in various times and countries, the state of symbols used for sex expression genes is chaotic. Different investigators have used the same symbols for different genes. In some cases the same gene has been given several different symbols and in other cases a symbol has not been assigned (1). in 1976, Robinson and Munger et al, were requested by the vegetable Breeding and Varieties Committee of the American Society of Horticulture Science to resolve this problem. They designated F as the female gene to replace Acr (9), acr^F (10, 12), st (2), and D (90); In-F (an intensifier of female sex expression) for F (5); m (andromonoecious gene) for a (92) and g (9); m_2 (andromonoecious-2) for h (94); gy (a recessive allele of gynoecious) for g (93); and a for the androecious gene. The gene symbols used in this paper will be those assigned by Robinson and Munger et al.

Sex expression in cucumber is subject to both genetic and non-genetic variations. Shfriss indicated that in a genetic background conditioning a relatively weak male tendency, the four basic sex forms behaved in inheritance as fairly stable qualitative characters.These characteristics are associated with the following genes:

Gynoecious-------$\underline{F}$, $\underline{m}^+$

Hermaphroditic---$\underline{F}$, $\underline{m}$

Monoecious-------$\underline{F}^+$, $\underline{m}^+$

Andromonoecious--$\underline{F}^+$, $\underline{m}$

$\underline{F}$, associated only with gynoecious, functions as accelerator. Genes $\underline{m}^+$ and $\underline{m}$ are alleles governing the potentialities for pistillate and perfect flowers, respectively (1, 9, 49). Galun (2) reported that the two major genes $\underline{m}$ and $\underline{F}$, a complex of polygenes, and some non-genetic factors controlled sex expression in Cucumber. The gene $\underline{F}$ affects sex by inducing a shift of the flowering pattern toward the base of the plant. As this pattern is composed of a staminate stage followed by a mixed (staminate-pistillate) stage and a pistillate stage, a double dose of $\underline{F}$ will induce a change from normal monoecious sex expression to absolute gynoecious. The second major gene studied, $\underline{m}$, known previously to control sex in the individual flower ($\underline{m/m}$-andromonoecious, $\underline{m}^+$-monoecious), also interacts with factors affecting the flowering pattern by inducing male tendency. He assumed: 1.) stamens and pistils

are controlled by different amounts of certain substances.
2.) The plant supplies these substances to flower buds in
different amounts during ontogeny. 3.) A mutation occurred
($\underline{m}$--$\underline{m}^+$), producing a trigger mechanism permitting in each
flower primordium the development of either stamens or
pistil (2).

Kubicki suggested there are multiple alleles at the $\underline{F}$
locus. He established that different gynoecious inbred lines
differ in their degree of female sex expression, but this
may be due to genetic background differences as well as to
multiple allelism. His data indicate, at least in certain
crosses, that monoecious lines may differ for a single gene
for production of only pistillate flowers vs. production of
both staminate and pistillate flowers continuously. He
suggested this gene is at the $\underline{F}$ locus, and postulated a
single major gene that interacts with In-F and increases
female sex expression. A new recessive gynoecious form of
cucumber was obtained by Kubicki by induced mutations. This
gynoecious type is conditioned by a single recessive gene
designated by the symbol $\underline{gy}$, which is linked to $\underline{F}$ and
intensifys the effect of $\underline{F}$ (7). The interaction of alleles
at the $\underline{m}$ and $\underline{F}$ loci produces, unless modified by genetic
background or environment, is $\underline{++}$--monoecious, $\underline{+F}$--
gynoecious, $\underline{m}^+$--andromonoecious, and $\underline{mF}$--hermaphroditic.

Genetic analysis by Kubicki (6) of crosses between male
and female plants by Kubicki (6) have shown maleness to be

conditioned by a single recessive gene a, which only expresses its effect in the presence of F^+. Gene F, was found to be hypostatic. Plants with a genotype of F^+F^+aa are androecious, while plants with a genotype of FFaa are gynoecious. Heterozygote FF^+aa may also develop into gynoecious plants.

In view of the previous studies, Lower and Edwards (49) indicated that sex expression in cucumber is under the control of at least three major loci:

1. m^+, m Governs the specificity of the stimulus to develop primordial staminate and pistillate flower parts.homozygote for the m allele exhibit nonspecific developments, resulting in hermaphroditic flowers. m^+/- genotypes are strictly diclinous.

2. F^+, F Controls the degree of female tendency. The F allele is partially dominant and intensifies female expression. The locus is apparently subject to strong environmental influence and background genetic modification.

3. a^+, a Homozygote for the a allele intensify male tendency. The effects of this locus are subordinate to the F locus (hypostatic to F), and so male intensification is contingent upon F^+/F^+. The genotypes m^+/-, F^+/F^+, a/a and m/m, F^+/F^+, a/a are typically androecious.

The combinations of genotypes at these loci can yield the following basic sex types:

Phenotype	Loci and Genotype		
	m	F	a
Androecious	-/-	F^+/F^+	a/a
Monoecious	m^+/m^+	F^+/F^+	-/-
Hermaphroditic	m/m	F/F	-/-
Gynoecious	m^+/m^+	F/F	-/-

Although the interpretation of sex expression in cucumber seems to be reasonable, part of the difficulty in specifying the source(s) and degree(s) of genetic influence(s) in control of sex expression lies in the extreme instability of sex type of cultivars grown in different environments (49).

Inheritance of Two Marker Characteristics

Fruit shape Many genes influence fruit shape. Lines homozygous for monoecious sex type (ff) and/or indeterminate growth habit had greater fruit length (26). Fruit shape is considered to be a quantitative character. Long fruit is dominant to short fruit (50).

Spines and tubercles Fruit of NSCC has larger than normal tubercles (warts) projecting from the fruit surface and have

white spines on the tops of the tubercles (88). Number and size of fruit spines are pleiotropic or completely linked (101). Spine fineness and spine frequency are likely to be the pleiotropic expression of the same gene since no crossovers have been reported and both affect the same morphological structure.

Most NSCC cultivars differ from Western cultivars for a gene Tu (101,102), that controls the development of tubercles on immature fruit. Tu is modified by an intensifying gene. Warty and large spine are dominant over non-warty and fine spined characteristics(50).

The Role of Environmental Factors in
Sex Expression of the Cucumber

Environmental factors such as temperature (18, 85, 86, 72), photoperiod (24, 25), light intensity (18), chemicals (14, 23), seasonal and climatic change (78), and mechanical stress (22, 58), have considerable influence on the sex expression in cucumber even though it is controlled by a three-locus mendelian system.

Change of sex expression in cucumber following seasonal change was reported by Scott (78). During summer days plants of some varieties have more male flowers and during winter days plants have more female flowers (78). The effect of

seasonal change on sex expression in cucumber could be attributed to the complex influence of temperature, light and other factors. Tiedjiens (103) found that pistillate flowering in monoecious cucumber was favored by low light intensity and short photoperiod. An interaction of short days and cool nights favors formation of more pistillate flowers (71, 72, 80, 85, 86, 104). However, Lower et al. (105) observed that photoperiod and temperature had no influence on flowering of a completely gynoecious cultivar. More recently, Canliffe observed that more staminate flowers were produced under 17,200 lux light intensity than 8,600, 12,900, or 25,800 lux. Pistillate flowering appeared to be quantitatively controlled by light intensity; generally increasing with increased intensity from 12,900 to 25,800 lux. Many cultivars had a higher proportion of pistillate flowers at one or both of the 2 higher intensities. Altering the length of the photoperiod or red and far-red light exposure at the end of the light period had no influence on sex expression. The largest number of pistillate flowers reached anthesis at 26° or 30° C. Temperature influenced sex expression more than light intensity or photoperiod (18).

Previous reports on the effects of physical factors on the sex expression in cucumber indicate that pistillate sex expression is promoted in monoecious cultivars by conditions which reduce the plant growth rate. More staminate flowers form under conditions that favor rapid

growth. Ito and Saito observed that the first female flower differentiates on a lower node after stem pinching and lower nitrogen application (81, 84, 86). Increasing plant density reduced the percentage of pistillate nodes/plant and the percentage of gynoecious plants in both gynoecious inbreds and in their hybrids. Hybrids with one gynoecious parent and one monoecious parent were the least stabile for pistillate flowering under conditions of environmental stress (18, 53). Inadequate fertilization did not affect the sex expression, but sand culture can produce changes in sex expression (12).

Role of some chemicals in sex expression

1. Effects of ethylene, auxin and 1-aminocyclopropane-1-carboxylic acid (ACC). Sex expression of cucumber is influenced not only by environmental factors such as daylength, light intensity and temperature etc., but also by growth regulators. Ito and Saito (85) reported that female flower formation of cucumber was hastened by NAA, IAA and 2,4-D, with NAA the most effective (82). Endogenous and exogenous auxins are associated with female tendency of cucumber plants (55, 75, 82, 83,). Ethylene in plant tissue also enhances gynoecious flowering (106). Takahashi and Jaffe concluded that ethylene is a major factor regulating feminization and that exogenous auxin induces pistillate

flower formation through its stimulation of ethylene production (61).

2. Effects of gibberellic acids ($GA_{3/7}$), silver ion and other chemicals. Hybrid cucumbers from crosses of gynoecious and monoecious lines are rapidly replacing open-pollinated cultivars. The technique for producing seed of the inbred gynoecious parent using gibberellic acids ($GA_{3/7}$) and silver ion to induce staminate flowers on gynoecious plants has been reported (33, 38, 39, 44, 51, 54, 109, 110). However in commercial seed production of a gynoecious parent line, GA frequently fails to induce large numbers of staminate flowers on all gynoecious plants treated.

$AgNO_3$ is much more effective for staminate flower induction in gynoecious cucumbers than GA (39, 55). Silver thiosulphate ($Ag(S_2O_3)_2$) also is effectively used for inducing male flowering of a gynoecious parent line, and its effective concentrations have not shown deleterious side-effects like those of $AgNO_3$ if treated plants are in poor growing conditions. Even very strongly female lines can be induced to male flowering with silver ions. This increases the feasibility of large scale seed production of gynoecious x gynoecious cucumber hybrids (38, 55).

