Use of Ethephon and Chlorflurenol in a Once-Over Pickling Cucumber Production System[1]

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Abstract. Ethephon and chlorflurenol were applied to hybrid pickling cucumber *Cucumis sativus* L. cvs. Pioneer and Pickmore to study the use and effectiveness of the chemicals on promoting fruit yields and quality in a once-over harvest system. Ethephon was applied either at the first or the fourth true-leaf stage of growth. Chlorflurenol was applied at 0, 50 or 100 ppm when 6–8 female flowers reached anthesis. Dollar value per ha was increased by approximately 14% when ethephon or chlorflurenol was used alone. However, when these 2 growth regulators were used in combination, yields were increased by as much as 68% in 'Pioneer' and 40% in 'Pickmore.' Chlorflurenol significantly increased the number of fruit per plant and reduced the length to diameter ratio. Fruit shape and L:D ratio were significantly improved when ethephon was applied in the fourth true-leaf stage regardless of chlorflurenol usage. Chlorflurenol slightly reduced the fresh quality of 'Pioneer' but had no such effect on 'Pickmore.' Salt stock quality was improved slightly by chlorflurenol. To obtain best yield, fruit shape, fresh salt stock quality, ethephon should be applied twice, 1 week apart commencing at the fourth true-leaf stage, followed by a 50 to 100 ppm spray application of chlorflurenol when 6–8 female flowers have reached anthesis.

In recent years, harvest labor shortages and higher costs for labor have increased the need to seek labor-saving means by which to harvest many horticultural crops. As a result, each year a larger percentage of the pickling cucumber crop in North America is being harvested by machine. The transition from hand harvesting to machine harvesting of pickles would be more rapid except that average returns to the grower using machines are generally no better than those received from hand harvest operations. Although yields from once-over machine harvesting of cucumbers have increased in the past 5 years by using new hybrid cultivars and better production practices, net returns have not increased dramatically. This is primarily because of increased production costs over the same period.

Yields of cucumbers could be greatly increased if the number of fruit per plant could be increased. However, continued cucumber fruit set usually is limited by seed development of the earliest fruits that set and this restricts development of additional fruits (6). Parthenocarpy, either genetic (9) or chemically induced (1), overcomes this inhibition of fruit set (13). Chlorflurenol and several other auxin transport inhibitors have significantly increased the number of fruits produced per plant under greenhouse and field conditions (1, 4, 5, 7, 10, 11). Thus far the effectiveness of these compounds under simulated grower conditions for commercial usage for once-over harvest has not been clearly demonstrated. Also, there is no information on how chlorflurenol or other auxin transport inhibitors affect cucumber fresh and salt stock quality.

Our purpose was to determine the effect of chlorflurenol on yield and fruit quality of cucumbers grown in the field. The use of ethephon followed by chlorflurenol application was also studied. Ethephon was used primarily to assure a large percentage of female flowers (8, 12), thus enhancing the potential for chlorflurenol to increase yield.

Materials and Methods

Cucumbers (*Cucumis sativus* L. cvs. Pioneer and Pickmore) seeds were planted in a sandy loam soil with a Stanhay seeder to give a population of approximately 250,000 plants per ha. The seeds were placed 8 cm apart in rows 30 cm apart. The rows were in beds with 1.5 m centers and 4 rows to a bed. Fertilizer was disked in before planting at a rate of 600 Kg/ha of 6-24-24 and 100 Kg/ha N as NH_4NO_3. Dyanap (dinoseb + naptalam) was applied immediately after seeding for weed control. Recommended practices for disease and insect control were followed. Irrigation was used after the herbicide application and during fruit development to supplement rainfall. One hive of bees per 50,000 plants was present.

