Table 2. Total number of staminate flowers on the main stem and laterals and perfect flowers on the main stem (averaged over stage and application number) resulting from $AgNO_3$ application in hermaphroditic cucumber lines.

$AgNO_3$ concn (mg/liter)	Total staminate flowers (main stem and laterals) + perfect flowers (laterals)[z]	
	MSU 7152H	MSU 669H
0	53.2	58.4
100	58.2	66.0
200	58.3	81.6
300	65.8	72.6
400	59.4	78.2

[z]Scheffe's MSD within columns is 7.1 (5% level).

increasing the concentration or making more than 1 or 2 applications.

Maximum benefit from conversion is achieved by inducing as many staminate flowers as possible during the critical period of fruit set. The number of staminate flowers produced on the main stem and laterals was influenced by the interaction between stage, concentration, and application number. Treatments initiated at stages 1 and 2 produced the greatest numbers, up to 89, in stage 2 (Fig. 2). Two applications of 300–400 mg/liter $AgNO_3$ induced the maximum number of staminate flowers for stage 2 plants. More applications were required when treatments were begun at earlier stages (e.g., 3 applications for stage 1 and 4 applications for stage 0).

Other researchers have used the number of staminate nodes as an indication of the effectiveness of treatments on sex expression (1, 2, 5, 6, 9, 10). We examined the percentage of staminate nodes to take into account the difference in the number of nodes caused by the determinate and indeterminate growth habits of the 2 lines used in this study. The conclusions were similar to those for duration of staminate flowering.

An unanticipated observation was that $AgNO_3$-treated plants produced more flowers than control plants (Table 2). It appears that $AgNO_3$ stimulates supernumerary bud development. A similar effect has been noted by researchers working with gibberellic acid (1, 4).

The maximum number of staminate flowers resulted when treatments were initiated at stages 1 and 2. Since the maximum period of early conversion occurred for treatments initiated at stages 0 and 1, stage 1 was determined to be the optimum stage at which to begin $AgNO_3$ treatment. Conversion to staminate flowering for G x H hybrid seed production was optimized by 3 to 4 applications of 200 to 400 mg/liter $AgNO_3$ initiated at stage 1. We suggest that seedsmen use these guidelines to experiment with the use of $AgNO_3$ to improve seed yields in stock seed programs and in hybrid production schemes using hermaphroditic cucumbers.

Literature Cited

1. Atsmon, D. and C. Tabbak. 1979. Comparative effects of gibberellin, silver nitrate, and aminoethoxyvinyl glycine on sexual tendency and ethylene evolution in the cucumber plant (*Cucumis sativus* L.). Plant & Cell Physiol. 20:1547–1555.
2. 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.
3. El-Shawaf, I.I.S. and L.R. Baker. 1981. Performance of hermaphroditic pollen parents in crosses with gynoecious lines for parthenocarpic yield in gynoecious pickling cucumber for once-over mechanical harvest. J. Amer. Soc. Hort. Sci. 106:356–359.
4. Fuchs, E., D. Atsmon, and A.H. Halevy. 1977. Adventitious staminate flower formation in gibberellin treated gynoecious cucumber plants. Plant & Cell Physiol. 18:1193–1201.
5. Kalloo, R.K.J. and S. Franken. 1978. Chemical induction of staminate flowers in four determinate gynoecious lines of pickling cucumber. Gartenbauwissenschaft 43:280–282.
6. Owens, K.W., G.E. Tolla, and C.E. Peterson. 1980. Induction of staminate flowers on gynoecious cucumber by aminoethoxyvinylglygine. HortScience 15:256–257.
7. Pike, L.M. 1974. 'TAMU Triple Cross' pickling cucumber. HortScience 9:83.
8. Pike, L.M. and W.K. Mulkey. 1971. Use of hermaphrodite cucumber lines in development of gynoecious hybrids. HortScience 6:339–340.
9. Pike, L.M. and C.E. Peterson. 1969. Gibberellin A_4/A_7 for induction of staminate flowers on the gynoecious cucumber (*Cucumis sativus* L.). Euphytica 18:106–109.
10. 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 14:542–544.

