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YIELD INCREASES FOR ONCE-OVER HARVEST WITH

MULTIPLE-PISTILLATE FLOWERING IN PICKLING CUCUMBERS

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YIELD INCREASES FOR ONCE-OVER HARVEST WITH MULTIPLE-PISTILLATE FLOWERING IN PICKLING CUCUMBERS

By

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ABSTRACT

YIELD INCREASES FOR ONCE-OVER HARVEST WITH MULTIPLE-PISTILLATE FLOWERING IN PICKLING CUCUMBERS

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Gynoecious cucumber (Cucumis sativus L.) F_3 lines selected for multiple-pistillate flowers per node were tested for yield potential. Two preliminary experiments, one under greenhouse and the other under field conditions, were carried out to determine yields of the F_3 lines in comparison to 3 commercial hybrids with single-pistillate flowers per node. The increased numbers of pistillate flowers on the F_3 lines resulted in greater numbers of fruits per plant and reduced the percentage of fruit inhibition; and subsequently, more yield of pickling cucumbers for once-over harvest than the commercial F_1 hybrids. Development of pickling cucumber hybrids with multiple-pistillate flowers per node offers a new breeding possibility to increase yields for once-over harvest systems.

Guidance Committee:

This thesis is condensed into a format suited and intended for publication in the Journal of the American Society for Horticultural Science.

To my wife Eglee, and

to my son Noe Alfonso

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INTRODUCTION

One of the major objectives of pickling cucumber research is to enhance the female flowering habit of commercial cultivars so as to further concentrate fruit set and increase yield for once-over mechanical harvest (1,30). Yield of pickling cucumbers in this single harvest system is influenced by the ability of plants to develop several fruit simultaneously. This concentration of fruit set is unapparent in current pickling cucumber hybrids since they usually produce one to two marketable fruits per plant (1,5,7,26,28,30,37,28). Tiedjens (42) in 1928 was the first to report that the low number of fruits per plant was due to an inhibitory effect by the first-set fruit. The presence of a developing fruit exerted an inhibitory effect upon growth of subsequent fruit as well as upon the production of pistillate flowers and further vegetative growth of the plant. Since then, several researchers have confirmed the same "inhibitory first-fruit effect" in *Cucumis sativus* (3,4,5,6,7,10,11,14,15,16,17,18,27,33,35,38,45) and other cucurbit species (9,19,25,34). This fruit growth depression proceeds with seed development in fertilized fruit, and remains until the seed coats harden, whereupon the plant starts to exhibit signs of renewed vegetative growth, flowering, and fruiting (16,27,33).

Several ways to overcome fruit inhibition have been suggested. The fruit may be picked or excised from the plant which removes the inhibitory effect until the next fruit begins to develop when it will again exhibit inhibition over other fruits (10,19,27,42). Gustafson

(17) demonstrated that parthenocarpic fruits had little inhibitory effect on other fruit and confirmed McCollum's observations (27) that developing fertilized ovules produced a growth inhibitor. Since auxins have been suggested to be the growth inhibitor compounds several workers have stimulated parthenocarpic fruit set with natural and synthetic auxins and auxin transport inhibitors (3,4,5,6,12,18,33). Pike and Peterson (35) and Denna (11) showed that genetically parthenocarpic cucumber lines produced several fruits per plant which indicated that parthenocarphy, at least partially, overcomes fruit-set inhibition.

Tiedjens (42) in 1928 and Cantliffe (4) in 1974 suggested that by breeding varieties which develop many fruits simultaneously at the same node, inhibition could be overcome. Whitaker and Davis (45) stated that, within a particular cultivar, there is a correlation between the number of flowers and the number of fruit produced. Yield, among other factors, depends on (1) the ability of a variety to produce a large number of flowers, (2) to produce them early, (3) to fertilize a high percentage of the total number of pistillate flowers, and (4) to fertilize those which appear early in the growing season. The objectives of this research were: a) to breed gynoecious cucumber lines which produce multiple-pistillate flowers at the same node, b) simultaneously to pollinate these large number of pistillate flowers over a short time period so as to overcome "first-fruit inhibition," and c) consequently, yield would be higher due to the increased number of fruit per plant for pickling cucumbers used in once-over mechanical harvest systems.

MATERIALS AND METHODS

Plant material. In order to develop hermaphroditic pollen parents necessary for the production of gynoecious hybrid seed, crosses of several gynoecious lines with a Russian hermaphroditic line (MSU 4108H) were made in 1971. It was observed that MSU 4108H produced multiple hermaphroditic flowers per node and that a low frequency of gynoecious F_2 recombinants also produced multiple-pistillate flowers per node. Based on this observation, the yield potential of several early generation gynoecious lines that express multiple-pistillate flowers per node was measured (Table 1).

Evaluation and selection of F_2 plants. On December 15, 1976 twelve F_2 seeds of each selected F_2 family were germinated in peat pots with soil culture. Two weeks later, six seedling of the selected families were transplanted into raised greenhouse soil benches. On February 1 the number of pistillate flowers per node per plant was counted from the sixth to the tenth nodes. From this first evaluation, 44 gynoecious plants with the highest number of pistillate flowers per node were selected out of the 542 plants initially planted. The number of pistillate flowers on nodes eleven through fifteen were counted on February 21 for the 44 selected plants. Sixteen outstanding plants from the second evaluation were selected for self-pollination and seed increase (Table 2). Lateral cuttings were taken from the selected individual plants for rooting and cloning. The rooted and transplanted cuttings were treated with GA4/7 (37) to induce staminate flowers for self-pollination and F_3 seed production.

Table 1. Pedigrees selected for F_2 evaluation, which by observation, segregated F_2 gynoecious recombinants with multiple-pistillate flowers per node.

Greenhouse no.	MSU pedigree	No. of families
4499	Gy3 x 4108H	8
4500	713-5G x 4108H	12
4502	183G x 4108H	14
4503	3393G x 4108H	18
4504	153G x 4108H	11
4505	Gy54 x 4108H	10
4508	844G x 4108H	7
4795-1	Gy54 x 4108H	2
4823-8	Gy3 x 4108H	1
4824-1	Gy3 x 4108H	1
4827-2	Gy3 x 4108H	1
4836-2	35G x 4108H	1
4846-1	183G x 4108H	1
		Total 87

Table 2. Outstanding individual F_2 cucumber plants selected for highest number of pistillate flowers per node and self-pollinated to produce F_3 lines.