Treatments in the main plots consisted of plants to which 250 ppm ethephon[3] [(2 chloro) ethylphosphonic acid] was applied in the first true-leaf stage and again 7 days later, 250 ppm ethephon applied in the fourth true-leaf stage and again 7 days later, and untreated plants. After approximately 6–8 female flowers reached anthesis, the plants within each ethephon treatment were sprayed with chlorflurenol[4] (methyl-2-chloro-9-hydroxyfluorene-[9]-carboxylate) at concentrations of 0, 50, and 100 ppm. Tween 20 at 0.1% concentration was added to all spray solutions. The solutions were applied to runoff with a portable motor driven greenhouse sprayer. All treatments were replicated 4 times, and individual plot size was 7.6 m by 1.5 m. The experiment was conducted for 3 years; however, data reported represents only 1972 and 1973 experiments since 'Pickmore' was not included in the 1971 trial. The 1971 data for 'Pioneer' were similar to the 1972 and 1973 data (3).

All the fruit from 5 m of row was harvested, graded, and weighed when 10% of the fruit reached 4.1 cm in diameter. The grades and dollar values were: less than 1.9 cm fruit diameter ($253/metric ton), 1.9 to 2.5 cm ($171/ton), 2.5 to 3.2 cm ($149/ton), 3.2 to 3.8 cm ($83/ton, 3.8 to 4.1 cm ($61/ton), 4.1 to 5.1 cm ($28/ton), and over 5.1 cm ($22/ton). The percentage of offshapes, "nubs" and "crooks", was determined from 25 fruits randomly sampled from each replication. Length to diameter ratios were measured on 10 randomly sampled cucumbers in the 1.9 to 4.1 cm size grades from each replication. Fresh quality was measured on a 25-fruit random sample from each replication according to the values listed in Table 1. At harvest time, the number of male flowers, female flowers and fruit were counted to node 15 on 10 randomly sampled plants from each replication.

Fruits (1.9 to 4.1 cm) were placed in mesh bags and brined in vats by a commercial pickle company.[5] When cured, the samples were graded for salt stock quality according to the values listed in Table 1

Results and Discussion

Ethephon, applied at either stage of development, significantly increased dollar value of yields from both 'Pioneer' and 'Pickmore' cucumbers (Tables 2 and 3). Without ethephon, dollar values of both cultivars were significantly increased over the control only by the 50 ppm concentration of chlorflurenol. When ethephon was applied at

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[3] Ethephon was provided by Amchem Products, Windsor, Ontario.
[4] Chlorflurenol provided by Ciba-Geigy Canada Ltd., Etobicoke, Ontario representing E. Merck, now CelaMerck, West Germany.
[5] We wish to thank Canadian Canners Ltd., (Aylmer-DelMonte), Waterford, Ontario, for brining the samples.

Table 1. Point system for fresh and salt stock evaluations.

I. Fresh quality evaluations.[z]
- A-Shape
  - Shoulder and stem attachment (5 points)
  - Blossom-end taper (5 points)
  - Ridging and spines (10 points)
- B-Color
  - Green quality and stippling (10 points)
  - Uniformity (10 points)
- C-Internal quality
  - Skin texture and flesh firmness (10 points)
  - Seed cavity size (10 points)
  - Seed size (10 points)
  - Carpel separation (10 points)

II. Salt stock evaluation.[z]
- External color (10 points)
- Internal color (10 points)
- Cure (10 points)
- Bloater (10 points)
  - Ballon
  - Lens
  - Honey-comb
- Carpel separation (10 points)
  - Center
  - Attachment

[z] Ratings: 1, poorest quality; highest number = best quality.

Table 2. Effect of ethephon and chlorflurenol on yield of 'Pioneer' pickling cucumber harvested once[z].

Yield expressed as	Ethephon conc. (ppm)	Chlorflurenol Conc. (ppm)		
		0	50	100
Dollars per ha	0	1680a[w]	1903b	1685a
	250[y]	1932b	2399cd	2254c
	250[x]	1974b	2473d	2819e
Tons (metric) per ha	0	33.0e[w]	28.7cd	25.8ab
	250	34.1e	29.6d	27.8b-d
	250	29.6d	25.3a	26.2a-c
No. Fruit/plant	0	2.3a[w]	3.1b	3.0b
	250	2.8b	4.7d	4.0c
	250	2.3a	4.8d	4.9d

[z] Averages for 1972 and 1973.
[y] Ethephon applied when the plants were in the first true leaf stage and again 1 week later.
[x] Ethephon applied when the plants were in the fourth true leaf stage and again 1 week later.
[w] Mean separation, within type of yield, by Duncan's multiple range test at the 5% level.

the first true-leaf stage, chlorflurenol at both concentrations significantly increased dollar yields of the 2 cultivars over the ethephon treatment alone. When 100 ppm chlorflurenol was applied to plants receiving 2 sprays of ethephon commencing at the fourth true-leaf stage, dollar yields per ha of both cultivars were significantly increased above all other treatments.