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Parthenocarpy in Gynoecious Cucumber as Affected by Chlorflurenol, Genetical Parthenocarpy, and Night Temperatures

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Abstract. **Methyl-2-chloro-9-hydroxyfluorene-(9)-carboxylate (chlorflurenol) effectively promoted parthenocarpic fruit development in gynoecious pickling cucumbers, *Cucumis sativus* L. Treatment with chlorflurenol increased yields of fruits under both greenhouse and open-field conditions. Yields were dependent on the degree of genetic parthenocarpy for each cultivar. Parthenocarpic yields following chlorflurenol treatment were higher with night temperatures of 16° and 21°C than with 27°.**

Once-over mechanical harvest of pickling cucumbers in Michigan produces a marketable yield of one to 2 fruits per plant with 115,000 plants/ha (11). The yield limitation in seeded cucumber is probably due to a phenomenon known as crown-fruit dominance (9) or "first-fruit" inhibition (17). First-fruit inhibition is an inhibitory effect on subsequent flowering, fruiting, and vegetative growth that is imposed by the first-fruit set on the vine. Therefore, in a once-over destructive harvest, only the one or 2 dominant fruits are removed and any further yield is precluded. Growers harvest mechanically when the majority of the fruit reach a size of 3.8 to 5.1 cm diameter to maximize economic returns (11). The large-sized fruits provide a large part of the value per hectare because of their weight, but price per unit weight is relatively less than for smaller fruits. Obviously, economic returns would be increased substantially if large numbers of small premium fruit could be harvested while

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Table 1. Effect of chlorflurenol on parthenocarpic yield of gynoecious pickling cucumber in the greenhouse.[z]

Main effects	Parthenocarpy phenotype	No. fruit	Fruit wt (g)
Cultivar			
MSU 684 x 581	Strong	16.1 a[y]	703 a
MSU 41 x 581	Moderate	11.8 b	422 b
MSU 713-5	None	9.9 c	296 c
Femcap	None	5.9 d	265 c
Chlorflurenol	Concn (mg/liter)		
	0	2.8 c	156 b
	40	12.8 b	540 a
	80	17.2 a	569 a
Cultivar x chlorflurenol			
MSU 684 x 581	0	7.3	470
	40	18.0	900
	80	23.0	734
MSU 41 x 581	0	3.3	123
	40	11.3	541
	80	20.7	601
MSU 713-5	0	0.3	24
	40	14.0	431
	80	15.3	342
Femcap	0	0	0
	40	8.0	404
	80	9.7	483

[z]5 plants

[y]Mean separation in columns within groups by Duncan's multiple range test, 5% level. Cultivar x chlorflurenol concn significant at 5% level.

achieving the same total weight per hectare.

Environment plays a major role in parthenocarpic fruit set. In particular, daylength is an important factor in seeded-fruit development (10) and thermophotoperiod for parthenocarpic fruit set (16) of pickling cucumber. Parthenocarpy can also be induced in pickling cucumber by several growth-regulating compounds (1, 2, 3, 4, 6, 8, 12, 14, 15). Chlorflurenol is an auxin transport inhibitor effective in promoting parthenocarpy in pickling cucumber (1). Although chlorflurenol increased the number of fruit per plant in research trials, commercial adaptation has not been accomplished. Genetic parthenocarpy has been reported in cucumber (5, 7, 13, 16), but pickling-cucumber cultivars bearing this trait are unavailable commercially. The aim of our research was to determine the effects of chlorflurenol, genetical parthenocarpy, and night temperatures on the parthenocarpic yield of gynoecious cultivars of pickling cucumber.