Sex determination in cucumbers is thought to be controlled by a balance between auxin and gibberellin. Current theory holds that auxin exerts its effect by controlling the ethylene production rate (107). The silver

ion is a potent inhibitor of ethylene action (51, 38). Other anti-ethylene compounds were evaluated for their potential to induce staminate flowers on gynoecious cucumber. Aminothoxyvinylglycine (AVG) and Phthalimid have been shown to inhibit ethylene production and induce significant staminate flower formation on gynoecious cucumber (14, 36, 38). However, the fundamental basis of the action of ethylene and anti-ethylene compounds on sex expression in cucumber still remain an enigma.

Breeding for and Maintaining High Gnoeciousness

Gynoecious plants are reproducible by the action of some chemicals which stimulate the formation of male flowers. Self-pollination and reproduction of gynoecious plants in the form of pure lines is possible (3, 49). After gynoecious plants are obtained from a natural cultivar population or progenies of a hybrid, they can be treated with GA, $AgNO_3$ or $Ag(S_2O_3)_2$ and selfed with the induced male flowers. The percent of gynoecious plants continues to increase in successive generations until pure gynoecious lines are established (3, 49, 50). Plants with few male flowers (predominantly female plants) in monoecious cultivar populations can also be selected, selfed and stablized for femaleness (50).

Another approach to breeding for gynoecious is to combine sib-mating and selfing . The gynoecious plants can

be sib-mated with predominantly gynoecious plants during the earlier generations and the selected gynoecious inbreds can be selfed during the later generations with the induced male flowers (50).

The maintenance of gynoecious in cucumber is carried out by continuously selfing with the induced male flowers. Roguing of monoecious segregates during increases of gynoecious lines is important both for the development of stable inbreds and the maintenance of sex expression purity in established inbreds. Artificially stressing gynoecious lines has also been suggested as a means of more stringent selection for stability. Cultivation at high density under high temperatures and long days (such as broadcasting seed in a flat in a summer greenhouse environment) strongly promote male tendencies and may allow considerable selection pressure for gynoecious stability (49).

To retain the stability of gynoecious lines, pollination must be done under the controlled conditions. Female and induced male flower buds may be clipped prior to opening in fields. Gynoecious plants treated with chemicals for male flowers may be sown under screen or in greenhouses where the plants are pollinated by bees or by man.

Materials and Methods

All field phases of this research were done on the research farm of Sunseeds Company at Brooks, Oregon. General cultural methods were those used by Sunseeds and were similar to the commercial practices used in the area. Irrigation was by overhead sprinkler.

The greenhouse phases of the study were done in the research greenhouse of Sunseeds, also at Brooks, Oregon.

Four monoecious cultivars from the Northern Series of Chinese cucumber, plus two American and one European gynoecious inbreds were chosen as parents in this study. The Chinese cultivars were M2(name unknown), M3(Ningyang), M18(Third Leaf) and M21(Taishan). The gynoecious parents were G15, G16 and G19(female inbreds). These seven parental types differ genetically, not only in gynoecious expression, but also in growth potential of plants, fruit shape, wartiness, spines and other characteristics. Pedigree, flowery type, and source of each parent are listed in Table 1. Seeds of each cultivar were obtained from Dr. August Gabert of Sunseeds Company. G15, G16 and G19 are proprietary inbred lines of Sunseeds Company.

All parents were planted in the field of the Sunseeds Company in the summer, 1986 to make preliminary observation of flowering habit and related characteristics (Table 2).

Table 1. Pedigree, flowering type and source of cucumber
parents

Code	Name	Pedigree	Type	Source[z]
Chinese Type				
M2	--	23B-113-B	Monoecious	NSCC, China
M3	--	23B-114-A	Monoecious	NSCC, China
M18	Third leaf	23B-579	Monoecious	NSCC, Liaoning
M21	Taishan	23B-118	Monoecious	NSCC, Shandong
American Type				
G15	--	23B X 527-R	Seg. Gy.	Sunseeds
G16	--	23B X 705	Seg. Gy.	Sunseeds
European Type				
G19	--	23B-116	Female inbred	Sunseeds

[z] NSCC: Northern Series of Chinese Cucumbers

Table 2. Female flowering tendency and related
characteristics of cucumber parents

Parents		Female tendency		Fruit	
Code	Designation[z]	% female nodes[y]	% gynoecious[x]	L/D [w]	S W[v]
M2	LN	36	--	8.0	S+W
M3	MN	46	--	8.0	S+W
M18	HN	54	--	8.5	S+W
M21	HN	73	--	4.1	S+W
G15	LF	--	43	7.0	S
G16	MF	--	67	3.1	S
G19	HF	--	91	8.5	none

[z] LN, MN, and HN = low, medium, and high percent of female
flowering nodes, respectively, in monoecious parents.
LF, MF, and HF = low, medium, and high percent of
gynoecious plants, respectively, in gynoecious parents.

[y] Female flowering tendency expressed as percent female
flowering nodes on monoecious plants.

[x] Percent gynoecious plants in gynoecious inbreds.

[w] Fruit shape expressed as ratio of length / diameter.

[v] Presence of spines(S) or warts(W).

Crosses between the American gynoecious inbreds and Chinese monoecious cultivars were made in the summer of 1986 in the field. In successive generations, plants were grown in the greenhouse during the fall, winter and spring, and in the field during the summer months of 1987 and 1988.

Three studies were conducted in the earlier generations during the process of transferring the gynoecious character to Chinese cucumber.

Study I

This experiment began by crossing three Western gynoecious inbreds with three Chinese monoecious cultivars in the greenhouse during the summer of 1986. A factorial experiment was used and two groups of parents were designated as main variables. Each cultivar group was divided into three levels of female flowering expression. These were high (HF), medium (MF) and low (LF) percent female plants in the Western gynoecious inbreds, and high (HN), medium (MN) and low (LN) percentage of female flowering nodes in the Chinese monoecious cultivars. The factorial set of combinations among the coded parents contained 3 X 3 (9) crosses:

1. HF(G19) X HN(M18)   6. MF(G16) X LN(M2)
2. HF(G19) X MH(M3)   7. LF(G15) X HN(M18)
3. HF(G19) X LN(M2)   8. LF(G15) X MN(M3)

4. MF(G16) X HN(M18)   9. LF(G15) X LN(M2)

5. MF(G16) X MN(M3)

One third of the seeds from each cross were sown in the greenhouse during the winter of 1986-1987. The plants were selfed and the F_2 seeds were harvested in bulk for each cross.

The remaining F_1 seeds of the nine crosses were sown in the field in the summer of 1987. A complete randomized block design with two blocks was used. Each block consisted of nine plots, each plot containing the F_1 progeny of one cross. Each plot contained 100 plants spaced 20 cm apart with 150 cm spacing between rows.

The F_2 populations were tested at the same time and in the same way as the F_1 tests except that a completely randomized design was used for the F_2.

After emergence and when the flower buds could be identified, the percent gynoecious plants was recorded weekly. To accurately distinguish gynoecious plants from non-gynoecious plants, non-gynoecious plants were rogued and open flowers on gynoecious plants were picked off after a count was recorded. The whole recording (or observation) process was carried out from the first sidentifiable floral bud through the 15th node.

Percentage of female flowering nodes was obtained by observing the first fifteen nodes on each plant. It was used

as the expression of the relative female tendency in the three monoecious parents.

Percentage of gynoecious plants was recorded for the gynoecious parents, F_1 and F_2 populations.

Study II

The extent of female expression in segregating F_2 populations and the effects of different mating systems on female expression in F_3 populations were investigated in the field during the summers of 1987 and 1988. At the same time, the success of transferring gynoeciousness to the NSCC type (with warty spine and long fruit) with the different mating systems was determined.

During the summer of 1987, F_2 populations from the crosses G19(HF) X M18(HN), G16(MF) x M18(HN), and G15(LF) X M18(HN) comprised three experimental units. In each of these units, ten predominantly female plants(1-3 male flowers below 15th node) and ten all-female (gynoecious) plants were selected. Five plants of each 10 plant group were selfed. In the case of the all-female plants, pollen was obtained from male flowers induced by use of $Ag(S_2O_3)_2$ at 500 ppm. The remaining five all-female plants (seed parents) and five predominantly female plants (pollen parents) were half sib-mated and seed was saved from each of the five gynoecious plants to produce five families from each cross.

During the summer of 1988, the 45 families from the three units described above were tested in the field. For further classification these 45 families consisted of 15 families from each of three crosses. Each group of 15 families was derived as follows:

A. five families derived from selfing predominately gynoecious plants;

B. five families derived from selfing (by Ag^+ induction) all-gynoecious plants; and

C. five families produced as half sib on all gynoecious plants pollinated by a sister group of predominately gynoecious plants.

The field plot arrangement consisted of three adjacent blocks, each one containing the families from one unit (cross). Within each unit, the respective 15 families described above were planted in one plot each in completely randomized order. The percentage of gynoecious plants was determined weekly in each family after the floral buds on the plants could be identified at the first 15 nodes. The occurrence of two Chinese cucumber characteristics, wart-spine and long fruit shape, was determined in the gynoecious plants. These two characters were used as markers to indicate the degree of success in incorporating gynoecious flowering character into Chinese monoecious cucumber backgrounds.

Study III

This experiment was conducted in the field during the summer of 1987 to determine the effect of seeding time on the percentage of gynoecious plants in a segregating population. The experiment utilized an F_2 population from a cross of G19 (HF), a Sunseeds gynoecious inbred, with M21, the Chinese monoecious cultivar Taishan. Seeding times were 20 May, 10 June, 30 June, and 20 July.

The complete randomized block experiment consisted of two blocks and four plots (four planting dates) in each block. Each plot (10 m x 2 m) was planted with 100 seeds of the F_2 population G19 x M21. After the seedlings emerged and the floral buds on the plants could be identified, the percent of gynoecious plants was determined weekly. The observation methods were similar to that used in Study I. However, the observations in this study were not confined to the growth period below 15th node, but through the entire growth season.

In the observation process, non-gynoecious plants were eliminated until all of the remaining plants were gynoecious based on the sex expression of the first 15 nodes. The reversion of all-gynoecious plants to predominately gynoecious plants was recorded after the observations of the first 15 nodes for flower sex was completed.