Chlorflurenol increased the number of fruit set per plant (Tables 2 and 3). Fruit set was further improved by applying ethephon before chlorflurenol to increase and concentrate the number to pistillate flowers. The increased dollar value due to chlorflurenol application generally reflected a higher percentage of fruit in the smaller, higher priced grades. This showed up as an increase in fruit number with a decrease in the wt/ha of fruit.

Because of the high number of fruit that set per plant when ethephon and chlorflurenol were used, dollars per ha returns might be further increased by delaying fruit harvest to yield more wt per ha. The harvest criterion used in this experiment (10% fruit reaching 4.1 cm) was based on the premise that under normal conditions concentrated fruit set is not achieved. To insure a sufficient percentage of fruit in the smaller size grades under these conditions, the crop must be harvested before many large fruits appear. However, when ethephon and chlorflurenol are used in combination, flowering and fruit set are highly concentrated (Fig. 1). When concentrated fruit set and development are achieved, a higher percentage (25%) of fruit could be allowed to go into larger size grades without drastically altering the amount of fruit in the smaller grades.

Another significant benefit from ethephon was to remove crown fruit set (Fig. 1). Ethephon aborted the lower female flowers. Crown fruit set is known to reduce plant yields (6). By removing crown set, the plant is generally stronger at fruit set and able to support more fruit.

Chlorflurenol is known to induce parthenocarpy in the cucumber and thereby improve fruit set (11). Under commercial conditions, it would be hard to exclude pollinating insects. In our experiments, bees were placed in the fields for pollinating, yet fruit set was significantly improved by chlorflurenol. Seed development was observed in the larger fruit. However, when chlorflurenol was used, there appeared to be a higher percentage of fruit with fewer seeds or no seeds at all. This is consistent with the results of previous greenhouse experiments (2). Hence, pollination has little or no inhibitory effect on cucumber fruit set when chlorflurenol is used.

Chlorflurenol significantly decreased the number of male flowers per plant in 'Pioneer' and the percent of male plants of both cultivars when ethephon was not used (Tables 4 and 5). Monoecious pollinator seed was incorporated with 'Pioneer' but not 'Pickmore', nevertheless, the percentage of male plants in 'Pioneer' was far above the 15% of pollinator seed used. Many of the male flowers on the non-ethephon treated plants appeared to be developing at higher node numbers and the application of chlorflurenol appeared to abort these. With ethephon, chlorflurenol had no effect on male flower development since the ethephon promoted almost exclusive female flower development. In some cases, chlorflurenol reduced the number of female flowers. Abortion of these flowers was not observed in the chlorflurenol-treated plants. The lengths of the vine were not shortened by chorflurenol (Fig. 1), and it is not otherwise apparent what caused this slight reduction in the number of female flowers. Even though ethephon aborted flowers for the first several nodes when applied in the fourth leaf stage, the total number of flowers produced for 15 nodes was not reduced.

Equally important to yield is the effect of these growth regulators on fruit shape and fresh and processed quality. Chlorflurenol had no adverse effect on fruit shape in either cultivar (Tables 6 and 7). However, significantly less fruit was misshapen when ethephon was applied at the fourth leaf stage than if applied at the first leaf stage or the controls. This apparently resulted from less stress on developing fruits by aborting fruit below node 4–6 with ethephon (Fig. 1). Length

Table 3. Effect of ethephon and chlorflurenol on yield of 'Pickmore' pickling cucumbers harvested once[z].