Greenhouse experiments used 4 gynoecious pickling cucumbers: Michigan State Univ. (MSU) gynoecious 713-5; MSU experimental hybrids 41 x 581 and 684 x 581; and the hybrid 'Femcap' (D. Vander Ploeg's Elite Zaden B.V., Barendrecht, Holland). Plants were grown in the spring with 25-cm diameter clay pots on greenhouse benches at 24°C (day) and 18° (night) temperatures using natural photoperiod. Fertilizer was applied every 2 weeks with 6 g per plant of 20N–8.6P–16.6K soluble fertilizer. The vines were maintained as single stems on bamboo stakes by pruning all laterals. Foilage was sprayed to runoff with appropriate chlorflurenol treatments when flowers appeared on nodes 8 to 10. Control plants were sprayed with distilled water. Fruits were harvested when about 10%, by weight, of the fruit had reached a size 3 grade for a given block/treatment combination. The experimental design was a randomized complete block with 5 plants per treatment in 3 blocks.

The same gynoecious lines were grown under field conditions at the Horticultural Research Center near East Lansing, Mich., using standard cultural practices (10). Plots were fertilized with 25 kg/ha N as urea prior to planting and 25 kg/ha N as NH_4NO_3 by sidedressing when the plants were about 20 cm long. The experimental design was a randomized complete block with 3 blocks. Each plot was 6.1 m long by 2.1 m wide (12.8 m^2) with 4 equally spaced rows and 160 plants per plot. Chlorflurenol was applied in the evening when flowers of the gynoecious plants were at anthesis on nodes 8 to 10. Application was made using a compressed CO_2 backpack sprayer with a boom attachment. Aqueous solutions of chlorflurenol were applied to the foliage at concentrations of 160 and 320 mg/liter at the rate of 1.6 liters per plot. Fruits from each plot were harvested by hand when 10%, by weight, had reached the size 3 category. The size-graded fruits were counted and weighed to estimate yields per plant based on Pickling Cucumber Improvement Committee sizes:

Grade	*Fruit diam (cm)*
1	<2.7
2	>2.7<3.8
3	>3.8<5.1
4	>5.1<5.7
5	>5.7<6.4
6	>6.4

To determine the effect of temperature on fruit yields, plants of MSU 41 x 581 were grown in the same greenhouse (24°C day, 16° night) prior to chlorflurenol application. Following chlorflurenol application, 5 plants

Table 2. Effect of chlorflurenol on parthenocarpic yield of gynoecious pickling cucumber in the field.[z]

Main effects	Parthenocarpy phenotype	No. Fruit	Fruit wt (kg)
Cultivar			
MSU 41 x 581	Moderate	347 a[y]	17.0 a
MSU 684 x 581	Strong	248 b	13.5 b
Femcap	None	156 c	9.2 c
713-5	None	143 c	6.8 d
Chlorflurenol	Concn (mg/liter)		
	0	95 c	6.9 c
	160	258 b	14.7 a
	320	318 a	13.3 b
Cultivar x chlorflurenol			
MSU 684 x 581	0	161 (27)[x]	9.2 (0.3)[x]
	160	403 (105)	18.2 (1.3)
	320	424 (113)	16.2 (1.6)
MSU 41 x 581	0	211 (39)	14.3 (0.5)
	160	602 (196)	22.8 (2.4)
	320	720 (258)	19.8 (3.1)
Femcap	0	58 (15)	3.3 (0.4)
	160	211 (46)	13.1 (0.7)
	320	374 (114)	13.9 (1.6)
MSU 713-5	0	38 (8)	2.1 (0.1)
	160	223 (61)	9.7 (0.7)
	320	351 (115)	10.6 (1.2)

[z]160-plant plots.

[y]Mean separation in columns within groups by Duncan's multiple range test, 5% level. Cultivar x chlorflurenol concn significant at 5% level.

[x]Indicates grade 1 contribution to total.