Data Analysis

In all experiments, the data, which was in the form of percent gynoecious plants, were transformed by arcsine prior to analysis of Variance. Mean separations were then tested by LSD with transformed means and differences indicated by letters on the data tables in their natural form.

Results and Discussion

Study I. Effects of female flowering level in gynoecious and monoecious parents on the percent gynoecious plants in F_1 and F_2 progenies.

The percent gynoecious plants observed in nine F_1 populations derived by crossing three gynoecious inbreds (high, medium and low levels of female expression) with three monoecious cultivars (high, medium, and low percent of female nodes) is shown in Table 3. The relatively strong effect of the monoecious parent is evident from the occurrence of F_1 progenies with 0% gynoecious plants when the LN parent was used, even in combination with the HF gynoecious parent. The effect of female expression level was highly significant (p=0.01) in the monoecious parent The interaction between gynoecious and monoecious parents was non-significant.

Separations of means among the nine crosses and the mean effect of parental types is shown in Table 5. The differences in mean effects of the three monoecious parent types were pronounced. Comparison of means within rows showed significant differences relating to the HN, MN, and LN levels of female expression in the monoecious parent regardless of whether HF, MF, or LF parents were used. Comparisons of the overall means (main effects) resulting from the three levels of female flowering tendency in the

monoecious parents were also significantly different. These results show a strong relationship between percent of female flowering nodes in the monoecious parent and percent gynoecious plants in the F_1. The differences, though non significant, between individual means and overall means of the gynoecious parents indicate some effect of gynoecious parent since there was a trend for the higher levels of female flowering in gynoecious lines to result in more gynoecious plants in the F_1.

The effect of gynoecious and monoecious parents on percent gynoecious plants in the F_2 was similar to that observed in the F_1 generation, except that both gynoecious and monoecious parent effects were significant. When data from the F_2 plants shown in Table 6 were tested by the analysis of variance (Table 7), effects of both gynoecious and monoecious parents were highly significant with the monoecious parent effects producing an F value about double that of the gynoecious parent effect. The gynoecious X monoecious interaction was very small and non-significant. Mean effects (Table 8) of the three monoecious parents were significantly different (p = 0.05). As expected, the percent gynoecious plants were higher in F_2 populations from the HN parent and lowest in those from the LN parent. This trend was apparent in the individual means within gynoecious parents, but effects of the HN and MN parents were not different when HF and MF gynoecious lines were parents. In

combination with the LF gynoecious parent, the effects of the HN, MN, and LN parents were all different. In the case of the gynoecious parents, the individual and main effects were identical, with non-significant differences between HF and MF but these resulting in a higher percent gynoecious plants than the LN parent.

The monoecious parent affected the percent gynoecious plants in the F_1 generation, and both the gynoecious and monoecious parents affected the percent gynoecious plants in the F_2, but the effect of the monoecious parent was more pronounced. Each parent influenced the percent gynoecious plants in the progenies independently but the parents interacted in a generally additive manner so that the highest level of female flowering tendency was obtained by using HF and HN parents, and the lowest was obtained by using LF and LN parents. The percent gynoecious flowers was much higher in the F_2 population than it was in the F_1. In transferring the gynoecious character to new genetic materials, the breeder should select both gynoecious and monoecious parents with the highest possible level of female flowering expression, and especially avoid using monoecious lines in the LN category and gynoecious lines in the LF category.

Table 3. Percentage of gynoecious plants in F_1 progenies of crosses between gynoecious and monoecious parents with three levels of female flowering expression.

	Percent gynoecious plants		
Cross[z]	Replication I	Replication II	Cross Mean
HF X HN	30.9	33.1	32.0
HF X MN	9.1	13.0	11.1
HF X LN	0.0	4.5	2.3
MF X HN	33.5	31.0	32.2
MF X MN	5.6	6.5	6.1
MF X LN	0.0	1.3	0.6
LF X HN	18.6	24.2	21.4
LF X MN	7.4	6.0	6.9
LF X LN	1.8	0.0	0.9

[z] HF, MF, and LF indicate high, medium, and low degree of female flowering in gynoecious inbreds; HN, MN, and LN indicate high, medium, and low percentage of female flowering nodes in monoecious parents.

Table 4. Analysis of variance of effects of female
flowering level in gynoecious and monoecious
parents on arcsine transformed percent gynoecious
plants in F_1 populations

Source of variation	Degrees of freedom	Mean square of percent gynoecious plants	F
Replication	1	17.75	1.12 NS
Gynoecious parent	2	30.93	1.96 NS
Monoecious parent	2	1165.49	73.74 **
Gynoecious X monoecious interaction	4	10.84	0.68 NS
Error	8	15.81	

** Significant at 1% probability.

NS Not significant.

Table 5. Effects of levels of female flowering of gynoecious
and monoecious parents on percent gynoecious plants
of F_1 populations

Gynoecious[z]	Monoecious parent[x]			
parent	HN	MN	LN	Mean
HF	31.99 a	11.05 b	2.25 c	15.10
MF	32.22 a	6.05 b	0.64 c	12.97
LF	21.39 a	6.94 b	0.88 c	9.74
Mean	28.53 a	8.01 b	1.26 c	

[z] HF, MF, and LF indicate high, medium, and low degrees of
female flowering in gynoecious parents.

[x] HN, MN, and LN indicate high, medium, and low percentage
of female flowering nodes in monoecious parents.
Mean separation by LSD at 5% level derived from Arcsine
transformed data. Means within rows different if letter a,
b, and c are different. The effects of gynoecious parent
(within columns) were non significant.

Table 6. Percentage of gynoecious plants in F_2 populations
of crosses between gynoecious and monoecious
parents with three levels of female flowering
expression.

| Cross[z] | Percent gynoecious plants | | |
	Replication I	Replication II	Cross mean
HF X HN	37.9	35.9	36.9
HF X MN	29.6	34.4	32.0
HF X LN	22.9	19.1	21.0
MF X HN	36.6	34.6	35.6
MF X MN	33.3	27.0	30.2
MF X LN	19.6	20.0	19.8
LF X HN	27.7	31.4	29.5
LF X MN	17.4	17.9	17.7
LF X LN	11.3	14.3	12.8

[z] HF, MF, and LF indicate high, medium, and low degree of
female flowering in gynoecious inbreds; HN, MN, and LN
indicate high, medium, and low percentage of female
flowering nodes in monoecious parents.

Table 7. Analysis of variance of effects of female
flowering level of gynoecious and monoecious
parents on arcsine transformed percent gynoecious
plants in F_2 populations

Source of variance	Degrees of freedom	Mean square	F
Gynoecious parent	2	81.27	31.08 **
Monoecious parent	2	175.08	66.95 **
Gynoecious X monoecious interaction	4	4.07	1.56
Error	9	2.62	

** Significant at 1%

Table 8. Effects of levels of female flowering of gynoecious
and monoecious on percent gynoecious plants of F_2
populations

Gynoecious[z]	Monoecious parent[x]			
parent	HN	MN	LN	Mean
HF	36.88 aP	31.99 aP	20.97 aP	29.95 P
MF	35.58 aP	30.15 aP	19.82 bP	28.51 P
LF	29.54 aQ	17.68 bQ	12.78 cQ	20.00 Q
Mean	34.00 a	26.61 b	17.86 c	

[z] HF, MF, and LF indicate high, medium, and low degrees of
female flowering in gynoecious parents;

[x] HN, MN, and LN indicate high, medium, and low percentage
of female flowering nodes in monoecious parents.
Mean separation by LSD at 5% level. Means within rows
different if letters a, b, and c are different. Means
within columns different if letters P, Q, and R are
different. Arcsine transformation of data resulted in
identical separation.

Study II. Effect of mating system on percent gynoecious
plants in F_3 families during transfer of the
gynoecious character to Chinese monoecious
genotypes

The use of three different gynoecious parents with HF,
MF, and LF levels of female flowering had no significant
effect on the percent gynoecious plants in the F_3 families
derived from crosses of these parents with a common HN
monoecious cultivar (Table 9). The interaction between
mating systems and crosses was likewise non-significant but
the effect of mating systems was highly significant
$(p = 0.01)$.

Table 10 shows the mean percentages of gynoecious
plants in F_3 families derived from the three crosses by
three mating systems: (A) half sib-mating selected
gynoecious plants by pollinating them with pollen from
predominately gynoecious sisters, (B) selfing of
predominately gynoecious plants, and (C) selfing all-
gynoecious plants induced to flower by $Ag(S_2O_3)_2$ treatment.
Differences between mating systems occurred only in the
cross HF(G19) X HN(M18) and in the overall mating system
means. Families derived from selfing completely gynoecious
F_2 selections (by using Ag treatment) had the highest
percentage of gynoecious plants, followed in the three
crosses by families obtained from selfing predominately

female F_2 plants. Families derived from half sib mating all-gynoecious plants with predominately gynoecious sister selections had the lowest percentage of gynoecious plants. Within cross HF(G19) X HN(M18), families from selfed all-gynoecious plants (C) were significantly different (p = 0.05) from those obtained from self predominantly gynoecious F_2 plants (B) and those derived from half sib mating (A). However, there were no differences in percent gynoecious plants between the selfing families (B) and the sib mating families (A). Due to the sensitivity of sex expression in cucumber, some plants (including predominantly gynoecious and gynoecious plants) modified by environmental factors were probably selected in self and sib-mated F_2 populations by accident. This lead to a high variability of the percent gynoecious plants among tested families except for the effects of two marker characters (Table 11 and 12). While the differences between crosses were non significant, there was a trend for percentage of gynoecious plants to be related to the level of female flowering in the gynoecious parent. This trend suggested that LF gynoecious lines should be avoided in selection of parents for converting monoecious cultivars to the gynoecious condition.

The second phase of study II involved the analysis of F_3 family data to determine the effect of parents and mating systems on the recovery of the gynoecious character in

combination with the long fruit and warty spine characters of the monoecious cultivars. It should be noted that the gynoecious parents MF(G16) and LF(G15) both had medium long fruit and spines, and with the system used in classification of progeny plants, all of their progenies were classified as having long fruit and spines. Thus, segregation was apparent only in the progenies of HF(G19) X HN(M18) and the values shown in Table 12 for the crosses MF(G16) X HN(M18) and LF(G15) X HN(M18) were the same as those shown in Table 10.