Greenhouse no.	Seed source	MSU pedigree	MSU line no.
7592-4	4503	3393G x 4108H	592-4G
7598-1	4503	3393G x 4108H	598-1G
7598-2	4503	3393G x 4108H	598-2G
7598-3	4503	3393G x 4108H	598-3G
7598-4	4503	3393G x 4108H	598-4G
7602-3	4503	3393G x 4108H	602-3G
7603-5	4503	3393G x 4108H	603-5G
7604-4	4503	3393G x 4108H	604-4G
7607-4	4503	3393G x 4108H	607-4G
7608-2	4503	3393G x 4108H	608-2G
7608-4	4503	3393G x 4108H	608-4G
7612-3	4824-1	Gy3 x 4108H	612-3G
7644-2	4504	153G x 4108H	644-2G
7644-3	4504	153G x 4108H	644-3G
7648-3	4504	153g x 4108H	648-3G
7661-5	4502	183G x 4108H	661-5G

Greenhouse experiment. During the Summer of 1977, the yield potential of the outstanding 16 individual F_3 selections was tested using a randomized complete block design with 3 blocks and 6 plants per block for line tested. The lines were compared with four commercial hybrid cultivars: Green Star (Harris Seed Co.), Premier and Pioneer (Asgrow Seed Co.), and Kora (Nundems Zaden Co.). The first three hybrids are currently used in Michigan for pickling cucumber production, while the last one, Kora, is a pickling cucumber used in the Netherlands which exhibits multiple-pistillate flowers per node (13,21). The seeds were planted in peat pots with soil culture on June 29 and transplanted into raised greenhouse beds on July 11. Plants were fertilized every other week by irrigating with a solution containing 6 g fertilizer per plant (20.0%N: 8.7%P: 16.6%K) to 4 l water. The main stem of each plant was trained vertically on a 2 m bamboo stake. All lateral branches were pruned prior to pollination (34). Cucumber flowers were hand-pollinated in the morning with randomly mixed pollen from 2 staminate flowers obtained from monoecious (MSU 8519) and androecious (MSU 5802A) lines. All flowers on the main stem of each plant were pollinated when the first flower opened at the sixth node and when subsequent flowers opened over a 5-consecutive day period (8).

Harvesting was done on an individual plant basis. Each plant was harvested when at least one fruit reached 5 cm (2 inches) in diam (28,30). The following data were collected: number and weight of fruits per plant, number of pistillate flowers per node per plant from the 6 through 15 nodes, and the number of pollinated flowers per day. The number and weight of the fruits harvested according to each pollination day was then calculated.

Field experiment. The sixteen selected lines were evaluated in the field using a randomized complete block design with 3 blocks and single plots. Soil samples were taken from each block prior to planting for analysis by the MSU Soil Testing Laboratory (45). Results indicated that standard fertility recommendations were warranted (30). Forty seeds were planted per plot of 7.62 m (25 feet) long and 1 m (3.33 feet) wide rows were used to eliminate plant population as a yield factor. Twenty-five plants per plot were desired, but due to severe bird attacks and soil crusting during germination, a minimum of 10 plants were obtained. The monoecious line, MSU 8519, was planted as the outside guard row and as every third plot to provide an abundant pollen source for bee pollination. Standard cultural practices (30) were used throughout the growing season and irrigation was supplied as needed. Harvesting was done when one or two fruits per plot reached 5 cm (2 inches) in diam (28,30). The following data were collected: number and weight of fruits per plot, and the number of pistillate flowers per node per plant (nodes 6 through 15) from a random sample of four plants per plot.

Analyses of variance were performed using the computer program SPSS (33) of the Michigan State University Computer Laboratory. Mean comparisons were made by Duncan's Multiple Range Test for equal sample sizes, and by the t and F tests for unequal sample size (42). Correlation and regression analyses were done following the procedures explained by Little and Hills (24).

RESULTS AND DISCUSSION

Evaluation and selection of F_2 plants. The number of pistillate flowers per node from the selected 16 individual outstanding F_2 plants ranged from 4.3 (MSU 607-4G) to 2.5 (MSU 612-3G) (Table 3). Other characteristics such as fruit and spine color, spine type, and plant growth were also noted, but are not reported here since they are not of interest to the immediate objectives of this research.

Greenhouse experiment. The total number of pistillate flowers produced per 10 nodes by each line varied from 2.1 to 41.3 and their differences were highly significant (Table 4). The 15 MSU lines selected for multiple-pistillate flowers produced more pistillate flowers than any of the four commercial hybrid cultivars. The line MSU 598-2G was discarded because the plant stand was lost. The MSU lines with the highest total numbers of pistillate flowers were 604-4G, 598-3G, 602-3G, 598-1G, and 598-4G ranging from 41.3 to 37.6 total pistillate flowers for the 10 nodes. In contrast, the four commercial hybrids ranged from 9.6 to 2.1 pistillate flowers for the same 10 nodes.

Highly significant differences were also found for the number and weight of fruit produced per plant (Table 5). The MSU lines with multiple-pistillate flowers per node produced higher yields than any of the commercial hybrids. The total number of pistillate flowers pollinated per plant during the 5-pollination days also was highly significant for the lines and varieties (Table 6). The MSU lines with multiple-pistillate flowers provided higher number of flowers for pollination;

Table 3. Number of pistillate flowers per node for selected individual outstanding F_2 plants in preliminary greenhouse screening used to derive F_3 lines.

MSU line no.	No. pistillate flowers/node[z]
407-4G	4.3 ± 1.49
604-4G	3.4 ± 1.26
661-5G	3.4 ± 2.06
608-2G	3.3 ± 0.67
598-4G	3.2 ± 0.63
608-4G	3.2 ± 0.91
644-3G	3.2 ± 1.39
603-5G	3.0 ± 0.47
602-3G	3.0 ± 0.81
598-2G	3.0 ± 1.33
644-2G	2.9 ± 0.73
598-1G	2.8 ± 0.91
648-3G	2.8 ± 1.03
592-4G	2.8 ± 1.03
598-3G	2.5 ± 1.08
612-3G	2.5 ± 1.35
Range	4.3 to 0.7

[z]Each value is the mean and the standard deviation of the number of pistillate flowers per node from 10 nodes (nodes 6 through 15).

Table 4. Number of pistillate flowers from 10 nodes per plant in a greenhouse experiment with F_3 lines of pickling cucumbers with multiple-pistillate flowers per node compared to standard hybrid varieties.

Variety or line number	Pistillate flowers/node for node number										Total per 10 nodes**
	6	7	8	9	10	11	12	13	14	15	
604-4G	2.2	2.3	2.6	3.0	3.7	5.1	5.0	5.4	5.8	6.2	41.3a[z]
598-3G	2.7	2.8	3.4	3.5	3.9	3.9	4.2	4.8	4.8	4.8	38.8ab
602-3G	2.5	3.7	3.4	3.5	3.6	3.7	4.4	4.4	4.4	4.4	38.0abc
598-1G	2.8	3.6	3.8	4.1	3.9	3.9	4.0	3.9	4.0	3.7	37.7abc
598-4G	3.1	3.3	3.7	3.9	3.8	3.9	3.9	4.1	4.1	3.8	37.6abc
648-3G	2.2	2.7	2.9	3.6	2.9	3.8	4.3	4.8	3.6	4.2	35.0bcd
603-5G	2.5	2.7	3.1	3.2	3.7	3.6	3.7	3.9	3.6	4.0	34.0bcd
592-4G	2.9	2.8	3.2	3.4	3.6	3.5	3.7	3.6	3.4	3.1	33.2cd
608-2G	2.7	2.5	2.9	2.9	3.0	3.2	3.4	3.4	3.5	3.6	31.3de
644-2G	2.7	2.9	2.6	2.7	3.3	3.6	3.7	3.2	3.3	3.2	31.2de
608-4G	1.7	1.9	2.3	2.7	2.8	3.1	2.8	2.9	3.1	2.8	26.1ef
644-3G	1.8	1.8	2.2	2.1	2.2	2.2	2.3	2.4	2.9	2.9	22.8fg
607-4G	1.4	1.3	2.1	2.2	2.3	2.4	2.7	2.6	2.4	2.8	22.3fg
611-5G	2.0	2.0	2.2	2.0	2.2	2.5	2.2	2.0	2.2	2.5	21.8fg
612-3G	1.3	1.5	1.9	1.6	1.2	1.8	2.3	1.7	2.2	2.4	17.9g
Kora	0.3	0.2	0.5	0.6	0.5	0.7	1.6	1.7	1.8	1.7	9.6h
Pioneer	0.7	0.3	0.6	0.4	0.5	0.5	0.5	0.4	0.6	0.7	5.2hi
Green Star	0.1	0.4	0.4	0.2	0.1	0.2	0.1	0.4	0.7	0.7	3.3i
Premier	0.1	0.2	0.2	0.1	0.3	0.1	0.3	0.2	0.3	0.3	2.1i

**Highly significant difference at 1% level.

[z]Mean separation in column by Duncan's Multiple Range Test, 5% level; C.V. = 10.9%.