Yield expressed as	Ethephon conc. (ppm)	Chlorflurenol conc. (ppm)		
		0	50	100
Dollars per ha	0	1816a[w]	2036bc	1927ab
	250[y]	1991bc	2226d	2231d
	250[x]	2137cd	2288d	2533e
Tons (metric) per ha	0	32.5cd[w]	31.2cd	33.6d
	250	29.6bc	28.7bc	29.4bc
	250	25.8ab	22.9a	23.5a
No Fruit/plant	0	1.7a[w]	2.7bc	2.2b
	250	2.6bc	3.4de	2.9cd
	250	2.3b	3.9e	3.7e

[z] Averages for 1972 and 1973.
[y] Ethephon applied when the plants were in the first true leaf stage and again 1 week later.
[x] Ethephon applied when the plants were in the fourth true leaf stage and again 1 week later.
[w] Mean separation, within type of yield unit, by Duncan's multiple range test at the 5% level.

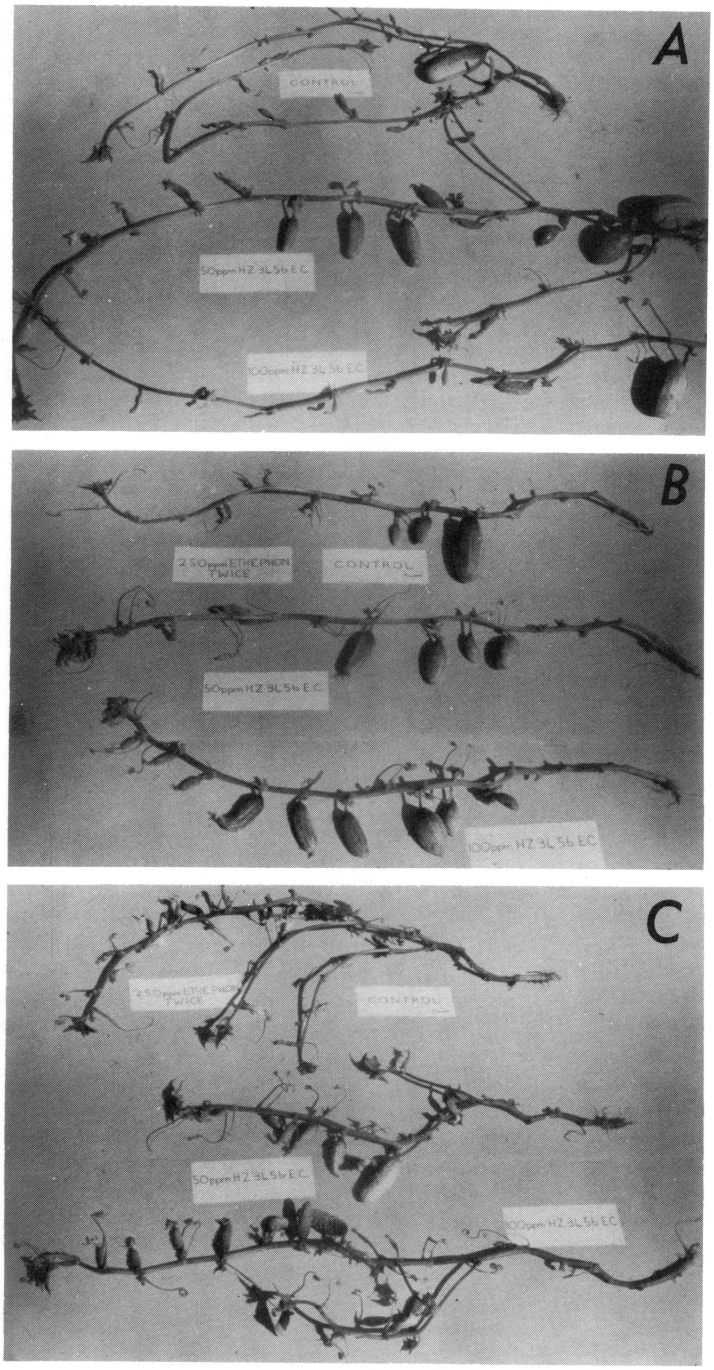

Fig. 1. Effect of ethephon and chlorflurenol on number and location of cucumber fruit set on 'Pioneer.' Plants in each section represent: Top = 0 ppm, middle = 50 ppm, bottom = 100 ppm chlorflurenol. Section A. No ethephon pretreatment. Note crown fruit set. B. Ethephon applied at 250 ppm in the first true leaf stage and again 1 week later. Note lack of crown fruit and increased numbers of fruit. C. Ethephon applied at 250 ppm in the fourth true leaf stage and again 1 week later. Note the position and concentration of fruit set.