In the analysis of variance (Table 11) the effect of crosses on percent gynoecious plants with long fruit and wart-spines was non-significant, as was the interaction between mating systems and crosses. The effect of mating systems was significant at 0.01 level. Results of statistical separation of the means shown in Table 12 were identical to the separation of means of percent gynoecious plants (Table 10). In the cross HF(G19) X HN(M18) and the overall mating system means, F_3 families from selfed gynoecious plants (C) produced significantly higher percentages of gynoecious-warty-long fruit plants than did half-sib mated gynoecious plants (A) and selfed predominately gynoecious plants (B). All other comparisons were non significant. Differences resulting from crosses did not follow the trend observed for percent gynoecious plants (Table 10) because in this case (Table 12) values shown for HF(G19) X HN(M18) were reduced because segregation for wart

spine and long fruit occurred, while in the other two crosses, all gynoecious plants also had long fruit and wart spines.

The analyses of the effect of mating systems on percent gynoecious plants in F_3 families indicated strongly that selfing completely gynoecious plants with pollen induced with Ag^+ was the most effective method for transfer of the gynoecious character to monoecious cultivars. However, with this system, the selection cycle is longer by about 50 days. Because predominately gynoecious plants do not have pure gynoecious genes, selfing predominantly gynoecious plants and sib-mating gynoecious with predominantly gynoecious plants resulted in a dilution of the gynoecious character and resulted in a lower percentage of gynoecious plants in F_3 families.

The effect of the crosses involved this study was not significant, whether percent gynoecious plants alone, or percent gynoecious plants with long fruit and wart spines was considered. Because the gynoecious parent with the highest expression of female flowering lacked the long fruit and wart spine characters, it was obviously less effective in producing a high percentage of gynoecious, long fruited, wart spined progeny plants. Thus, using gynoecious parents with characteristics in common with the monoecious parent which is to be converted will increase the numbers of gynoecious plants with the characteristics of the monoecious

parent. However, it is possible that obtaining large numbers of gynoecious plants in the progenies is not nearly as important as the level of the gynoecious character achieved. High levels of gynoecious expression may best be obtained by using gynoecious parents of the highest possible level of female flowering.

Table 9. Analysis of variance of percent gynoecious F_3 plants[z] as affected by three mating systems and three gynoecious lines crossed with a monoecious cultivar.

Source of variation	Degrees of freedom	Mean square	F
Crosses	2	630.60	2.21NS
Mating systems	2	1981.19	6.95**
Cross X mating system interaction	4	78.73	0.28NS
Error	36	285.041	

[z] Percent gynoecious plants transformed by arcsine.

** = significant at 0.01 probability.

NS = not significant at 0.05 probability.

Table 10. Influence of three mating systems on the
percent gynoecious plants in F_3 families from
gynoecious X monoecious crosses

	Percentage gynoecious plants			
	Mating Systems[Y]			
Cross[Z]	A	B	C	Cross means
HF(G19) X HN(M18)	53.4 A	59.4 A	93.3 B	68.7
MF(G16) X HN(M18)	52.9 A	52.4 A	77.9 B	61.1
LF(G15) X HN(M18)	41.6 A	45.5 A	64.4 B	49.2
Mating system means	49.3 A	51.1 A	78.6 B	

[Y] A: Half sib-mating: Selected gynoecious plants pollinated
with pollen from male flowers of predominately
gynoecious sisters.

B: Self: Selected predominately gynoecious plants selfed
with pollen from their own male flowers.

C: Induced self: Selected gynoecious plants selfed with
pollen from induced male flowers.

[Z] HF, MF, and LF = high, medium and low female expression in
gynoecious lines; HN = monoecious lines with high percent
female nodes.

Mean separations by LSD at 5% probability derived from
arcsine transformed data. Means within rows (mating

systems) different if letters A and B are different.
Column means (crosses) not significantly different.

Table 11. Analysis of variance of percent[z] of F_3 plants with gynoecious flowering, long fruit and warty spines, as affected by three mating systems and three gynoecious lines crossed with a monoecious cultivar.

Source of variation	Degrees of freedom	Mean square	F
Crosses	2	256.57	0.79NS
Mating systems	2	1815.10	5.58**
Cross X mating system interaction	4	53.29	0.16NS
Error	36	325.05	

[z] Percent of gynoecious plants transformed by arcsine.

** = significant at 0.01 probability.

NS = not significant at 0.05 probability.

Table 12. The effect of three mating systems on percentage

of plants with gynoecious flowering, long fruit,

and warty spines in F_3 families from gynoecious X

monoecious crosses

| | Percentage gynoecious plants | | | |
| | Mating Systems[y] | | | |
Cross[z]	A	B	C	Cross means
HF(G19) X HN(M18)	40.5 A	34.0 A	72.2 B	48.9
MF(G16) X HN(M18)	52.9 A	52.4 A	77.9 A	61.0
LF(G15) X HN(M18)	41.6 A	41.6 A	64.4 A	49.2
Mating system means	45.0 A	42.7 A	71.5 B	

[y] A: Half sib-mating: Selected gynoecious plants pollinated

with pollen from male flowers of predominately

gynoecious sisters.

B: Self: Selected predominately gynoecious plants selfed

with pollen from their own male flowers.

C: Induced self: Selected gynoecious plants selfed with

pollen from induced male flowers.

[z] HF, MF, and LF = high, medium, and low female expression

in gynoecious lines; HN = monoecious lines with high

percent female nodes.

Mean separations by LSD at 5% probability derived from

arcsine transformed data. Means within rows (mating

systems) different if letter A and B are different.

Column means (crosses) not significantly different.

Study III.   The effect of planting date on expression of

gynoeciousness

When the entire growing period was included in the data analysis, planting date did not affect the percentage of gynoecious plants (Tables 13 and 14) in a genetical variable population obtained by crossing a gynoecious with a monoecious parent. However, if the observations of the first and second half of the growth season were analyzed separately, different statistical results were obtained.

Planting date significantly affected percent gynoecious plants during the first half of the growth season (Table 15 and 16, Figure 1). The plots planted on 20 May had a significantly higher percent of gynoecious plants than those planted on 10 June, 20 June and 20 July. Plots planted on 10 June had a significantly higher percent of gynoecious plants than those planted on 30 June and 20 July. No difference in percent gynoecious plants was found between the 30 June and 20 July plantings. As Figure 1 also shows, percent gynoecious plants was reduced rapidly during the period 20 May - 30 June, leveling off in the 30 June - 20 July period. This maximum planting date effect would have been indicated in the analysis of variance if only these earliest two periods were included.

One or two male flowers appeared on a few female plants in each plot during the second half of the growth season.

The incidence of these reversions of plants from completely gynoecious to predominantly gynoecious was significantly different at 0.10 probability in the arcsine transformed data (Table 17, 18; Figure 2). In this case, arcsine transformation made an important difference in data evaluation since without transformation, planting date effects were significant at 0.05 probability.

The percent of gynoecious plants reverting was greater in the earliest planting, diminishing in each successive date. At 0.10 significance level, the 20 May planting did not statistically differ from the 10 June planting, the 10 June planting did not differ from the 30 June planting, and the 30 June planting did not differ from the 20 July date. The trend for a larger numbers of reversions in earlier planting was clear.

It appears that conditions occurring in the earlier part of the season favored a higher percentage of plants with exclusively female flowering at that time. This early part of the season differed from the later part in that temperatures were slightly lower and light intensity was less (Figure 3). Later cucumber plantings had fewer gynoecious individuals during the first half of their respective growing season, possibly because these plants were exposed to higher temperatures and greater sun intensity during that part of their growth period. Earlier plantings showed a higher percentage of reversion from

gynoecious to partially gynoecious plants during the last half of their growing season than did the later plantings. The percent reverting in the earliest planting (Table 18) was essentially the difference between the early and late plantings during the first half of their respective seasons (Table 16), 7.5%. The relationship among planting date effects is thus a matter of early environments favoring more plants flowering exclusively female, and conditions later in the summer causing these plants to revert to monoeciousness. All plantings eventually had about the same percent gynoecious plants (Table 14). The early plantings essentially produced some false gynoecious classifications during the first half of their growth period, and late plantings had fewer plants flowering all female during the first half of their growth period than for the whole season. It appears that later plantings would provide greater opportunity to select plants with a high potential for producing stable gynoecious lines.

Table 13. Analysis of variance of the effect of four
planting dates on arcsine transformed percent
gynoecious plants during the entire growing
season

Source of variance	Degrees of freedom	Mean square	F
Replications	1	0.1615	0.08NS
Planting date	3	2.1066	1.05NS
Error	3	2.0122	

NS = non significant at 0.05 probability.

Table 14. Effect of planting date on percent gynoecious
plants in a segregating population over the entire
growing season [z]

| | Percent gynoecious plants | | |
Planting date	Replication 1	Replication 2	Mean
20 May	24.62	25.86	26.14
10 June	24.00	20.00	22.00
30 June	22.37	25.00	23,69
20 July	25.81	24.36	25.09

[z] Both replication and planting date differences were non-
significant at 5% probability.

Table 15. Analysis of variance of the effect of four
planting dates on the arcsine transformed percent
gynoecious plants during the first half of the
growing season

Source of variance	Degrees of freedom	Mean square	F
Replications	1	0.1407	0.81NS
Planting date	3	11.4140	66.02**
Error	3	0.1729	

** Significant at p = 0.01.

Table 16. Effect of planting date on percent gynoecious

plants during the first half of the growing season

z

	Percent gynoecious plants		
Planting date	Replication I	Replication II	Mean [y]
20 May	28.32	28.80	28.6 A
10 June	24.10	23.26	23.7 B
30 June	20.40	21.16	20.8 C
20 July	20.58	21.70	21.1 C

[z] From planting date through the 15th node stage, amounting

to about half of the growing season.

Means bearing the same letters were not significantly

different at the 5% level. Mean separation by LSD derived

from arcsine transformed data.

Table 17. Analysis of variance of the effect of planting
date on arcsine transformed percent of completely
gynoecious plants reverting to predominately
gynoecious plants during the second half of the
growing season

Source of variance	Degrees of freedom	Mean square	F
Replications	1	5.8267	0.57NS
Planting date	3	58.5238	5.72*
Error	3	10.2243	

* Significant at the 0.10 level.