Table 5. Yield as number and weight (g) of fruits per plant from a greenhouse experiment with F_3 lines of pickling cucumber with multiple-pistillate flowers compared to hybrid varieties with single-pistillate flowers. Varieties are ranked in Table by mean total fruits per plant.

Variety or Line Number	Number and Weight of fruits per plant by grades^y										Total fruits**	Total wt.**
	No.1	Wt.1	No.2	Wt.2	No.3	Wt.3	No.4	Wt.4	No.C	Wt.C		
608-4G	1.33	12	1.05	52	1.22	137	0.06	210	0.06	1	4.88a^z	412ab^z
608-2G	0.61	4	1.11	53	1.28	154	1.44	241	0.28	13	4.72ab	465a
648-3G	1.27	8	0.17	12	0.72	95	1.47	328	0.37	29	4.00abc	472a
598-3G	1.22	8	0.22	11	0.72	92	1.55	349	0.22	10	3.93abc	470a
598-4G	1.22	8	0.33	21	0.56	69	1.22	253	0.39	29	3.72abcd	380ab
592-4G	0.92	7	0.18	11	0.77	87	1.29	202	0.40	26	3.56abcd	333abc
604-4G	1.11	7	0.00	00	0.45	65	1.28	307	0.56	34	3.40abcd	413ab
602-3G	0.67	5	0.22	11	0.61	86	1.39	263	0.33	5	3.22abcd	370ab
Green Star	0.92	7	0.35	16	0.34	42	1.33	290	0.18	8	3.12abcd	363ab
598-1G	0.55	3	0.39	21	0.78	87	1.28	234	0.11	3	3.11bcd	348abc
603-5G	0.45	5	0.50	22	0.50	63	1.50	265	0.11	5	3.06bcd^z	360ab^z
661-5G	0.56	3	0.17	7	0.33	39	0.56	91	1.33	78	2.95cd	218c
644-2G	0.67	4	0.33	13	0.56	67	1.22	219	0.00	00	2.78cd	303bc
644-3G	0.61	3	0.11	6	0.33	34	1.33	242	0.33	12	2.71cd	297bc
Kora	0.61	4	0.22	11	0.11	13	1.17	229	0.22	17	2.33cd	274bc

Table 5. Continued.

Variety or Line Number	Number and Weight of fruits per plant by grades[y]										Total fruits**	Total wt.**
	No.1	Wt.1	No.2	Wt.2	No.3	Wt.3	No.4	Wt.4	No.C	Wt.C		
607-4G	0.33	2	0.07	3	0.32	42	1.15	219	0.19	13	2.06d	279bc
612-3G	0.00	0	0.31	11	0.58	58	0.97	136	0.11	5	2.05d	210c
Premier	0.33	2	0.20	9	0.28	33	1.07	233	0.14	10	2.02d	287bc
Pioneer	0.35	3	0.18	6	0.00	00	1.31	291	0.17	9	2.01d	309bc

**Highly significant difference at 1% level.

[z]Mean separation in columns by Duncan's Multiple Range Test, 5% level; C.V = 28.22%.

[y]Fruit size grades were determined using the grading system adopted by the Pickling Cucumber Improvent Committee, St. Charles, Il 60174. They are as follows: size no. 1 fruit are less than 2.5 cm diam (<1-1/16 in.); size no. 2 fruit are 2.7 to 3.8 cm diam (1-1/16 to 1 1/2 in.); size no. 3 fruit are 3.8 to 5.1 cm diam (1 1/2 to 2 in.); size no. 4 are greater than 5.1 cm diam (>2 in.); culls (C) include nubs and crooks.

Table 6. Number of pistillate flowers pollinated per plant during a period of 5 days in a greenhouse experiment with F_3 lines of pickling cucumbers with multiple-pistillate flowers in contrast to hybrid varieties with single-pistillate flowers.

Variety or Line Number	Number flowers pollinated per day					Total flowers**
	1^{st}	2^{nd}	3^{rd}	4^{th}	5^{th}	
Kora	1.4	1.1	1.6	2.4	3.9	10.4 a^z
598-3G	1.6	1.3	0.8	1.8	2.1	7.6 ab
648-3G	1.6	1.3	1.1	1.4	1.9	7.3 abc
661-5G	1.4	0.7	1.8	1.1	2.2	7.2 abc
598-4G	1.2	1.2	1.3	1.4	1.5	6.6 bcd
602-3G	1.2	0.6	1.1	1.4	1.9	6.2 bcd
608-4G	1.3	0.9	0.9	1.1	1.6	5.8 bcd
592-4G	1.6	0.9	1.0	0.8	1.4	5.7 bcd
644-3G	1.3	0.9	1.0	1.2	1.1	5.5 bcd
608-2G	1.4	0.8	1.2	1.1	1.1	5.4 bcd
Green Star	1.5	1.1	1.0	1.1	0.6	5.3 bcd
604-4G	1.2	0.9	1.3	1.1	0.7	5.2 bcd
607-4G	1.5	0.7	0.6	1.6	5.1	5.1 bcd
598-1G	1.2	0.6	0.8	0.9	1.2	4.7 bcd
644-2G	1.2	0.3	0.7	1.3	1.1	4.6 bcd
612-3G	1.2	0.4	0.6	1.2	0.9	4.3 cd
Pioneer	1.2	0.6	0.7	0.7	1.0	4.2 cd
Premier	1.1	0.4	0.7	0.8	0.9	3.9 d
603-5G	1.4	0.5	0.4	0.7	0.8	3.8 d

**Highly significant differences at 1% level.

^{z}Mean separation in column by Duncan's Multiple Range Test, 5% level; C.V. = 10.91%.

although Kora also produced an abundance of pistillate flowers. The variety Kora produced multiple-pistillate flowers per node, but was relatively late in this expression as compared to the precocious flowering of the MSU lines. Previous researchers have made the same observation (13, 21). Under greenhouse conditions Kora performed as a typical monoecious plant as described by Nitsch (33). At early stages, only single staminate and occasional pistillate flowers per node were produced; but at later stages, continuous pistillate flowers were borne. However, Kora was different in that large numbers of flowers were produced in a concentrated flowering pattern; i.e., several open flowers per node per day.