Table 3. Effect of chlorflurenol and night temperature on pathenocarpic fruit yield of gynoecious MSU 41 x 581 cucumber.

Night temp (°C)	No. fruit per plant[z]		Wt (g) fruit/plant[z]	
	Control	Treated	Control	Treated
		Expt. 1		
16	2.7 a	4.8 a	116.2 a	111.9 a
21	1.4 b	2.6 b	84.2 ab	92.3 ab
27	0.1 c	2.6 b	12.8 b	39.7 b
		Expt. 2		
16	0.2	7.6 a	0.6	65.8 a
21	0	2.8 b	0	68.1 a
27	0	1.4 b	0	97.2 a

[z]Mean separation in columns by Duncan's multiple range test, 5% level.

were transferred to separate greenhouses in which night temperatures were maintained at 16°, 21°, and 27°, with day temperatures of 24° in all greenhouses with natural photoperiod. A randomized complete block design was used with single-plant plots and 5 blocks. The experiment was run twice: once at Michigan State Univ. (Expt. 1) from February to April 1977 and once at Washington State Univ. (Expt. 2) from January to March 1979. Chlorflurenol was applied as an aqueous solution of 80 mg/liter until runoff when flowers at nodes 8 to 10 reached anthesis. Plants were harvested 10 to 14 days after treatment and yield was estimated by weight and number of fruit per plant.

In the greenhouse, chlorflurenol produced higher yields in parthenocarpic cucumber than in nonparthenocarpic (Table 1). The nonparthenocarpic 'Femcap' and MSU 713-5 had fewer fruits and lower weight than did the parthenocarpic lines. More fruits were produced with chlorflurenol application to MSU 713-5 than to 'Femcap'; both produced few fruits without chlorflurenol inducement. The moderate and strong parthenocarpic hybrids MSU 41 x 581 and MSU 684 x 581 produced 4.1 and 4.6 fruit per plant, respectively, with the high rate of chlorflurenol. Chlorflurenol induced more fruit set with 80 mg/liter chlorflurenol than with the 40 mg/liter rate, but the fruit weights were not significantly different at the 5% level. Notably, both the number and weight of fruits produced as a result of chlorflurenol application were significantly higher than those produced by the control when averaged across all lines and cultivars. On the average, chlorflurenol increased fruit numbers 4–6 times over the untreated plants; and cultivar differences for fruit numbers ranged from 5.9 to 16.1 (2.7 times).

Chlorflurenol increased yields significantly in the field experiment (Table 2). Overall, the higher concentration of chlorflurenol resulted in greater fruit numbers (about 3 times), whereas the lower concentration resulted in greater fruit weight (about 2.5 times) than in the control plants. Parthenocarpic cultivars produced greater fruit numbers and weight than did the nonparthenocarpic cultivars, whether treated with chlorflurenol or not.

Temperature has been shown to affect parthenocarpic fruit set (16). In our 2 experiments, fruit number was significantly less for each increase in night temperature in Expt. 1, but was not consistently less in Expt. 2 (Table 3). The difference in weight of fruit produced under different night temperatures was significant for Expt. 1, but not for Expt. 2. Apparently, presumed differences in respiratory rates as influenced by night temperatures could not account for all the differences in fruit yields.

Yields were enhanced by chlorflurenol under both field and greenhouse conditions. The yield increase was expressed as high numbers of fruit per plant which could be harvested once-over when the fruits were small and of premium value. The primary effect of chlorflurenol on parthenocarpy might be a redirecting of photosynthate to young ovaries on a more equal basis, alleviating fruit dominance and competition with vine growth (5). The success of chlorflurenol may be influenced by temperatures following application. We suggest that chlorflurenol might be used more successfully in growing areas with cooler (less than 21°C) night temperatures. Genetically parthenocarpic cultivars are more responsive to chlorflurenol than are nonparthenocarpic cultivars. Accordingly, stabilization of genetically parthenocarpic gynoecious cultivars by the timely application of chlorflurenol has real potential for increasing yields. A direct comparison of chlorflurenol-induced yields with conventional-seeded cucumber yields cannot be made because of the necessity for parthenocarpic fruit set and, hence, isolation from pollen. Nonetheless, pickling cucumber producers commonly realize relatively low yields of small-size fruit from once-over mechanically harvested fields. Development of a chlorflurenol treatment for the outdoor production of gynoecious cucumbers would contribute to increased yields of smaller sizes, especially for once-over harvest regimes.