NS = non significant at 0.10 probability.

Table 18. Effect of planting date on the reversion of
completely gynoecious plants to predominantly
gynoecious plants during the second half of the
growing season

Planting	Percent of gynoecious plants reverting[z]		
date	Replication I	Replication II	Mean [y]
20 May	7.0	8.0	7.5 A
10 June	5.0	5.0	5.0 AB
30 June	2.0	1.0	1.5 BC
20 July	0.0	2.0	1.0 C

[z] Plants initially classified as gynoecious during the first
half of the growing season, but producing male flowers
during the second half.

[y] Mean separation by LSD derived from arcsine transformed
data. Means having the same letter were not significantly
different at the 0.10 probability.
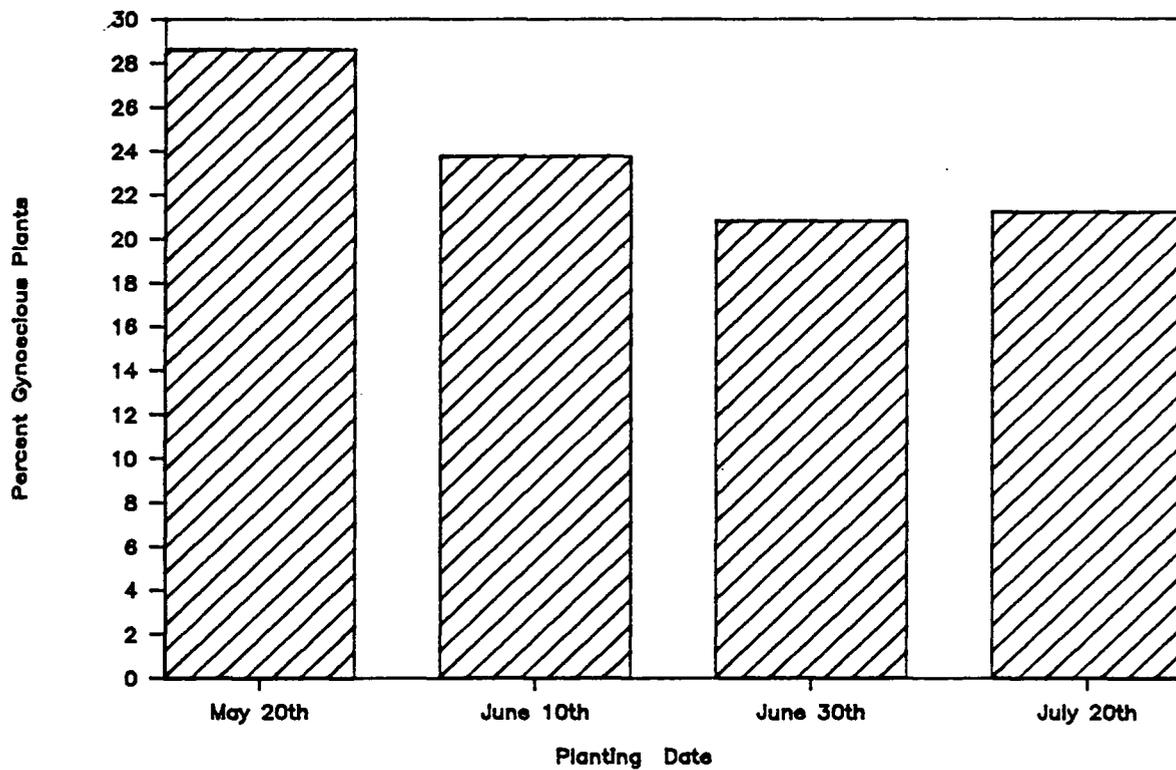
Figure 1. Relationship of planting date to percent gynoecious plants during the first half of the growing season.
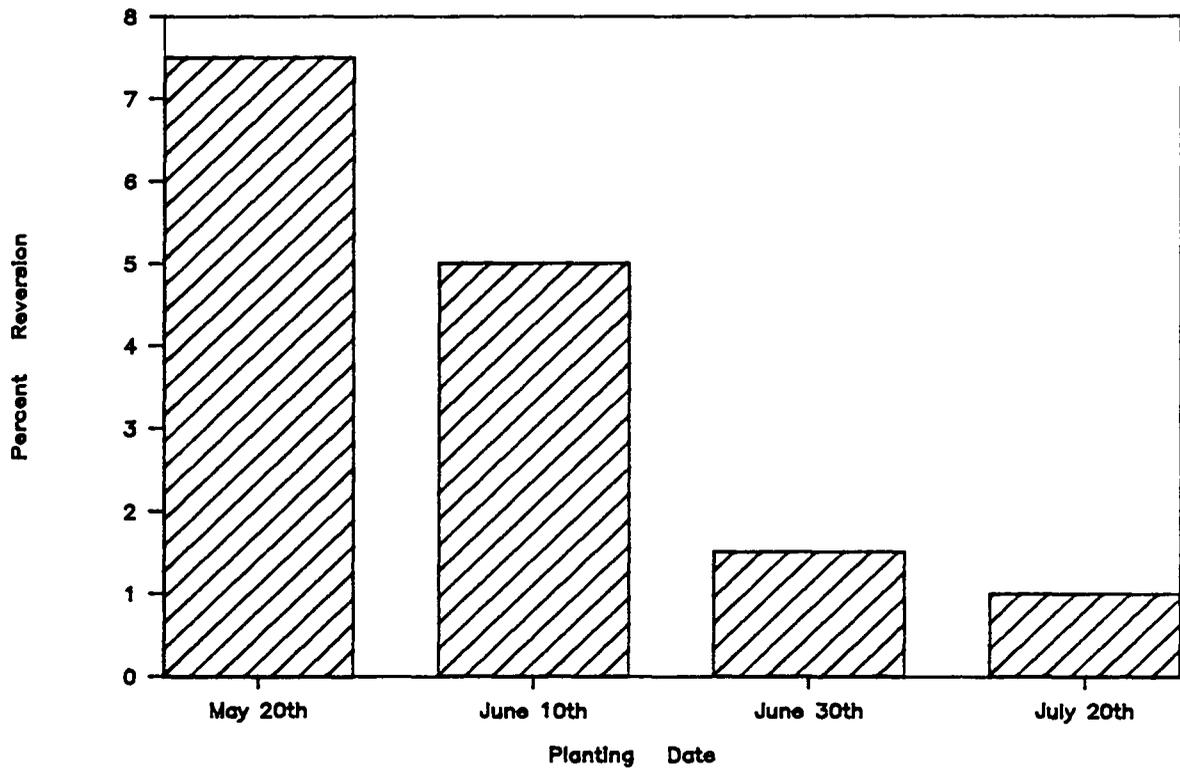
Figure 2. Relation of planting date to percent reversions of gynoecious to predominately gynoecious plants during the second half of the growing season.
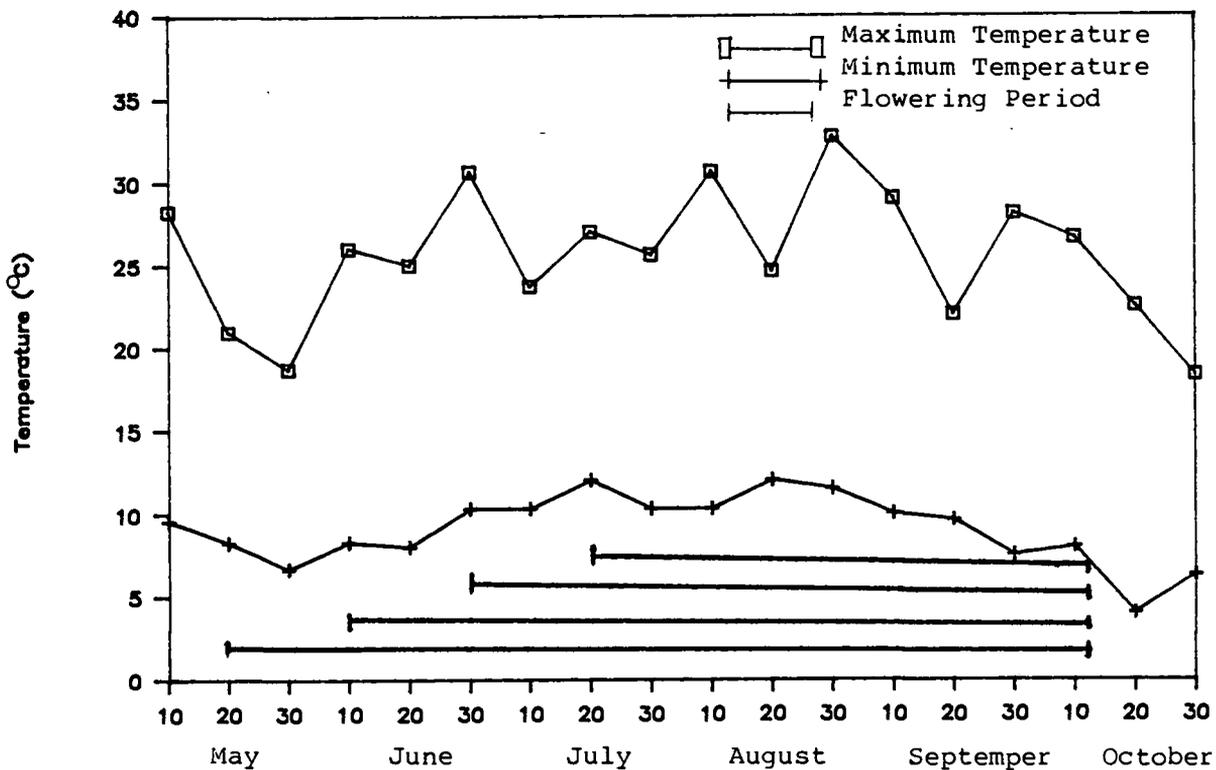
Figure 3. Flowering period of plants planted on four dates and average
temperature ($^{\circ}$C) of ten-day intervals during the entire growing
season (The temperature data from Climatological Data, Oregon,
Vol. 93, 1987)

General Discussion

The most serious problem in the development of superior gynoecious lines for use as inbred parents in F_1 hybrids of cucumbers is the instability of the gynoecious character. This instability is related in part to the sensitivity of cucumber sex expression to changes in some environmental factors. The difficulty in specifying the source(s) and degree(s) of genetic control of sex expression is likewise in its sensitivity to environmental factors. Many articles about sex expression in cucumber have been published, but no definite conclusion about its genetics has been possible. Many gynoecious cucumber lines have been used widely. However, it has been difficult to keep the percent of gynoecious plants at a high level. From the point of view that the distribution of gynoecious plants in a population is not continuous, gynoeciousness is a qualitative characteristic. However, in that it is easily affected by environmental factors, it behaves as a quantitative characteristic. In view of these aspects, in this study we did not attempt to identify Mendelian gene effects controlling segregation for the gynoecious characteristic. Our experiments were designed to measure the general effects of parental levels of the gynoecious tendency and several mating systems on the effectiveness of transfer of the gynoecious character to monoecious cucumber types. The

effect on occurrence of gynoeciousness in an F_2 population of one controllable environmental factor, planting date, was also studied.