In order to establish the relationship among all these variables, which may affect yields for once-over harvest, correlation and regression analyses were performed (Table 7). Strong support was found for the assumption that large numbers of pistillate flowers might increase the yield potential for once-over harvest. A highly significant positive correlation (0.59**) was found between the number of flowers and the number of fruits per plant (Figure 1). Moreover, the number of fruits per plant and the weight of these fruits was also highly correlated (0.81**) (Figure 2). A multiple regression analysis was done to define the relationship among the three components of yield (number and weight of fruits, and number of pistillate flowers). The multiple regression coefficient was found to be highly significant ($R = 0.82^{**}$; Figure 3). The number of flowers and fruits accounted for 66.4% of the variability in weight (yield) of the fruits per plant. The number of flowers accounted for 30.2% of the variability in weight of fruits; whereas, the number of fruits accounted for 65.6% of the variability

Table 7. Simple correlation coefficients for yield characteristics of pickling cucumbers evaluated in a greenhouse and field experiment.

Characteristics	Coefficients of correlation			
	(1)	(2)	(3)	(4)
<u>Greenhouse Experiment</u>				
No. flowers/plant (1)	1.00	0.59**	0.55*	0.08^{ns}
No. fruits/plant (2)		1.0	0.81**	0.22^{ns}
Wt. fruits/plant (3)			1.00	0.13^{ns}
No. pollinated flowers/plant (4)				---
<u>Field Experiment</u>				
No. flowers/plant (1)	1.00	0.02^{ns}	-0.35^{ns}	---
No. fruits/plant (2)		1.00	0.00^{ns}	---
Wt. fruits/plant (3)			1.00	---

** and * indicate highly and significant differences at 1% and 5% levels, respectively; ns is nonsignificant at 5% level.

Figure 1. Effect of multiple and single-pistillate flowers per node on the yield of pickling cucumber.

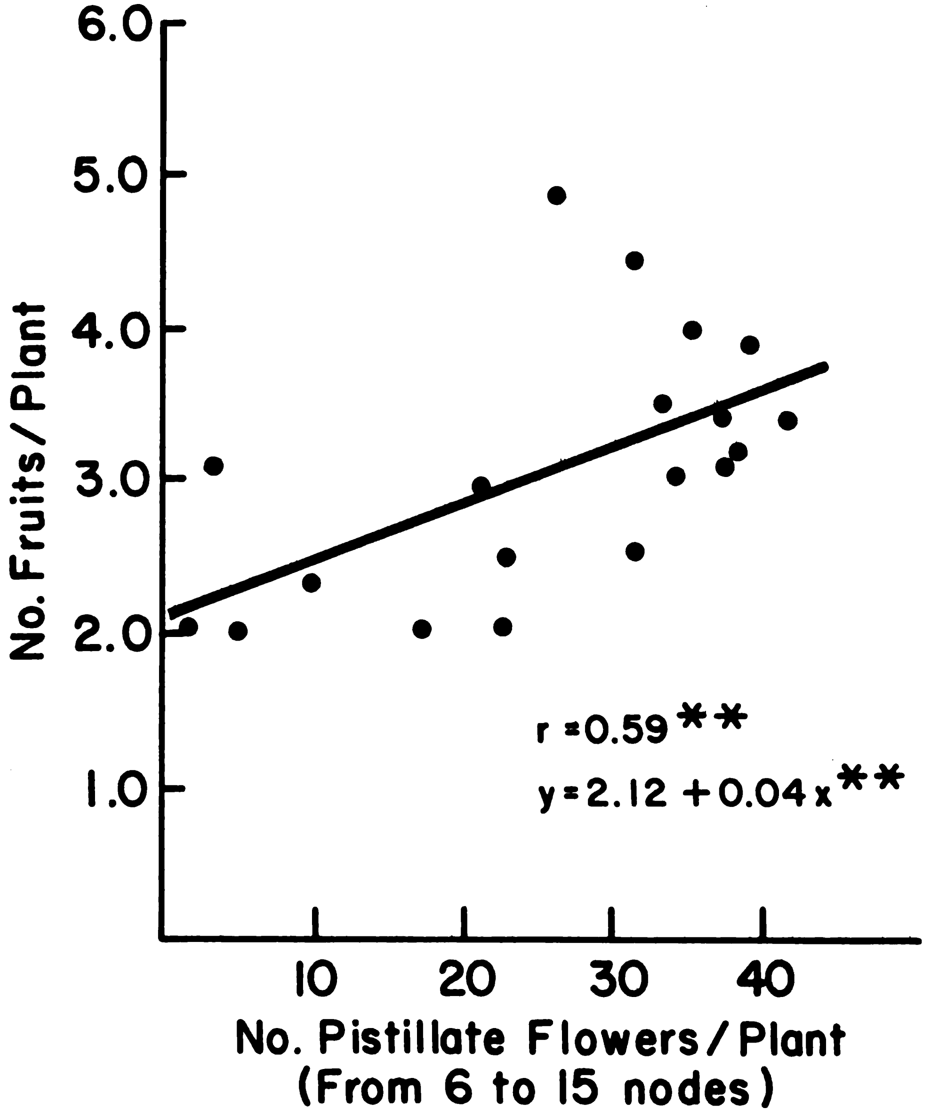

6.0
5.0
4.0
3.0
2.0
1.0
No. Fruits/Plant
r = 0.59 **
y = 2.12 + 0.04 x **
10
20
30
40
No. Pistillate Flowers/Plant
(From 6 to 15 nodes)

Figure 2. Effect of number of fruits set per plant on the weight of these fruits in pickling cucumber.