Literature Cited

1. Beyer, E.M., Jr., and B. Quebedeaux. 1974. Parthenocarpy in cucumber: mechanism of action of auxin transport inhibitors. J. Amer. Soc. Hort. Sci. 99:385–390.
2. Cantliffe, D.J., R.W. Robinson, and R.S. Bastdorff. 1972. Parthenocarpy of cucumber induced by triiodobenzoic acid. HortScience 7:285–286.
3. Cantliffe, D.J. 1972. Parthenocarpy in the cucumber induced by some plant growth-regulating chemicals. Can. J. Plant Sci. 52:781–785.
4. Cantliffe, D.J. and S.C. Phatak. 1975. Parthenocarpic fruit development from grafted ovaries of *Cucumis sativus* L. Plant Physiol. 55:1107–1109.
5. Denna, D.W. 1973. Effects of genetic parthenocarpy and gynoecious flowering habit on fruit production and growth of cucumber *Cucumis sativus* L. J. Amer. Soc. Hort. Sci. 98:602–604.
6. Elassar, G., J. Rudich, D. Palevitch, and N. Kedar. 1974. Induction of parthenocarpic fruit development in cucumber by growth regulators. HortScience 9:238–239.
7. El-Shawaf, I.I.S. and L.R. Baker. 1981. Inheritance of parthenocarpic yield in gynoecious pickling cucumber for once-over mechanical harvest by diallel analysis of six gynoecious lines. J. Amer. Soc. Hort. Sci. 106:359–364.
8. Gustafson, F.G. 1942. Parthenocarpy: natural and artificial. Bot. Rev. 8:599–654.
9. McCollum, J.P. 1934. Vegetative and reproductive responses associated with fruit development in the cucumber. Cornell Memoir 163.
10. Miller, C.H. and S.K. Ries. 1958. The effect of environment on fruit development of pickling cucumbers. Proc. Amer. Soc. Hort. Sci. 71:475–479.
11. Motes, J.E. 1977. Pickling cucumbers: Production-harvesting. Michigan State Univ. Ext. Bul. E-837.
12. Palevitch, D., E. Pressman, and J. Rudich. 1972. Induction of parthenocarpy by triiodobenzoic acid in cucumbers (*Cucumis sativus* L.) Z. Pflanzenphysiol. Bd. 67 S. 457–459.
13. Ponti, O.M.B. de and F. Garretsen. 1976. Inheritance of parthenocarpy in the cucumber (*Cucumis sativus* L.) and linkage with other characters. Euphytica 26:633–642.
14. Quebedeaux, B. and E.M. Beyer, Jr. 1972. Chemically induced parthenocarpy in cucumber by a new inhibitor of auxin transport. HortScience 7:474–476.
15. Quebedeaux, B. and E.M. Beyer, Jr. 1974. Induction of parthenocarpy by N-1-naphthylphthalamic acid in cucumbers. HortScience 9:396–397.
16. Rudich, J., L.R. Baker, and H.M. Sell. 1977. Parthenocarpy in *Cucumis sativus* L. as affected by genetic parthenocarpy, thermophotoperiod, and femaleness. J. Amer. Soc. Hort. Sci. 102:225–228.
17. Uzcategui, N.A. and L.R. Baker. 1979. Effects on multiple pistillate flowering on yields of gynoecious pickling cucumbers. J. Amer. Soc. Hort. Sci. 104:148–151.