The results of the first study indicated that the expression of female flowering tendency in the F_1 and F_2 populations was strongly affected by the level of female flowering tendency in the monoecious parent. There was no effect of the gynoecious parent, nor was there an interaction between gynoecious and monoecious parents. In the case of the F_2 generation, both gynoecious and monoecious parent effects were significant, but again the monoecious parent effects were greater than those of the gynoecious parent and there was no gynoecious X monoecious interaction.

Even though the gynoecious parent effects were not significant in the F_2, this study clearly indicates that use of combinations of both gynoecious and monoecious parents with high female flowering tendency will maximize the chances of getting stable gynoecious lines. The results also indicate that the gynoecious character is under quantitative genetic control and that the effects of the gynoecious and monoecious parents are additive in determining the percent gynoecious plants.

Selection, reproduction and maintenance of gynoeciousness in a breeding population are carried out in different ways by cucumber breeders. Generally, self

pollination after treatment with $Ag(S_2O_3)_2$ is used in maintaining new gynoecious lines after gynoecious plants are selected. Sometimes the selfing of predominantly gynoecious plants, and sib-mating them with completely gynoecious plants is used when the percentage of gynoecious plants in a synthesized population is low. In this study, we found that self pollination of selected gynoecious F_2 plants (induced to produce male flowers) was the most effective means of maintaining a high level of gynoecious (incidence of gynoecious plants) in F_3 progenies. There were no differences in transferring efficiency between the other two methods tested (self pollination of predominantly gynoecious plants, or half sib mating gynoecious plants with predominantly gynoecious plants). When selfing of induced gynoecious plants is used, a selection cycle is about 50 days longer and requires more chemicals and labor than the other two systems. Although the transferring efficiency of the self and sib-mating system are low, they may be useful for quickly increasing the progeny population when the size of a F_2 population is small and the number of gynoecious individuals available for selection is small.

Because predominantly gynoecious plants do not have pure gynoecious genes, selfing predominantly gynoecious plants and sib-mating gynoecious plants with predominantly gynoecious plants result in the dilution of gynoecious factors and a lower percent gynoecious plants in F_3

families. Because of the sensitivity of sex expression in cucumber, in some conditions favorable for male flowering certain gynoecious plants can become predominantly gynoecious ones, however, in certain environments favorable for female flowering some monoecious plants become predominantly gynoecious, and predominantly gynoecious become completely gynoecious plants. This could be a reason that there was high variability in the percent gynoecious plants among families.

Whether gynoecious alone or gynoecious with the two marker characters, long fruit and warts, were involved in classification of F_3 plants in F_3 families, the differences in percent gynoecious plants among crosses was not significant. This may suggest that gynoecious level or female tendency of parents affects the percent gynoecious plants in F_1 and F_2 populations, more than it does in the F_3 generation. However, it should be recognized that in Study II there were only differences in the gynoecious parents and that there was therefore no way to separate effect of gynoecious from monoecious parents.

The effect of the planting date on the percent gynoecious plants in this study was probably the result of the influence of combinations of environmental factors. Expression of gynoecious flowering in cucumber has been described in some literature as being influenced by temperature, light and certain chemicals. The low

temperature and low light intensity affecting the earlier
plantings were possibly favorable for female flowering and
unfavorable for male flowering. The higher temperature and
higher light intensity to which the late plantings were
exposed may have had an opposite effect on sex expression.
The earlier plantings received more influence from
conditions favorable for female flowering and produced more
gynoecious plants. However, in the earlier plantings, some
gynoecious plants became monoecious in the second half of
their growth period because conditions changed to become
favorable for production of male flowers. The later
plantings may have produced a higher percentage of
monoecious plants in the first half of the growth season
because they had been in a favorable light and temperature
environment for male expression from the time that they were
planted. Most of the predominantly gynoecious plants
expressed themselves on the basis of their genotype during
the first half of their growing season. There were only one
or two of them to become completely gynoecious because of
some other environmental factors. There were therefore
fewer plants likely to appear as reversions from gynoecious
to monoecious flowering than those in the earlier plantings
during the second half of the growth period because the
plants of the late plantings with monoecious genotype had
fully expressed during the first part of the growing season.
If planting times are scheduled as early as possible in the

production of F_1 hybrid seed, there should be a greater possibility of having seed parents that are 100% gynoecious and avoid the probability of selfing. If the gynoecious inbred stocks are not pure for gynoecious flowering, late planting would be favorable to use in the inbred maintaince procedures because the monoecious plants would be fully expressed late in the season and could be eliminated.

Summary and Conclusions

These studies investigated the influence of parents, mating systems and planting dates on the expression of female flowering during the transfer of gynoecious flowering to Chinese monoecious cucumbers. The conclusions drawn from these investigations are as follows:

1.) The level of female flowering tendency of the monoecious parents strongly affected the expression of female flowering tendency in F_1 and F_2 populations. Level of female flowering tendency, expressed by percentage of female flowering nodes, in the monoecious parents had a much greater effect on the percentage of gynoecious plants in the F_1 and F_2 generation than did the degree of female flowering in the gynoecious parents. The effect of the gynoecious parent on percent gynoecious in the F_1 was non significant.

2.) Self pollination of completely gynoecious selected plants, requiring male flowering induction by chemical treatment, was most effective in obtaining highly gynoecious progeny lines compared with selfing predominantly gynoecious plants or sib-mating predominantly gynoecious and completely gynoecious plants.

3.) Planting date did not affect the percent of plants producing male flowers during the entire growing period, but early planting produced fewer plants with male flowers during the first half of their respective growing period

than late plantings. By the end of the season, early and late planting were about equal in percentage of gynoecious plants, because a higher percentage of plants in the early plantings reverted from gynoecious to monoecious flowering during the last half of the growth period.

LITERATURE CITED

1. Robinson, R. W., and H. M. Munger. 1976. Genes of the Cucurbitaceae. HortScience. 11(6):554-568.

2. Galun, E. 1961. Study of the Inheritance of Sex Expression in the Cucumber. The Interaction of Major Genes with Modifying Genetic and Non-genetic Factors. Genetica. 32:134-163.

3. Kubicki, B. 1969a. Investigations on Sex Determination in Cucumber (Cucumis sativus L.) III. Variability of Sex Expression in the Monoecious and Gynoecious Lines. Genetica Polonica. 10:3-22.

4. Kubicki, B. 1969b. Investigation on Sex Determination in Cucumber (Cucumis sativus L.) IV. Multiple Alleles of Locus acr. Genetica Polotica. 10:23-68.

5. Kubicki, B. 1969c. Investigations on Sex Determination in Cucumber (Cucumis sativus L.) V. Genes Controlling Intensity of Femaleness. Genetica Polonica. 10:69-86.

6. Kubicki, B. 1969d. Investigations on Sex Determination in Cucumber (Cucumis sativus L.) VI. Androecism. Genetica Polonica. 10:87-99.

7. Kubicki, B. 1980. Investigations on Sex Determination in Cucumber (Cucumis sativus L.) IX. Induced Mutant with the Recessive Character of Gynoecism. Genetica Polonica. 21:409-424.

8. Pike, L. M., and C. E. Peterson. 1969. Inheritance of Parthenocarpy in the Cucumber (Cucumis sativus L.). Euphytica. 18:101-105.

9. Shifriss, O. 1961. Sex Control in Cucumbers. J. Heredity 52:5-12.

10. Kubicki, B. 1972. The Mechanism of Sex Determination in Flowering Plants. Genetica Polonica 13:53-66.

11. William L. George, JR. 1970. Dioecism in Cucumbers, Cucumis sativus L. Genetics 64:23-28.

12. Kubicki, B. 1965. New Possibilities of Applying Different Sex Types in Cucumber Breeding. Genetica Polonica 6: 241-250.

13. Kubicki, B. 1965. Investigations on the Sex Determination in Cucumbers (Cucumis sativus L.) II. The effects of Polyploidy on Sex Expression in Monoecious and Gynoecious Cucumbers. Genetica Polonica 6:251-265.

14. Xu, S. Y., and M. J. Bukovac. 1983. Phthalimide-modification of Sex Expression in Gynoecious and Monoecious Cucumbers. J. Amer. Soc. Hort. Sci. 108(2):278-282.

15. Xu, S. Y., and M. J. Bukovac. 1983. Phthalimide-inhibition of the Ethylene Effect on Sex Expression in Monoecious Cucumber Plants. J. Amer. Soc. Hort. Sci. 108(2):282-284.

16. Robinson, R. W. , Shannon, s., and Guardia, M. D. De la 1969. Regulation of Sex Expression in the Cucumber. BioScience 19:141-142.

17. Denna, D. W. 1973. Effect of Genetic Parthenocarpy and Gynoecious Flowering Habit on Fruit Production and Growth of Cucumber (Cucumis sativus L.). J. Amer. Soc. Hort. Sci. 98(6):602-604.

18. Cantliffe, D. J. 1981. Alteration of Sex Expression in Cucumber Due to Changes in Temperature, Light Intensity, and Photoperiod. J. Amer. Hort. Sci. 106(2):133-136.