to diameter ratios were shortened when chlorflurenol was applied. However, when ethephon was applied at the fourth true-leaf stage, the L:D ratios of both cultivars were increased closer to the desirable 3:1 ratio. In combination with ethephon, L:D ratios were unaffected by chlorflurenol. Ethephon caused abortion of female flowers on the lower nodes seemed to account for this.

The fresh quality of 'Pioneer' was unaffected by ethephon but was reduced when chlorflurenol was applied either with or without ethephon (Table 6). This reduction was not the result of modifying any one particular criterion that was used to judge the fresh quality

Table 4. Effect of ethephon and chlorflurenol on sex expression[z] of 'Pioneer pickling cucumbers harvested once[y].

Sex expression	Ethephon conc. (ppm)	Chlorflurenol conc. (ppm)		
		0	50	100
No. male	0	5.0d[v]	2.2c	1.2b
flowers per	250[x]	0.1a	0.1a	0.1a
plant	250[w]	0.1a	0.1a	0a
No. female	0	7.1a[v]	6.8a	8.5d
flowers per	250	8.7d	7.1a	7.6b
plant	250	10.3e	8.2cd	8.5d
% Male plants	0	58.8c[v]	60.0c	35.0b
	250	5.0a	5.0a	5.0a
	250	2.5a	5.0a	0a

[z] Data taken to node 15.
[y] Averages for 1972 and 1973.
[x] Ethephon applied when the plants were in the first true leaf stage and again 1 week later.
[w] Ethephon applied when the plants were in the fourth true leaf stage and again 1 week later.
[v] Mean separation, within sex expression classes, by Duncan's multiple range test at the 5% level.

Table 5. Effect of ethephon and chlorflurenol on sex expression[z] of 'Pickmore' pickling cucumbers harvested once[y].

Sex expression	Ethephon conc. (ppm)	Chlorflurenol conc. (ppm)		
		0	50	100
No male	0	0.6a[v]	0.2a	0.1a
flowers per	250[x]	0a	0.1a	0.2a
plant	250[w]	0a	0a	0.1a
No. female	0	11.1de[v]	10.6cd	11.8ef
flowers per	250	10.9cd	9.8ab	10.3bc
plant	250	11.9f	9.6a	9.4a
% Male plants	0	12.5c[v]	5.0ab	2.5a
	250	0a	2.5a	7.5bc
	250	0a	0a	2.5a

[z] Data taken to node 15.
[y] Averages for 1972 and 1973.
[x] Ethephon applied when the plants were in the first true leaf stage and again 1 week later.
[w] Ethephon applied when the plants were in the fourth true leaf stage and again 1 week later.
[v] Mean separation, within sex expression classes, by Duncan's multiple range test at the 5% level.

(Table 1). Chlorflurenol-treated fruits were all judged acceptable for fresh pack processing. The fresh quality of 'Pickmore' was improved when ethephon was applied (Table 7). Chlorflurenol did not affect fresh quality in 'Pickmore'.

Salt stock quality of both cultivars was little affected by ethephon but was increased slightly by chlorflurenol (Tables 6 and 7). Improved salt stock quality was related to better color in the processed product. At the plant population used, fruit tended to be lighter in color. However, with chlorflurenol color was maintained and appeared more desirable after brining. There was no increase in the incidence of bloating or carpel separation by the use of either growth regulator.