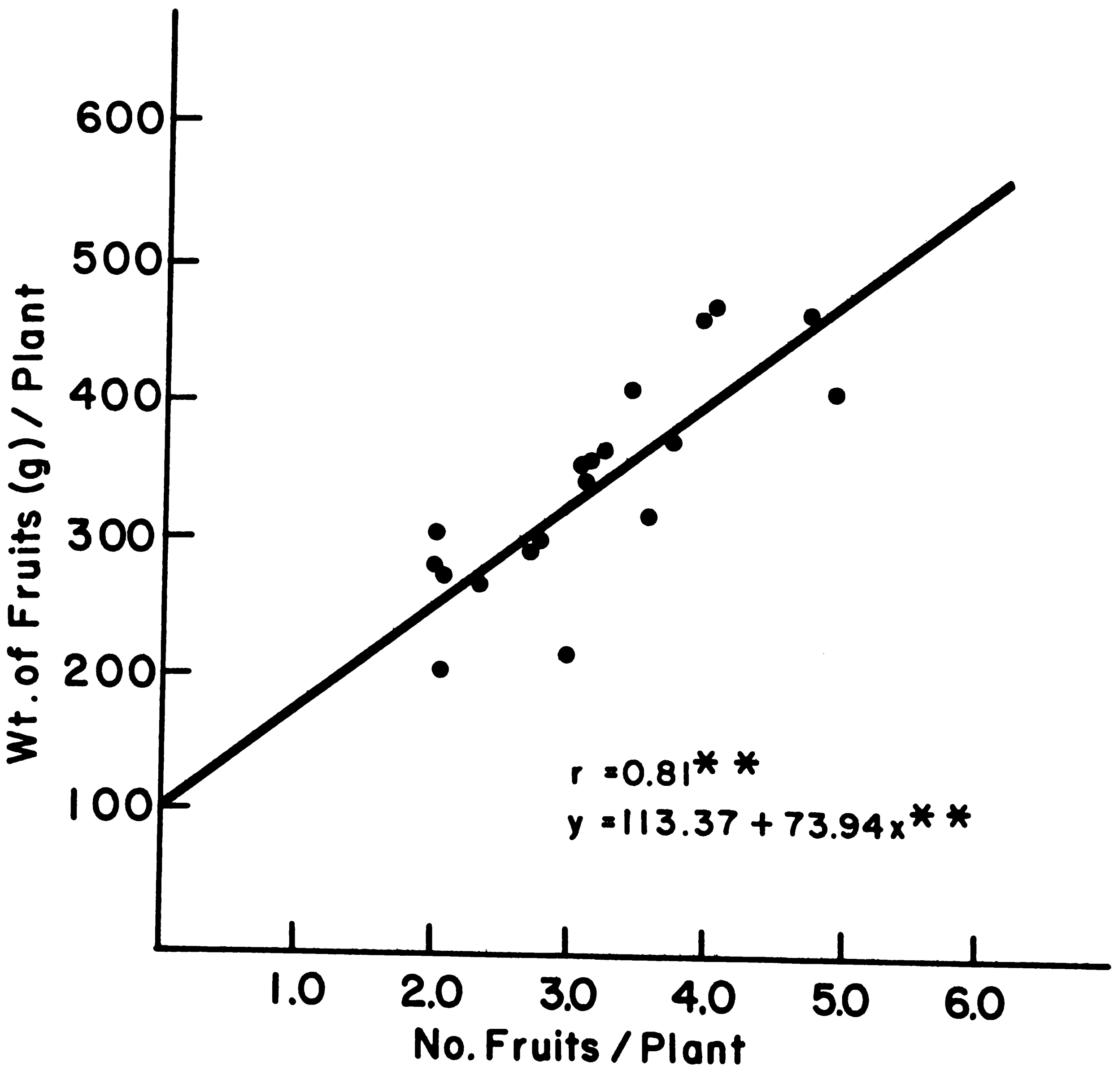
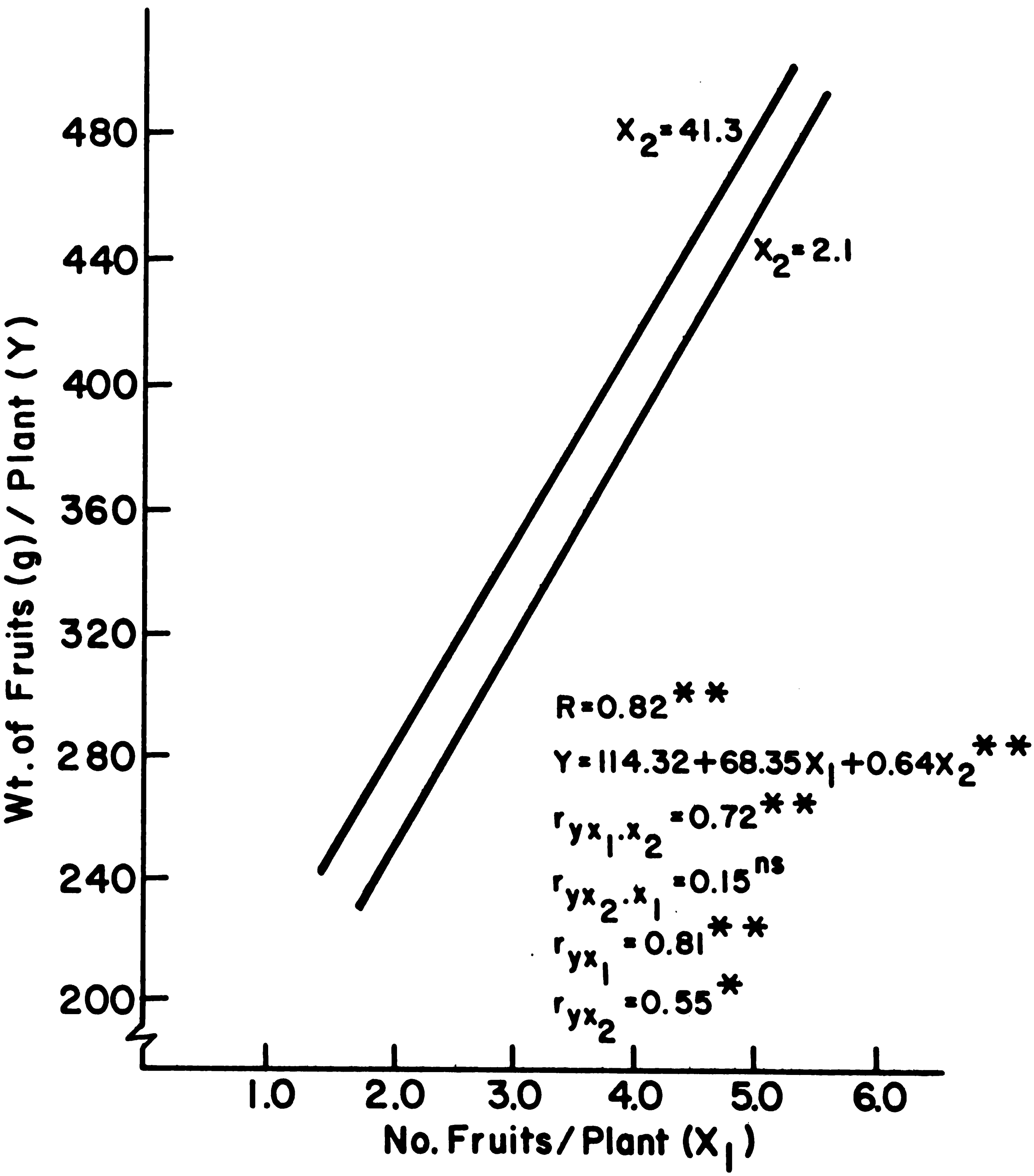

600
500
400
300
200
100
Wt. of Fruits (g) / Plant
r =0.81**
y =113.37 + 73.94x**
1.0
2.0
3.0
4.0
5.0
6.0
No. Fruits / Plant

Figure 3. Partial regression of yield, as weight of fruits per plant (Y), on number of fruit per plant (X_1) versus total regression where X_2 is number pistillate flowers per plant from 10 nodes.



480
440
400
360
320
280
240
200
Wt. of Fruits (g) / Plant (Y)
$X_2 = 41.3$
$X_2 = 2.1$
$R = 0.82^{**}$
$Y = 114.32 + 68.35X_1 + 0.64X_2^{**}$
$r_{yx_1 \cdot x_2} = 0.72^{**}$
$r_{yx_2 \cdot x_1} = 0.15^{ns}$
$r_{yx_1} = 0.81^{**}$
$r_{yx_2} = 0.55^{*}$
1.0
2.0
3.0
4.0
5.0
6.0
No. Fruits / Plant (X_1)

in weight of the fruits per plant. These correlations coincided with those reported earlier by Hutchins (20), although his correlation coefficients were higher than ours. Recently, Smith and Lower (41) found a correlation of 0.84** between the number of fruits harvested for once-over harvest and their harvest value which agrees closely with ours. They concluded that the number of fruits, as correlated to the dollar value of their size distribution, was the best parameter to estimate yield of pickling cucumbers for once-over harvest systems. Our data suggest that breeding for multiple-pistillate flowers per node in gynoecious pickling cucumbers might provide a means for increasing the number of fruits per plant for once-over mechanical harvest.