19. Nandgaonkar, A. K., and L. R. Baker. 1981. Inheritance of Multi-pistillate Flowering Habit in Gynoecious Pickling Cucumber. J. Amer. Soc. Hort. Sci. 106(6):755-757.

20. Delaney, D. E., R. L. Lower, and M. D. Edwards. 1983. Effect of Within Row Spacing on Mature Fruit Yield of Three Cucumis sativus var. hardwickii Derivatives and a Gynoecious Inbred of Cucumis sativus. Cucurbit Genet. Coop. Rep. 6:3-4.

21. Lertrat, K., and R. L. Lower. 1983. Pickling Cucumber Inbred Line Development by Full-sib Family Selection. Cucurbit Genet. Coop. Rep. 6:16-17.

22. Staub, J. E., and L. Crubaugh. 1987. Imposed Environmental Stresses and Their Relationship to Sex Expression in Cucumber (Cucumis sativus L.). Cucurbit Genet. Coop. Rep. 10:13-17.

23. Staub, J. E., and L. Crubaugh. 1987. Use of Silver Thiosulfate as a Potential Tool for Testing Gynoecious Sex Stability in Cucumber (Cucumis sativus L.). Cucurbit Genet. Coop. Rep. 10:18-20.

24. Della Vecchia, P. T., C. E. Peterson, and J. E. Staub. 1982. Effect of the Duration of of Short-day Treatment on the Flowering Response of a *Cucumis* *sativus* var. *hardwickii* (R.) Alef. Line. Cucurbit Genet. Coop. Rep. 5:2-3.

25. Della Vecchia, P. T., C. E. Peterson, and J. E. Staub. 1982. Inheritance of Short- day Response to Flowering in Crosses Between a *Cucumis* *sativus* var. *hardwickii* (R.) Alef. Line and *Cucumis* *sativus* L. Lines. Cucurbit Genet. Coop. Rep. 5:4-5. 26. Owens, K. W., and C. E. Peterson. 1982. Linkage of Sex Type, Growth Habit and Fruit Length in Two Cucumber Inbred Backcross Populations. Cucurbit Genet. Coop. Rep. 5:12-13.

27. Iezzoni, A. F., and C. E. Peterson. 1981. Effects of Ethylene on Hermaphroditic Cucumbers. Cucurbit Genet. Coop. Rep. 4:8-10.

28. Iezzoni, A. F., and C. E. Peterson. 1980. Complementation between Two Perfect Flowered Mutants in Cucumber. Cucurbit Genet. Coop. Rep. 3:12-13.

29. Nienhuis, J., R. L. Lower,and R. R. Horton. 1980. Heterosis Estimates for Several Characteristics in a Cross Between a Gynoecious Inbred of *Cucumis* *sativus* L. and *C.* *hardwickii* R. Cucurbit Genet. Coop. Rep. 3:20-21.

30. Nijs, A. P. M. den. 1980. Effectiveness of AVG for Inducing Staminate Flowers on Gynoecious Cucumbers. Cucurbit Genet. Coop. Rep. 3:22-23.

31. Ghaderi, A., and R. L. Lower. 1981. Estimates of Genetic Variances for Yield in Pickling Cucumber. J. Amer. Soc. Hort. Sci. 106(2):237-239.

32. Uzcategui, N. A., and L. R. Baker. 1979. Effects of Multiple-pistillate Flowering on Yields of Gynoecious Pickling Cucumbers. J. Amer. Soc. Hort. Sci. 104(2):148 -151.

33. Hunsperger, M. H., D. B. Hesel, and L. R. Baker. 1983. Silver Nitrate Induction of Staminate Flowering in Hermaphroditic Pickling Cucumbers. HortScience 18(3):347-349.

34. Dean, B. B. 1983. Parthenocarpy in Gynoecious Cucumber as Affected by Chlorflurenol, Genetical Parthenocarpy, and Night Temperatures. HortScience 18(3):349-351.

35. El-Shawaf, I. I. S., and L. R. Baker. 1981. Combining Ability and Genetic Variances of G X HF_1 Hybrids for Parthenocarpic Yield in Gynoecious Pickling Cucumber for Once-over Mechanical Harvest. J. Amer. Soc. Hort. Sci. 106(3):365-370.

36. Owens, K. W., G. E. Tolla, and C. E. Peterson. 1980. Induction of Staminate Flowers on Gynoecious Cucumber by Aminoethoxyvinylglycine. HortScience 15(3):256-257.

37. Prend, J., and C. A. John. 1976. Improvement of Pickling Cucumber with the Determinate (de) Gene. HortScience 11(4):427-428.

38. Veen, H. 1983. Silver Thiosulphate: An Experimental Tool in Plant Science. Scientia Horticulturae 20:211-224.

39. Tolla, G. E., and C. E. Peterson. 1979. Comparison of Gibberellin A_4/A_7 and Silver Nitrate for Induction of Staminate Flowers in a Gynoecious Cucumber Line. HortScience 14(4):542-544.

40. Cantliffe, D. J. 1977. The Induction of Fruit Set in Cucumbers by Chlorflurenol with or without Pollination. HortScience 12(1):58.

41. Elassar, G., J. Rudich, D. Palevitch, and N. Kedar. 1974. Induction of Parthenocarpic Fruit Development in Cucumber by Growth Regulators. HortScience 9(3):238-239.

42. Scott, J. W., and L. R. Baker. 1976. Sex Expression of Single and 3-way Cross Cucumber Hybrids with Androecious Pollinators. HortScience 11(3):243-245.

43. Rajasekaran, K., M. G. Mullins and Y. Nair. 1983. Flower Formation in vitro by Hypocotyl Explants of Cucumber (Cucumis sativus L.). Annal. of Botany 52:417-420.

44. More, T. A., and H. M. Munger. 1986. Gynoecious Sex Expression and Stability in Cucumber (Cucumis sativus L.). Euphytica 35:899-903.

45. Wehner, T. C., and C. H. Miller. 1985. Effect of Gynoecious Expression on Yield and Earliness of a Fresh -market Cucumber Hybrid. J. Amer. Sco. Hort. Sci. 110(4):464-466.

46. Cantliffe, D. J. 1984. Seed Orientation, Seed Quality and Their Effect on Emergence and Sex Expression in Cucumber. Proc. Fla. State Hort. Soc. 97:174-176.

47. Nienhuis, J., R. L. Lower, and C. H. Miller. 1984. Effects of Genotype and Within-row spacing on the Stability of Sex Expression in Cucumber. HortScience 19(2):273-274.

48. Takahashi, H., T. Saito, and H. Suge. 1983. Separation of the Effects of Photoperiod and Hormones on Sex Expression in Cucumber. Plant Cell Physiol. 24(2):147-154.

49. Lower, R. L., and M. D. Edwards. 1986. Cucumber Breeding. Vegetable Breeding. pp.173-207.

50. Tan, Q. M., and S. R. Chen. 1980. Vegetable Breeding. pp.232-242.

51. Beyer, E. Jr. 1976. Silver Ion: A Potent Antiethelene Agent in Cucumber and Tomato. HortScience 11(3):195-196.

52. Staub, J. E. 1986. Quality and Yield of Cucumber Hybrids using Gynoecious and Bisexual Parents. HortScience 21(3):510-512.

53. Lower, R. L., O. S. Smith, and A. Ghaderi. 1983. Effects of Plant Density, Arrangement, and Gynotype on Stability of Sex Expression in Cucumber. HortScience 18(5):737-738.

54. Den Nijs, A. P. M., and D. L. Visser. 1980. Induction of Male Flowering in Gynoecious Cucumbers (Cucumis sativus L.) by Silver Ions. Euphytica 29:273-280.

55. Rudich, J., A. H. Halevy, and N. Kedar. 1972. Ethylene Evolution from Cucumber Plants as Related to Sex Expression. Plant Physiol. 49:998-999.

56. Makus, D. J., D. M. Pharr, and R. L. Lower. 1975. Some Morphogenic Differences between Monoecious and Gynoecious Cucumber Seedlings as Related to Ethylene Production. Plant Physiol. 55:352-355.

57. Hume, B., and P. Lovell. 1983. Role of Aminocyclopropane-1-carboxylic Acid in Ethylene Release by Distal Tissue Following Localized Application of Ethephon in Cucurbita pepo. Physiol. Plant. 58:101-106.

58. Takahashi, H., and H. Suge. 1980. Sex Expression in Cucumber Plants as Affected by Mechanical Stress. Plant and Cell Physiol. 21(2):303-310.

59. Beyer, E. M. Jr. 1972. Mechanism of Ethylene Action Biological Activity of Deuterated Ethylene and Evidence Against Isotopic Exchange and Cis-trans-isomerization. Plant Physiol. 49:672-675.

60. Beyer, E. M. Jr. 1979. Effect of Silver Ion, Carbon Dioxide and Oxygen on Ethylene Action and Metabolism. Plant Physiol. 63:169-173.

61. Takahashi, H., and M. J. Jaffe. 1984. Further Studies of Auxin and ACC induced Feminization in the Cucumber Plant using Ethylene Inhibitors. Phyton-Int-J-Exp-bot. 44(1): 81-86.

62. Lower, R. L., D. M. Pharate, and E. K. Horst. 1978. Effects of Silver Nitrate and Gibberellic Acid on Gynoecious Cucumber. Cucurbit Genet. Coop. Rep. 1:8-9.

63. Robinson, R. W. 1978. Association of Fruit Shape and Sex Expression in the Cucumber. Cucurbit Genet. Coop. Rep. 1:10.

64. Robinson, R. W. 1978. Linkage of Male Sterility and Sex Expression Genes in Cucumber. Cucurbit Genet. Coop. Rep. 1:13.

65. Saito, T., and H. Ito. 1963. Factors Responsible for the Sex Expression of the Cucumber Plant. XIV. Auxin and Gibberellin Content in the Stem Apex and the Sex Pattern of Flowers. Tohoku J. Agric. Res. 14:227-239.

66. Atsmon, D. 1968. The Interaction of Genetic, Environmental, and Hoemonal Factors in Stem Elongation and Floral Development of Cucumber Plants. Ann. Bot. 32:877-882.