From these experiments, it is apparent that chlorflurenol will increase the number of fruit produced per plant and the dollar value of a pickling cucumber crop for once-over harvest. Present hybrid pickling cucumber cultivars may require the use of ethephon to promote the effectiveness of chlorflurenol by concentrating pistillate flower maturity. When sprayed at the fourth true-leaf stage, ethephon gave additional benefits of improved fruit shape and increased L:D ratios. Rates of ethephon and chlorflurenol may be adjusted for specific environmental conditions in different locations. The rates used in this experiment appear to be highly satisfactory for northern climates. A concentration of 100 ppm chlorflurenol was the most

Table 6. Effect of ethephon and chlorflurenol on fresh and salt stock quality of 'Pioneer' pickling cucumbers harvested once[z].

Quality indicator	Ethephon conc. (ppm)	Chlorflurenol conc. (ppm)		
		0	50	100
% Off shape	0	5.1bc[w]	6.4cd	7.5d
	250[y]	8.2d	8.7d	7.7d
	250[x]	2.1a	3.9ab	3.3ab
L:D ratio	0	2.7d[w]	2.4bc	2.4bc
	250	2.5c	2.3ab	2.2a
	250	2.9d	2.7d	2.8d
Fresh quality	0	55.6c[w]	51.1ab	50.4a
	250	55.4c	49.9a	51.1ab
	250	55.3c	52.4b	51.5ab
Salt stock quality	0	43.8bc[w]	43.9bc	43.6b
	250	42.5a	43.5b	44.2c
	250	43.9bc	44.3c	45.4d

[z] Averages for 1972 and 1973.
[y] Ethephon applied when the plants were in the first true leaf stage and again 1 week later.
[x] Ethephon applied when the plants were in the fourth true leaf stage and again 1 week later.
[w] Mean separation within quality indicator, by Duncan's multiple range test at the 5% level.

Table 7. Effect of ethephon and chlorflurenol on fresh and salt stock quality of 'Pickmore' pickling cucumbers harvested once[z].

Quality indicator	Ethephon conc. (ppm)	Chlorflurenol conc. (ppm)		
		0	50	100
% Off shape	0	6.9b[w]	7.1b	9.0b
	250[y]	7.3b	7.1b	7.3b
	250[x]	3.9a	3.5a	4.8a
L:D ratio	0	2.4bc[w]	2.3ab	2.2a
	250	2.5c	2.2a	2.4bc
	250	2.8d	2.8d	2.8d
Fresh quality	0	49.6b[w]	49.3b	43.6a
	250	56.1d	49.6b	51.3bc
	250	54.1cd	52.2bc	51.8bc
Salt stock quality	0	41.7a-c[w]	41.0a	42.6cd
	250	41.2a	41.3ab	42.6cd
	250	43.2d	42.2b-d	42.8d

[z] Averages for 1972 and 1973.
[y] Ethephon applied when the plants were in the first true leaf stage and again one week later.
[x] Ethephon applied when the plants were in the fourth true leaf stage and again one week later.
[w] Mean separation within quality indicator, by Duncan's multiple range test at the 5% level.

effective treatment when 250 ppm ethephon was applied in the fourth true-leaf stage. Otherwise, 50 ppm chlorflurenol was at least as effective as 100 ppm. To insure maximal activity from growth regulators, spray coverage must be complete. There appear to be no large differences among cultivars in their responses to the 2 chemicals.

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The Role of Seed Abortion and Parthenocarpy in the Production of Blank Pistachio Nuts as Affected by Rootstock[1]

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Abstract. Production of blank nuts in 'Kerman' pistachio was the result of both parthenocarpy and seed abortion, the latter being responsible for the major portion. The degree of parthenocarpy was relatively uniform throughout the entire tree population, but seed abortion varied according to the history of blank production of the individual trees. Production of blanks, therefore, appeared to be governed by the seedling rootstocks.

The production of blank nuts in the 'Kerman' pistachio (*Pistacia vera* L.) has been shown to result from seed abortion (1) as well as from parthenocarpy (3). Apparently, because of a strong parthenocarpic tendency in that cultivar, fruits that abort their seeds do not abscise. They become blanks, and together with parthenocarpic fruits, constitute, on the average, 26% of the total nuts harvested (3).

In 'Kerman', the extent of blank production has been shown to be associated with individual trees; some regularly produce relatively large percentages of blanks year after year, whereas others produce relatively few blanks (3). It was concluded, therefore, that variation in

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