All correlations between the number of flowers pollinated during the 5-day pollination period with number of flowers per plant, number of fruits, and weight of fruits were nonsignificant at the 5% level (Table 7). This was probably because of the higher number of flowers pollinated from Kora (10.4) in relation to the low number of flowers (9.6), low number of fruits per plant (2.33), and low weight of fruits per plant (274 g). By observation, Kora produced an abundance of pistillate flowers which increased dramatically with age and time. However, they were expressed after nodes 6 through 15 were read indicating an incipient expression of the multiple-flowering character. The correlations were then found significant at the 5% level. Hence, the large number of pistillate flowers per plant increased the number of flowers to be pollinated and subsequently the number of fruit set and resultant yield.

Field experiment. The MSU lines 608-4G, 608-2G, 648-3G, and 598-3G were omitted from the field experiment due to a stand loss in these plots.

Their results are reported for reference sake (Table 8) since they were outstanding lines in both greenhouse and field experiments.

Table 8. Number of pistillate flowers per plant for 10 nodes and number and weight of fruits per plant from 4 MSU lines omitted from the field experiment due to a stand loss in field plots.

MSU line no.	No. flowers	No. fruits	Wt. (g) fruits
598-3G	32.8	6.60	304
608-2G	29.0	7.35	267
608-4G	24.3	5.10	184
648-3G	20.5	7.16	405

All the MSU lines, selected for multiple-pistillate flowers, produced as many flowers in the field as in the greenhouse, except MSU 661-5G (Table 9). Accordingly, this genetic character is not adversely affected by field growing conditions. The MSU lines expressed the higher pistillate flower counts with up to 39.2 pistillate flowers per plant from 10 nodes (MSU 598-1G); whereas, the commercial hybrids only produced 9.1 to 14.6 pistillate flowers per plant for 10 nodes.

Although the number of fruits per plant was nonsignificant across all varieties and lines, there were significant differences between means (Table 10). However, highly significant differences were found for the total weight of fruits per plant (Table 10). The correlation between number and weight of fruits and number of flowers per plant were nonsignificant (Table 7). Apparently, under field conditions the commercial hybrids expressed all their hybrid vigor; whereas, the F_3 lines with multiple-pistillate flowers were at a competitive disadvantage

Table 9. Number of pistillate flowers from 10 nodes per plant from a field experiment with F_3 pickling cucumber lines selected for multiple-pistillate flowers in contrast to 3 commercial hybrids with single-pistillate flowers.

Variety or line no.	Pistillate flowers/node for node number										Total per 10 nodes**
	6	7	8	9	10	11	12	13	14	15	
598-1G	3.7	3.3	3.8	3.8	4.1	4.2	.43	4.0	4.1	3.9	39.2 a[z]
603-5G	2.8	2.9	2.9	3.3	2.9	3.4	3.9	3.7	3.4	3.6	32.7 b
598-4G	2.5	2.8	2.9	3.0	3.3	3.6	3.7	3.4	3.8	3.7	32.7 b
598-2G	2.8	3.2	3.2	3.1	3.3	3.1	3.3	3.4	3.4	3.6	32.4 b
602-3G	2.2	2.3	2.2	2.8	2.8	3.4	3.1	3.3	3.5	3.3	28.9 bc
592-4G	2.3	2.3	2.7	2.6	2.8	3.0	2.9	2.6	3.2	3.3	27.7 bcd
644-2G	2.1	2.7	2.3	3.0	2.8	2.6	3.1	2.6	2.8	2.8	27.0 cde
644-3G	2.0	1.9	2.0	3.3	3.0	3.1	2.5	2.8	2.6	2.5	25.7 cde
607-4G	2.0	2.0	2.3	2.8	2.4	3.2	2.8	2.8	2.7	2.6	25.6 cde
612-3G	1.8	1.8	1.8	1.8	2.1	2.3	2.5	3.0	2.8	3.3	23.2 de
604-4G	1.7	1.3	1.7	2.9	2.4	.23	.25	2.2	2.5	2.9	22.4 e
Kora	1.1	1.2	1.3	1.1	1.3	1.3	1.5	1.4	2.3	2.1	14.6 f
Pioneer	0.9	1.0	1.1	1.0	0.9	0.9	1.1	1.3	1.7	1.1	11.0 fg
Green Star	0.8	0.9	0.9	0.8	0.9	1.1	1.1	1.1	1.0	1.3	9.9 fg
Premier	0.8	1.1	0.8	0.8	0.9	0.9	0.8	1.0	1.0	1.0	9.1 g
661-5G	0.7	0.6	0.7	0.6	0.8	0.7	0.8	0.8	0.6	0.5	6.8 g

**Highly significant differences at 1% level.

[z]Mean separation in column by Duncan's Multiple Range Test, 5% level; C.V. = 11.72%.

Table 10. Yield as number and weight (g) of fruits per plant from a field experiment with F_3 lines of pickling cucumber with multiple-pistillate flowers compared to hybrid varieties with single-pistillate flowers.

Variety or Line no.	Number and weight of fruits per plant[y]										Total fruits[ns]	Total wt.**
	No.1	Wt.1	No.2	Wt.2	No.3	Wt.3	No.4	Wt.4	No.C	Wt.C		
592-4G	5.62	43	1.43	76	0.61	86	0.09	18	0.25	10	8.00 a[z]	233 bcd[z]
Kora	5.03	25	1.23	75	1.13	145	0.08	18	0.33	8	7.80 a	271 abcd
603-5G	4.15	36	1.28	71	0.88	107	0.36	82	0.25	17	6.92 ab	313 abc
Green Star	4.94	33	0.88	49	0.64	49	0.29	79	0.00	0	6.75 ab	210 cd
Pioneer	3.72	30	0.97	51	1.06	150	0.63	151	0.20	16	6.58 ab	398 a
598-1G	4.28	33	1.17	75	0.70	90	0.15	38	0.27	10	6.57 ab	246 bcd
607-4G	4.48	36	0.71	31	0.80	103	0.17	38	0.14	5	6.30 ab	213 cd
602-3G	3.40	27	0.93	52	0.88	110	0.42	94	0.10	5	5.73 ab	288 abcd
644-2G	4.11	23	0.67	42	0.53	76	0.20	56	0.03	2	5.55 ab	199 cd
612-3G	1.94	16	0.90	44	1.83	201	0.77	138	0.10	6	5.54 ab	405 a
Premier	3.03	19	0.90	45	0.36	84	0.61	218	0.10	2	5.00 ab	368 ab
604-4G	2.08	25	1.09	44	0.85	134	0.26	82	0.52	37	4.80 ab	322 abc
598-4G	2.13	18	0.85	50	0.73	98	0.38	94	0.42	19	4.51 b	279 abcd
644-3G	2.68	20	0.73	43	0.76	91	0.21	61	0.21	5	4.48 b	220 cd
598-2G	2.91	26	0.46	27	0.74	101	0.06	8	0.17	10	4.33 b	172 d
661-5G	2.16	16	0.38	25	0.59	74	0.63	132	0.34	28	4.10 b	275 abcd

**Highly significant difference at 1% level; ns is not significant at 5% level.

[z]Mean separation in columns by Duncan's Multiple Range Test, 5% level; C.V. = 26.87%.