67. Atsmon, D., A. Long, and E. N. Light. 1968. Contents and Recovery of Gibberellins in Monoecious and Gynoecious Cucumber Plants. Plant Physiol. 43:806-810.

68. Hayashi, F., D. R. Boerner, C. E. Peterson, and H. M. Sell. 1971. The Relative Content of Gibberellin in Seedlings of Gynoecious and Monoecious Cucumber (Cucumis sativus). Phytochemistry 10:57-62.

69. Hemphill, D. D., Jr., L. R. Baker, and H. M. Sell. 1972. Different Sez Phenotypes of Cucumis sativus L. and C. melo L. and Their Endogenous Gibberellin Activity. Euphytica 21:285-291.

70. Byers, R. E., L. R. Baker, H. M. Sell, R. C. Herner, and D. R. Dilley. 1972. Ethylene: A natural Regulator of Sex Expression of Cucumis melo L. Proco. Nat. Acad. Sci. U.S.A. 69:717-720.

71. Ito, H., and T. Saito. 1957. Factors Responsible for the Sex Expression of Japanese Cucumber VI. Effects of the Day Length and Night Temperature, Unsuitable for the Pistillate Flower Formation, Artificially Controlled during the Various Stages of the Seedling Development in the Nursery Bed. J. Jap. Soc. Hort. Sci. 26:1-8.

72. Ito, H., and T. Saito. 1957. Factors Responsible for the Sex Expression of Japanese Cucumber. (VII) Effects of Long Day and High Night Temperature Treatment Applied for Short Duration at the Various Stages of Seedling Development on the Sex Expression of Flowers. J. Jap. Soc. Hort. Sci. 26:149-153.

73. Robinson, R. W. 1978. Pleiotropic Effects of the Glabrous Gene of the Cucumber. Cucurbit Genet. Coop. Rep. 1:14.

74. Dax-Fuchs, E., D. Atsmon, and A. H. Halevy. 1978. Vegetative and Floral Bud Abortion in Cucumber Plants: Hormonal and Environmental Effects. Scientia Hortic. 9:317-327.

75. Galun, E., S. Izhar, and D Atsmon. 1965. Determination of Relative Auxin Content in Hermaphrodite and Andromonoecious Cucumis sativus L. Plant Physiol. 40:321-326.

76. Trebitsh, T., J. Rudich, and J. Riov. 1987. Auxin Biosynthesis of Ethylene and Sex Expression in Cucumber (Cucumis sativu). Plant Grow. Regul. 5(2):105-113.

77. Galun, E. 1959. The Role of Auxins in the Sex Expression of the Cucumber. Physiologia Plantarum 12:48-61.

78. Edmond, J. B. 1931. Seasonal Variation in Sex Expression of Certain Cucumber Varieties. Amer. Sco. Hort. Sci. 27:329-332.

79. Shifriss, O., and E. Galun. 1946. Sex Expression in the Cucumber. Proc. Amer. Sco. Hort. Sci. 67:479-486.

80. Ito, H., and T. Kato. 1953. Factors Responsible for the Sex Expression of the Japanese Cucumber. Jour. Hort. Assoc. Japan. 22:138-144.

81. Ito, H., T. Kato, K. Hashimoto, and T. Saito. 1954. Factors Responsible for the Sex Expression of Japanese Cucumber. II. Anatomical Studies on the Sex Expression and Transformation of the Cucumber Flowers Induced by Pinching. Jour. Hort. Asssoc. Japan. 23:65-70.

82. Ito, H., and T. Saito. 1956. Factors Responsible for the Sex Expression of the Japanese Cucumber. III. The Role of Auxin on the Plant Growth and Sex Expression(1). Jour. Hort. Assoc. Japan. 25:101-110.

83. Ito, H., and T. Saito. 1956. Factors Responsible for the Sex Expression of the Japanese Cucumber. IV. The Role of Auxin on the Plant Growth and Sex Expression(2). Jour. Hort. Assoc. Japan. 25:141-151.

84. Ito, H., and T. Saito. 1956. Factors Responsible for the Sex Expression of the Japanese Cucumber. V. Causal Interpretation of the Effects of Pinching and Growth Substances on the Transformation of the Promordia of the Staminate Flower Nodes. Jour. Hort. Assoc. Japan. 25:213-220.

85. Ito, H., and T. Saito. 1957. Factors Responsible for the Sex Expression of the Japanese Cucumber. (VIII). Effects of Long Day and High Night Temperature Treatment of Short Duration, Accompanied by the Growth Substance Spray Application, on the Sex Expression of Cucumber. Jour. Hort. Assoc. Janpan. 26:209-214.

86. Ito, H., and T. Saito. 1958. Factors Responsible for the Sex Expression of the Japanese Cucumber. (IX). Effects of Nitrogen Application and Watering under the Controlled Day Length and Night Temperature in the Nursery Bed. Jour. Hort. Assoc. Japan. 27:11-20.

87. Knowles, P. F. 1977. Plant Breeding.

88. Li, J. W. 1980. Vegetable Culture.

89. Rosa, J. T. 1928. The Inheritance of Flower Types in Cucumbers and Citrullus. Hilgardia 3:233-250.

90. Pool, C. F. 1944. Genetics of Cultivated Cucurbits. J. Herid. 35:122-128.

91. Tkachenko, N. N. 1935. Preliminary Results of a Genetic Investigation of the Cucumber--Cucumis sativus L. Bul. Appl. Pl. Breed. Ser. 2, 3:311-356.

92. Wall, J. R. 1966. Correlated Inheritance of Sex Expression and Fruit Shape in Cucumis. Euphytica 16:199-208.

93. Kubicki, B. 1974. New Sex Types in Cucumber and Their Uses in Breeding Work. Proc. XIX Internatl. Hort. Congr. 3:475-485.

94. Odland, M. L., and D. W. Groff. 1962. Linkage of Vine Type and Geotropic Response with Sex Forms in Cucumbers Cucumis sativus L. Proc. Amer. Soc. Hort. Sci. 82:358 -369.

95. Shanmugasundaram, S., P. H. William, and C. E. Peterson. 1970. HortScience 6(3):213-214.

96. Kauffman, C. S., and R. L. Lower. 1975. Inheritance of an Extreme Dwarf Plant Type in the Cucumber. J. Amer. Soc. Hrot. Sci. 101(2):150-151.

97. Denna, D. W. 1970. Expression of Determinate Habit in Cucumbers (Cucumis sativus L.). J. Amer. Soc. Hort. Sci. 96(3):277-279.

98. Goerge, W. L., jr. 1970. Genetic and Environmental Modification of Determinate Plant Habit in Cucumbers. J. Amer. Soc. Hort. Sci. 95:583-586.

99. Cochran, F. D. 1938. Breeding Cucumbers for Resistance to Downy Mildew. Proc. Amer. Soc. Hort. Sci. 35:541 -543.

100. Hutchins, A. E. 1940. Inheritance in the Cucumber. J. Agr. Res. 60:117-128.

101. Strong, W. J. 1931. Breeding Experiments with the Cucumber (Cucumis sativus L.). Sci. Agr. 11:333-346.

102. Carlsson, G. 1961. Studies of Blind Top Shoot and Its Effect on the Yield of Greenhouse Cucumbers. Acta. Agr. Scand. 11:160-162

103. Tiedjens, V. A. 1928. Sex Rations in Cucumber Flowers as affected by Different Conditions of Soil and Light. J. Agr. Res. 36:721-746.

104. Atsmon, D., and E. Galun. 1962. Physiology of Sex in Cucumis sativus (L.) Leaf Age Patterns and Sexual Differentiation of Floral Buds. Ann. Bot. 26:137-146.

105. Lower, R. L., J. D. McCreight, and O. S. Smith. 1975.
     Photoperiod and Temperature Effects on Growth and Sex
     expression of Cucumber. HortScience 10:318.

106. Iwahori, S., J. N. Lyons, and O. E. Smith. 1970. Sex
     Expression in Cucumber as Affected by 2-
     chloroethylphosphonic acid, Ethylene, and Growth
     Regulators. Plant Physiol. 46:412-415.

107. Galun, E., Y. Jung, and A. Lang. 1963. Morphogenesis of
     Floral Buds of Cucumber Cultured in Vitro.
     Developmental Biology 6:370.

108. Hume, B., P. Lovell. 1982. Female Flower Production in
     Cucurbita pepo Is Controlled by ACC (1 Amino Cyclo
     Propane-1-carboxyic Acid) and not by Ethylene. Plant
     Physiol. 69 (suppl. 1982) 758.

109. Peterson, C. E., and L. D. Anhder. 1960. Induction of
     Staminate Flowers on Gynoecious Cucumbers with
     Gibberellin A_3. Science 131: 1673-1674.

110. Pike, L. M., and C. E. Peterson. 1969. Gibberellin
     A_4/A_7 for Induction of Staminate Flowers on the
     Gynoecious Cucumber. Euphytica 18:106-109.

APPENDIX

Appendix Table 1. Average temperatures(^{o}C) on three-day intervals at Salem WSO AP Station*, Oregon, 1987 (quoted from Climatological Data, Oregon, Vol. 93, 1987)

Month	Ob. Time	Max/ Min.	Three-day interval / month											
			1-3	4-6	7-9	10-12	13-15	16-18	19-21	22-24	25-27	28-30	31	Mean
May	Mid	Max	17	27	33	26	20	17	21	20	17	20	17	21.4
		Min	9	9	11	10	11	4	4	.5	10	9	5	7.7
June	Mid	Max	26	26	26	27	26	22	22	27	36	33		26.7
		Min	5	10	10	9	10	5	9	9	11	11		9.7
July	Mid	Max	27	22	22	32	32	17	28	25	26	26	25	26.1
		Min	11	10	10	15	10	11	10	11	11	10	10	10.8
Aug.	Mid	Max	32	27	33	26	21	27	27	31	32	33	38	29.7
		Min	10	10	11	11	15	10	9	11	10	10	16	11.1
Sept.	Mid	Max	28	32	27	20	20	26	28	27	21	31		26.1
		Min	10	10	10	15	9	5	5	10	9	5		8.6
Oct.	Mid	Max	26	28	26	27	20	21	22	17	21	20	16	22.1
		Min	10	9	5	5	4	4	4	4	4	5	10	5.7

* The station close to the experimental field

76