[y]For fruit size distribution details, see Table 5.

in contrast to the protected greenhouse conditions. In this field experiment, the yield of hybrids may have been favorably influenced by the low plant density and the environmental conditions during this growing season. Franken (13) worked with Kora during 3 continuous years and found that Kora produced from 0.4 to 2.9 fruits per plant depending on the sowing date. Pioneer yielded from 0.6 to 2.3 fruits per plant with an average of 7.1 pistillate flowers per plant counted to 15 nodes (5,37,38). In our field experiment, Kora produced 7.8 fruits and Pioneer 6.6 fruits per plant with an average of 11 pistillate flowers per plant.

Our yields were probably higher, on a per plant basis, because of the low plant population with wider rows and fewer plants per linear foot of row than plantings for once-over harvest. Notably, the commercial hybrids did not yield more than the multiple-pistillate lines even with their advantage of hybrid vigor. Here again, there is evidence that breeding for multiple-pistillate flowers per node may provide a significant potential for increasing fruit-set and yield of hybrid varieties used for once-over mechanical harvest.

Multiple versus single-pistillate flowers. To determine the performance of the lines selected for multiple-pistillate flowers, two types of plants were defined. Multiple-pistillate flowers (MP) are all those lines which produced an average of two or more pistillate flowers per node. Lines with single-pistillate flowers (SP) are those lines with fewer than two pistillate flowers per node. The difference between means was calculated using t and F test when $n_1 \neq n_2$ (42). From the greenhouse experiment, the MP plants were significantly higher than SP plants for total number of flowers per plant, number of fruits per plant, and weight of fruits per plant. However, a nonsignificant difference was noted for the total pollinated flowers per plant (Table 11).

Table 11. Mean comparison test of lines with multiple-pistillate flowers per node (MP) and lines with a single-pistillate flower per node (SP) of pickling cucumbers.[z]

Flower type	Yield characteristics			
	No. flowers per plant	No. fruits per plant	Wt. fruits per plant (g)	No. pollinated flowers/plant
Greenhouse Experiment (n_{MP} = 14 and n_{SP} = 5)				
MP	32.22 $\pm$ 6.59**	3.44 $\pm$ 0.77**	365.71 $\pm$ 76.48*	5.76 $\pm$ 1.10^{ns}
SP	7.62 $\pm$ 6.41	2.33 $\pm$ 0.47	288.60 $\pm$ 55.55	5.62 $\pm$ 2.72
Field Experiment (n_{MP} = 11 and n_{SP} = 5)				
MP	28.87 $\pm$ 4.98**	5.70 $\pm$ 1.16^{ns}	262.73 $\pm$ 67.04^{ns}	---
SP	10.28 $\pm$ 2.86	6.50 $\pm$ 1.48	304.40 $\pm$ 76.97	---

[z]Differences between means were calculated using t and F test when $n_1 \neq n_2$.

**and * indicate highly and significantly difference at 1% and 5% levels, respectively; ns is nonsignificant at 5% level.

From the field experiment, MP plants produced significantly higher flower numbers than SP plants, although the number and weight of fruits produced was not different. These results agree with those reported by Motes (30); i.e., that yield is not necessarily related to number of pistillate flowers with current hybrids. We suggest that the yield potential of hybrid varieties for once-over harvest would likely be increased by the inclusion of the genetic trait for multiple-pistillate flowers per node with other necessary traits.

Fruit inhibition. A general definition for fruit set is stimulation of the ovary to develop into a fruit due to pollination and fertilization (14). Nitsch (33) stated that chemical stimuli may come from three sources: the vegetative part of the plant, the pollen and/or the ovules. This general definition does not agree with cucumber fruit set; because in 1937, Gustafson (16) showed that neither pollination and/nor fertilization were necessary for cucumber fruit set with parthenocarpic fruits. Later, parthenocarpic fruiting in cucumber was confirmed by several researchers (11,33,35). Thus, a new definition for cucumber fruit set can be proposed sinced growth of the ovary into a fruit is not always the result of embryo development and resulting seed. Fuller and Leopold (14) defined fruit set as follows: the condition in the cucumber ovary when it has received the signal from the plant itself to enlarge and develop into a fruit. This "fruit signal" is likely a plant hormone. Auxins, gibberellins and cytokinins have been shown to stimulate ovary development into a fruit (12,18,33). Moreover, auxin activity was found in pollen and in developing seeds (2,11,16,22,23,31,33). Earlier, Tupy and Ranganamy (43) suggested that the fruit set signal could be derived from other classes of compounds such as nucleic acids. Recently, Fuller and Leopold (15) demonstrated that "new" nucleic acid (RNA) synthesis is necessary for cucumber fruit growth which occurred within 9 hours after pollination.

The actual mechanism for cucumber fruit set is unknown; neither is the means of fruit inhibition by first-set fruit known. From our greenhouse experiment, the percentage of fruit inhibition for each pollination day in a comparison of MP with SP lines was made (Table 12). From both groups of plants, 1741 flowers were pollinated during the 5

Table 12. Comparison of pickling cucumber with multiple-pistillate and single-pistillate flowers per node for percentage of fruit inhibition for each pollination day; greenhouse experiment.

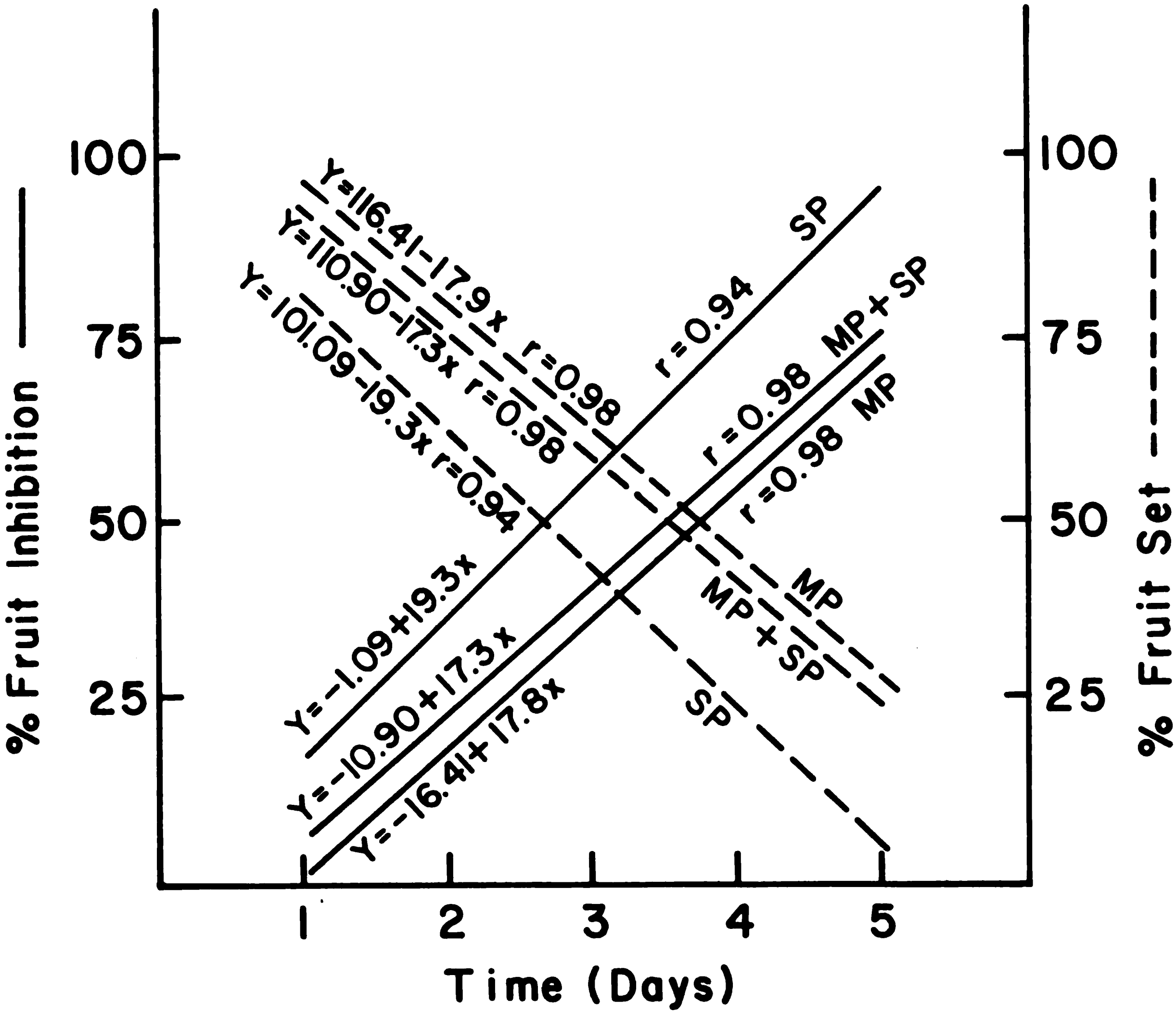
Pollination day number	Total pollinated flowers (no.)	Total fruits (no.)	Fruit inhibition (%)	Fruit set (%)	Total wt. fruits (g)
Multiple and single-pistillate flowers per node (305 plants)					
1	409	374	8.56	91.44	66975
2	249	207	16.87	83.13	23137
3	291	162	44.3	55.67	10654
4	354	130	63.28	36.72	4959
5	358	101	71.79	28.21	2658
Total	1741	974	44.06	55.94	108563
Multiple-pistillate flowers per node (221 plants)					
1	308	285	7.47	92.53	51429
2	191	169	11.52	88.48	19870
3	218	143	34.40	65.60	9752
4	257	107	58.37	41.63	3649
5	318	86	72.96	27.04	1624
Total	1292	790	38.85	61.15	86324
Single-pistillate flowers per node (84 plants)					
1	101	89	11.88	88.12	15546
2	58	38	34.48	65.52	3447
3	73	19	73.97	26.03	902
4	97	23	76.29	23.71	1310
5	120	15	87.50	12.50	1034
Total	449	184	78.84	21.16	22239

days and only 974 flowers set fruits or 44% fruit inhibition. The MP plants exhibited 39% fruit inhibition, whereas SP lines exhibited 79% fruit inhibition (Table 12 and Figure 4). Thus, the MP lines with genetic potential for multiple-pistillate flowers per node, which both increases the number of flowers to be pollinated and decreases the percentage first-fruit inhibition, subsequently produced more fruits per plant for the once-over harvest.

Our findings of fruit inhibition agree with those reported (7,26), but the mechanism for fruit inhibition is still unknown. Possibly, the same auxins responsible for fruit growth are also the chemical agents or signals which cause the inhibitory effect. There is some evidence that auxin transport inhibitors stimulate fruit set (3,4,5,6). Again, the question of source of auxin synthesis and mechanism for auxin transport in relation to fruit inhibition has not been adequately answered. Muir (31) determined that the endogenous auxins of pollen grains is insufficient to stimulate fruit set. It has been shown that the pollen tubes secrete an enzyme which synthesize auxin from tryptophane, the suggested precursor for indole-3-acetic acid (IAA;33), in the style, which subsequently stimulates ovary growth. Fuller and Leopold (14) found that fruit set occurred within 18 hours after pollination, but fertilization occurred 30 to 36 hours after pollination. Hence, pollination was a requirement for fruit set, but fertilization may not be required which corroborated the suggestion of Muir (31).

The possibility that ethylene plays a role in cucumber fruit inhibition has not been mentioned in the literature. The decrease in auxin content of the ovary shortly before anthesis may be signaled by ethylene.

Figure 4. Percentages of fruit inhibition (——) and fruit set (---) in the cucumber plant during a 5-day pollination period (MP is multiple-pistillate flowers and SP is single-pistillate flowers per node). The correlations of $r = 0.98$ are significantly different at the 1% level and $r = 0.94$ are significantly different at the 5% level.


% Fruit Inhibition ———
% Fruit Set - - - - - -
Time (Days)
100
75
50
25
1
2
3
4
5
Y=116.41-17.9x r=0.98
Y=110.90-17.3x r=0.98
Y=101.09-19.3x r=0.94
r=0.94 SP
r=0.98 MP+SP
r=0.98 MP
Y=-1.09+19.3x
Y=-10.90+17.3x
Y=-16.41+17.8x
MP
MP+SP
SP

High auxin concentrations stimulate ethylene synthesis (2); and conversely, high ethylene concentrations lower the level of auxin and inhibit auxin transport (2,22). Furthermore, very high auxin concentrations may make tissues insensitive to ethylene. We speculate that fruit inhibition occurs as follows: shortly before anthesis the decrease in auxin concentration is caused by ethylene production which blocks fruit growth. Then, at pollination, the pollen carrying the enzyme stimulates new auxin synthesis for fruit set which occurs within 18 hours of pollination (14). During this period, due to high auxin concentration, the ovary tissues become insensitive to ethylene, but ethylene production continues due to new auxin synthesis and its capacity for autocatalysis (2). Now, a large source of hormone which can be translocated throughout the plant inhibits (1) cell division or enlargement, (2) DNA synthesis, and (3) meristematic division of roots, shoots and auxillary buds, but without influencing RNA synthesis (2,22) is available from the "first-set" developing ovary.

This coincides with the results of Fuller and Leopold (15) regarding the necessity for RNA synthesis for fruit set. The inhibitory effect is removed by fruit harvest or maturation until a new fruit is set; and then, the inhibitory cycle is repeated. This agrees with our findings on fruit inhibition and those reported by Collison and Martin (7). Fruit inhibition occurred within 24 hours of pollination in our experiments, which coincided with the time for fruit set after pollination, 18 hours (15). Furthermore, fruit inhibition increased dramatically within 48 hours of pollination, which is the time required for fertilization and resultant higher auxin production rates and accumulation. This hypothesis might help explain the mechanism responsible for the contrast between the auxin content of the ovary before and shortly after pollination. More importantly, it could explain the well-known "first-fruit" inhibition effect so prevalent in cucumber plants. This idea merits further research regarding its validity.

CONCLUSION

Lines of pickling cucumber with multiple-pistillate flowers per node provide a significant potential for the development of new pickling cucumber hybrids for once-over harvest. The increased numbers of flowers per plant increases the number of flowers available for pollination which subsequently increases the number of fruits per plant by decreasing the percentage of fruit inhibition. There are more pistillate flowers per plant per day resulting in more possible pollinations with a more concentrated fruit set. This circumvents a portion of the "first-set" fruit inhibition, and produces more fruits per plant or yield for once-over mechanical harvest systems.

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